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PHD THESIS

ENGINEERING CONTRIBUTIONS TO A FUTURE OIL-FREE URBAN DEVELOPMENT

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“Taking all new developments and policies into account, the world is still failing to put the global energy system onto a more sustainable path”, (IEA)

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1. INTRODUCTION

1.1 Breakthroughs in city development through history

Rome felt in the VIth century AD, and the entire Roman Mediterranean network began to collapse within a hundred years in the face of Islamic expansion. Thus, the old Roman centers spread across Europe stagnated. However, several recovered beginning with the XIIth century, when new settlements were built around the old burgs (walled fortress) lasting since the Rome glory days. The increased trade supported the rise of the small merchants and traders, not dependent on the feudal lords, as well as new classes of elites, not directly tied to the Catholic Church. These changes were especially pronounced in the Northern Italy, where flourishing innovation and entrepreneurial activity supported the rise of autonomous mercantile centers such as Venice. Residents of the commercial centers came to be called bourgeois, with the etymology from burg or bourg, also the root of the word bourgeoisie. The ensuing mix of cultural, artistic and scientific developments that began in the XIVth century, were compiled in a progressive mix known under the label of Renaissance.

It is hard to emphasize the importance of the transformations that took place across Europe. Social changes altered the cities and the urban life, and also shaped the way subsequent generations understood the relations between urbanization, society and culture. As Wyly states [1], Kingsley Davis goes so far as to suggest that the 'real' urban revolution was not in Mesopotamia in 3500 BC, but in Western Europe 5000 years later, during Renaissance.

The decisive swing toward an open, reasoned endorsement of non-geometric urban planning came in the 18th century. The revolt was against the renaissance's theory and practice - the belief in the undeviating street prospect, the measured, uniform, order of the streets layout. Europe, even its colonial extent, responded to the imperatives of the perfectly order city specific to the renaissance thinking. The old gradual expanded towns, with their towered defensive, curtains and their patchwork streetscape, seemed obsolete.

From now on, the city expands as a result of inventions. One of the most significant was the steam engine invented by James Watt in 1776. Thus, the Industrial Revolution started. In the latest period of the Industrial Age (i.e., the Machine Age – from the late XIXth century up to the beginning of World War II), the most important impacts on the physical fabric of the settlement of mankind are invented: the car and the steam train, followed by the electrical train. All these brought an enormous development on the specific steric of the city, not only in the horizontal plane (e.g., enlarging the streets network), but also on the vertical level, where suspended roads were built for cars and trains in order to solve the problems of the overcrowding. One of the important developments brought about this revolution is the rapid expansion of the cities to the outside, along the transportation paths, leading to a starburst growth of the urban fabric, because many people moved to live in the suburbs in order to avoid the congestion. Moreover, at the beginning of the XXth century, the evolution of the airplane leads to the occurrence of the airports and their various facilities [2].

As shown above, modern cities took time to reach the actual level of development, and the Oil has been the main factor for developing city and changing its form, both as an engine towards new demands, and as an infrastructure support (many important building solutions, as technologies and materials are oil based). In the same time, oil effects upon the climate and environment are far from being sustainable. Cruel oil deposits are not without limits and the vision of an era without oil is very likely. Thus, a question rises. How the cities will function and develop after the oil resources will be insufficient? There is no doubt that answers for the future urban development may be found in the actual state of planning and future ideas, but also in the early oil free urban development. To clarify how the cities succeeded or failed, to explain the extent of the climate challenges over the urban development, to try to find the solution of the successful sustainable planning, we have to understand the initial impulse in giving birth to a city, the developing resources and the developing engines. Next, we shall briefly discuss about them over the Renaissance and Industrial Revolution.

1.2 Ancient/traditional building materials lasting through history

1.2.1 Building materials used in ancient civilizations

Since records were found with regard to *architecture* and *building* as human concerns, construction materials proved to be fundamental to the development of civilization. Anthropologists define the historical epochs by the materials used by the different civilizations such as the stone, copper, bronze and iron ages [3]. The major changes termed *styles* have been closely associated with the materials available and the technologies learnt by tradesmen to build those outstanding buildings which have come down to us as the great examples of the past architecture [4].

The materials were mainly timber, derivates of plants (e.g., ropes, covering leaves etc.), stone, copper, lead and ceramics as bricks, tiles and other forms of baked clay products (e.g., drain profiles, pipes). These traditional building materials have served man well for many centuries. The master craftsmen often became the building designers, even for such great works as the European and British cathedrals of the medieval times. Despite the local variation of the materials and skills/experience, the breadth and depth of their craft knowledge was generally transferable and adaptable to new situations. The many outstanding buildings designed by such people are still esteemed for their architectural and structural qualities, and are evidence of the value of the craft-type knowledge, when only a few materials are used [4].

Old civilizations built with the materials available on the surrounding environment. These local materials, such as adobe; pise; cob; puddled clay; stabilized soil; rubble stonework; limewash; light timber frames; log cabin, split timber; reed huts, wattle and daub; thatch; shingles and shakes, bought to future generations great buildings lasting thousands of years.

In the future evolution of the research performed within the doctoral studies, the old civilizations construction materials will be much considered as background solutions in the free of oil future urban development.

1.2.2 Ancient Egyptian civilization

The massive pyramids, temples and obelisks of the ancient Egyptians still wonder us after thousands of years. The huge blocks of stone, used to create these architectural antiques, were quarried and moved without any of the modern technologies equipment. Even now it is still difficult for us to imagine and understand how such edifices could be built without any existence of cranes, bulldozers, trucks, and other tools necessary in present-day normal building projects [4].

Sandstone, limestone and red granite were the primary types of stone used for the buildings and large decorative features at the Egyptian temples. Other stones, like red quartzite, black granite, and travertine were utilized in much smaller quantities. The use of stone in Egypt civilization was not limited within the walls and other bearing elements, even on roofs, memorials, doors, gateways and obelisks being assembled by stone. Furthermore, the pyramids had their limestone blocks bound together by a mortar of mud and clay [4].

Adobe 'sun-baked mud brick' construction was used for ancillary buildings and normal houses in ancient times and is still commonly used in rural Egypt. The hot, dry climate was ideal for mud-brick, which tends to wash away in the rain. The Ramesseum in Thebes, Egypt (Luxor) provides one of the finest examples of mud brick construction ever made [5].

Despite the fact that the dry alluvial soil of Egypt offered optimum building materials, the yearly inundation of Nile was the problem to keep in service the ordinary buildings made out of earth like clay and mud. That is why the slums built around the palaces, temples and pyramids had almost entirely vanished in time. However, even in palaces and temples some enclosure walls and pylons' ramps were made of large mud brick that still present visible tailings.

There is no doubt, wood also attended in the Egyptian architecture. Timber was brought from countries (e.g., from Eastern Africa and Lebanon) and used for gateways. Besides, the facades and pylons were ornamented with huge wooden flagstaffs. Decorations in bronze, silver, gold, or electrum were also used. [4].

1.2.3 Mesopotamia

With the development of mud brick, first found at Halaf in the Ubaid period (i.e., 5300-4000 BC), the alluvial plain entered into what might be called *the age of architecture*. The brick was small and was the ideal building unit, easy to handle. It was also used to build complicated shaped structures. Drawings survive on clay tablets from later periods showing that buildings were set out on brick modules. By 3500 BC, burned bricks and stone pavements came into use.

The leading building material was the mud-brick, formed in wooden molds similar to those used to make adobe bricks. The mud consists of water and soil preferably of a high clay content, into which chopped straw or dung is trodden - ingredients necessary to prevent warping or cracking during the process. After the excess is stuck off the top and mud in the form is smoothed by hand, the form is removed and the brick faces are turned to dry in the sun. In use, the bricks are bounded in place and their outer faces are coated with more fluid mixture of the same mud. [5]

Bricks varied widely in size and format, from small brick units that could be lifted in one hand, to ones as big as large paving slabs. Rectangular and square bricks were both common. They were laid in virtually every bonding pattern imaginable and used with considerable sophistication [6].

Contrary to the popular belief, the arch was not invented by the Romans, but was used in these civilizations. The latter Mesopotamian civilizations, particularly Babylon and then Susa, developed glazed brickwork to a very high degree, decorating the interiors and exteriors of their buildings with glazed brick relief. [5] At those very ancient times, many cultural patterns ran across the Mediterranean basin, spreading the knowledge of materials and building techniques.

1.2.4 Old China

China, being the cultural heart of Eastern Asia, many Far East construction methods derived from it. A famous example of the Chinese constructions is the Great Wall, which was built with rammed earth, stones, wood, and later bricks and tiles with bounded by lime mortar. Wooden gates blocked passageways. Moreover, the oldest archaeological findings reveal the extended use of mortise and tenon type woodworking joints.

Chinese temples are typically timber frames on an earth and stone base. The traditional Chinese timber structures do not use trusses but are assembled by posts and lintels. An important architectural element is the Dougong, a unique element of interlocking wooden brackets. The bricks used in China in the Songyue Pagoda dates from 523 AD. The yellow burned bricks were binded with clay mortar. The Anji Bridge is the world’s oldest stone segmental arch bridge, built in 595-605 AD. The sandstones are joined by dovetail iron mandrels [5].

1.2.5 Ancient Greece

The ancient Greeks built most of their ordinary structures also with mud bricks. The Greek temples, made mainly of stone, are the most dramatic evidence of the advances in building technology brought by the early Greeks (e.g., plumbing, urban planning, spiral staircase, central heating, water wheel, crane, etc.).

Timber subassemblies did not survive in time (e.g., roofs and floors), so the knowledge about them is incomplete. Before 650 BC, the famous ancient Greek temples were built of wood, but after this date began to be built of stone [7].

Burned clay, initially restricted to roofing tiles and associated decorations, was later considered for bricks employed with lime mortar. Outstanding buildings were roofed in stone tiles, which had the same shape as the terracotta counterparts. Despite other ancient practices, like building walls by stone skins embedding debris cores, the Greeks built with large cut blocks, joined with metal mandrels. Because it was a slow and costly effective building process, a small number of buildings are still evidence of this practice. Furthermore, the metal mandrels often broke due to corrosion. The structures were mostly double pine frames, assembled by simply supported beams and columns. The ancient Greeks never developed strong grouts to fix the stone or clay units.

1.2.6 Rome

Romans used brick and stone to build the apparent skins of the walls, and then filled the space between with debris. Thus, the masonry became a permanent embedded (i.e., lost) formwork [8]. Later it was introduced the wooden shuttering, which was removed so the concrete could cure.

The most brilliant Roman contribution is given by the Roman concrete, which was cheap and very easy to produce, requiring relatively unskilled labor. This enabled the Romans to build on an unprecedented scale. It is commonly believed that the ancient Romans were the first to use concrete. Even if not true, Romans were able to prepare high-quality hydraulic cements, because they used lime and pozzolana, the volcanic dust of Puteoli. The mixture of pozzolana and lime produces a hydraulic binder. The Romans called this binder *caementum* [9]. *Opus caementicium* was called the Roman Concrete. Probably, it was during the third century BC that hydraulic cement was first prepared by mixing pozzolana with the lime produced by heating limestone [10]. The aggregate could be made of pebbles, ceramic tiles and brick rubbles obtained from the demolition.

Any visit to Rome should include the Pantheon, Trajan's Market, Coliseum and other numerous and spectacular ancient Roman monuments that have been built during the Roman Empire. Most of these miraculous works, now monuments part of the world's heritage, have successfully lasted for long time. The Roman Imperial Concrete, a historic architectural concrete, made of tuff aggregate and pozzolanic cement, as for the Trajan's Market, dates from 100-110 AD, and absorbed the energy induced by numerous earthquakes and differentiated settlements during 2000 years [10].

The mortar that bounds the Roman Concrete and Roman Imperial Concrete aggregates is of scientific importance, not only because its unbelievable resilience and durability, but also for the many advantages linked to the present environmental issues. Modern concrete uses Portland cement as a binder. Production of Portland cement requires heating the mixture of limestone and clay to 1450° C, a process that releases large amounts of carbon. Given the 19 billion tons of Portland cement used annually worldwide, about 7% of the global carbon emission is caused only by the production of Portland cement. On the contrary, Roman concrete is a mixture of pozzolan, fresh water and lime that calcines at a much lower temperature than the production of Portland cement needs. Gross pieces of tuff and broken bricks are used as coarse aggregate, occupying about 45-55% of the concrete volume. The Romans also developed systems of hollow pots to build their domes and sophisticated heating and ventilation systems for their thermal baths. The Romans substituted bronze with wood in the roof trusses. The Romans also made bronze roof tiles for roof covering material and lead pluming for the water supply. They used glass in mosaics and clear glass in raised floors heated by wood or coal fire [8].

1.2.7 Macedonian and Mycenaean concrete

Besides conquering a large part of the world, the ancient Macedonians were avant-garde builders too [9]. They used pozzolanic concrete three centuries before the Romans [9]. Likewise, Mycenaean people knew and used concrete even before Romans, Carthaginians and Macedonians [11]. The archaeologists found that the oldest houses of the primitive human settlement had floors and walls made of lime concrete.

1.3 Oil discovery and urban development

Oil was known and used since the very beginnings of civilizations. As we do not know when exactly it was first used, the archaeological records tell us that oil existed near Hit in Iraq since 6000 years ago. Asphalt was extracted and used as mortar between the building stone units since, as well as it was used to waterproof the baths, potteries and boats [12]. According to Herodotus and Diodorus Siculus, asphalt was also used in the construction of the walls and towers of Babylon 4000 years ago; as the existence of oil pits near Ardericca (near Babylon)[13].

Later, records exist about oil utilization in the Egypt of the pharaoh's civilization, more than 3000 years ago. Scientists have discovered that all the heavy black material covering pharaohs' mummies are only plants covered with a waxy material that exist just in the raw material of oil. Pharaohs also used the oil to paint their boats, to protect it of water. Oil was also mixed with essential oils to become a high-quality perfume. Other uses were in lighting, heating, the establishment of quarries and the search for gold [14].

However the first oil probes were drilled in China in 347 AD. The oil was used to heat the brine in order to evaporate the water and to produce salt [15]. Oil was also used in the golden age of Islamicic civilization, when was registered a great the desire of the caliphs to build big cities. Thus, the first streets of Baghdad were paved with tar in the IXth century, a product derived from petroleum that became accessible from the natural fields of the region [16]. Distillation and using of oil had been available in Western Europe by the XIIth century through Islamic Spain [17]. It has also been present in Romania since the XIIIth century, being recorded as *oil fuel* (in translation *pacura)* [18]. In 1815, several streets in Prague were lighted with petroleum lamps.

The modern history of oil began in 1847. The process to distill kerosene from petroleum was invented by James Young, which succeeded in 1848 to set up a small business by refining crude oil [19].

In 1850, E.W. Binney & Co reached in 1851 the first truly commercial oil-works in the world, with the first modern oil refinery. Solid paraffin started to be sold after 1856 [19]. Consequently, oil has been wide spread to start searching for it all over the world. The use of it to replace the coal was quickly increase till the beginning of XXth century were the oil has become the main resource of energy.

Oil had a profound impact on various aspects of life, more than any other natural resource, in the history of humanity. After the era of the Industrial Revolution, which was a major turning point in urban planning, due to the invention of the *machine*, and what came with it, caused drastic changes of the medieval cities.

Above mentioned inventions grew and evolved during the age of the post-industrial revolution, especially when oil was processed in commercial quantities, thus generating a huge progress in many industrial branches. That led oil to become a decisive element in determining both internal and external political maneuvers.

With all that being said, it must be emphasized the fact that the biggest impact was felt in the economical domain. Oil was the primary factor for developing various kinds of industries, propelling them forward, and thus leading the world to a very much expected economic revolution, emerged as a result of the development of information technology in the world of markets. The revolution focused towards linking the global economy to one network. Not long after, technology started evolving rapidly, progress made in a relatively short period of time on a vast array of fields: construction, transportation, construction, energy, informatics, industry and trade.

Recently, the IT revolution started to moves the world towards a single entity, underlining the emergence of the phenomenon of globalization. According to Strobl and Kohler [20], globalization is the convergence, communication and openness to the world and interdependence among peoples, which started constitutes the most important characteristics of people's lives in their interactions and treated as if it were happening in one place, Atkinson [21] mentions that globalization caused a direct and obvious reflection over city planning and architectural patterns and worked to change the face of those cities as a result of these developments. On the other hand, behind this exaltation about oil and its impact on development, very few work reflects its impact on the environment and how has worked since its discovery to change the climate.

Population density was increasing and their various activities were developing, while the area of the city remained as it was. Meanwhile, transport means had doubled with ongoing inflation of the population size. The streets network kept expanding at such a rate that repairs became exponentially harder to be made. In general, that led to a random and excessive development of the cities, without any prior planning, accompanied by the emigration of people from the countryside to the city, which had become the center of trade and economic activity. The majority of the cities were not able to absorb all these changes.

Despite the constant development in different areas of science, city planning has not seen significant changes through time. On the other hand, there were some attempts to adapt to scientific progress but they all failed due to the restrictions brought by past perceptions. That has prompted urbanism specialists to look for solutions to this phenomenon, especially when slums began to emerge and evolve at the expense of agricultural land and the surrounding environment. All this led to several theories about the development of the cities, in an attempt to reduce random proliferation.

All of the above clearly point out the natural course of things, the rise in oil demand bringing up several constraints with direct impact upon city planning. Changes are especially visible for cities that already existed by the time of the Industrial Revolution, and the ones that quickly occurred next to the oil extraction locations.

1.4 Perspective upon the oil based urban construction materials

The Oil discovery made the world to be more urbanized, with a much higher proportion of population living in megacities and metropolitan settlements [22]. The world urban population was estimated to be about 50% of the total population in 2010 [23]. The major problems related to extended urbanization are that is accompanied by a large consume of natural resources and environmental depreciation. In fact, the increase of the inhabitants of urban population calls for more construction activities like housing and infrastructure which caused to search for construction materials that can helps that shift of construction industry [24].

Human society is at a crisis point which must be acknowledged, especially by those involved in construction related industries, which consume large quantities of materials and power in mining, harvesting, manufacture and construction, and continue to consume resources throughout the service of the buildings. The urban development of the XXth century bore little resemblance to the building forms of previous centuries. The range of building materials is still expanding depending on oil, consuming increasing quantities of energy, and further polluting the environment [25].

In the early XXth century, Berzelius proposed that *"substances of equal composition but different properties be called isomers"* [26]. The following, year he introduced the designation *polymeric* for the larger of two compounds with the same relative composition, but different absolute numbers of molecules. Along the XIXth century, the researchers studying the global compositions of the compounds developed the concepts of *stereochemistry* and *optical isomerism*.

Once stereochemistry was accepted by the international scientific community, research into monomers, oligomers and polymers started to develop. The first industrial plastics, like *rayon* and *celluloid*, were produced towards the end of the XIXth century based on natural products and not detailed chemical understanding [25].

The main types of polymers are:

- Thermo-plastics (i.e., nylon, polyethylene, polyvinyl chloride, rubber, etc.) consist of molecules that have covalent bonding within each molecule and van der Waals forces between them;
- Thermo-sets (i.e., epoxy, phenolics, etc.) consist of a network of covalent bonds. They are based on hydrogen, carbon and other non-metallic elements.

Polymers are amorphous, except a few thermoplastics. Depending by the type of bonding, polymers are usually electrical and thermal insulators. However, conducting polymers can be obtained by doping, and conducting polymer-matrix composites can be made by the use of conducting fillers [26].

Composite materials are made by an engineered combination of materials that result in a finished material with better properties than its constituents. Composite materials are multiphase materials. In general, composites are classified according to their matrix materials. The main classes of composites are metal-matrix, polymer-matrix, and ceramic-matrix [26].

Chapter 3 of the present thesis presents a more detailed perspective is given upon the oil based building materials, with impact upon all aspects of the urban development.

1.5 Research motivation

As shown above, oil and its products are presenting a significant influence on the urban and rural development. However, since the industrial revolution, oil products became vital and indispensable not only for urban development, but for all aspects regarding the human society evolution.

After 1980, when the sustainable development concept was defined and launched into the global and local politics, weakening of the crude oil resources and the consequences of the intensive use of oil products over the environment, including human health and life, raise a huge global challenge to all aspects regarding the progress of human society.

In this respect, researchers from all over the world and from the all research fields have to imply in a multidisciplinary effort to solve the above mention strategic problems. The present PhD thesis is based on the wish of its author to have a contribution within the international scientific effort. The approach follows the fundamental principles of research: *new solutions regularly arise from old, tested materials concepts, technologies*, etc. Therefore, the research is justified through a look back (i.e., consistent review) up to the ancient history.

1.6 The objectives of the PhD thesis

The general objective of the PhD research is to contribute to the future urban development, combining the engineering and architectural thinking resources, in a conceptual research focusing on history certainties and mysteries, ongoing and future demands of the human society respectively.

The achievement of this global objective is justified by the fulfillment of the following specific objectives

- **Objective 1:** To reach a comprehensive knowledge on the oil applications in the urban infrastructure, since ancient civilizations up to present;
- **Objective 2:** To acquire a solid background in the theory of urban planning through history;
- **Objective 3 :** To propose solutions to replace oil based products, intensive used in actual urban development practice, by sustainable products;
- **Objective 4:** To bring an elevated thinking with regard to the sustainable rehabilitation of the historical buildings;
- **Objective 5**: To develop an optimization methodology aiming to resolve future demands on urban development based on the sustainable development concept, linking the future by the values of the past in a holistic approach.

1.7 Content of the PhD thesis

The thesis content is distributed on five chapters and one appendix, the summary being presented forward.

Chapter 1, introductive, presents a complete background for the proposed research, emphasizing:

- The breakthroughs in urban development through history;
- The ancient/traditional building materials lasting through history;
- An innovative perspective upon the oil based construction materials.

Chapter 2 represents an original synthesis study regarding the evolution of the urban infrastructure during history. All decisive discoveries are original argued and objective stated. The impact of oil is emphasized, and the future possibilities are presented from the sustainability standpoint.

Chapter 3 presents in a comprehensive manner, dominated by the understanding capacity of the author over the significant urban achievements, a review of the conceptual urban development since the medieval age in the European and Middle East civilizations. The oil implications are scientifically identified. Its impact on the economy, social, politics, and environment are reviewed and its path in urban development is highlighted. The chapter ends with an original scientific analysis on the interaction between the oil and the city, and an objective identification of the key points of the urban development in both civilizations.

Chapter 4 represents the central part of thesis and treats main steps performed during the research project. If previous chapter are dominated by a substantial theory and rationality, the chapters brings the original contribution of the author to the required doctoral level, fructifying the knowledge level achieved previously. First, an important return in time is proposed to bring a gain to the sustainable development of the urban infrastructure, replacement of oil plastic products used in infrastructure of the cities respectively. Plastic pipes can be successfully partially replaced by clay pipes, without implementing the costly effective vitrification technologies. The result is justified through a proposed simple manufacturing technology, compliance with the standardized tests requirements and service life vs. costs. The next contribution is innovative through the courage to propose interventions based on the state of the art technology (e.g., customized photovoltaic solar panels, as a renewable energy source) in order to a sustainable capitalization of the historical buildings. Computer simulations and numbers manipulation are finally embedded in an optimizing procedure for the future design of the cluster urban fabrics, based on parametric analyses and green concepts.

Chapter 5 presents the conclusion of PhD thesis, and underlines the contribution of the author to the addressed topic:

- The objective definition and identification of the oil applications in urban development and their consequences upon the present and future progress of the earth population;
- Identifying the relations (i.e., links) between the urban planning historical stages, with an accent on the European and Middle East paths;
- Solution proposal to replace the oil based plastic pipes with ceramic clay ones, not using the vitrification technology. The proposal is justified by an innovative simple manufacturing technique and the compliance with the requirements of the standard tests normalized by the euronorms.
- To bring an elevated thinking with regard to the sustainable rehabilitation of the historical buildings, besides maintain the cultural values, importance being given to an economical and environmental friendly service;
- An optimization methodology in urban planning of the cluster fabrics for a sustainable development, using green concepts and parametrical analyses (e.g., sunshade, sun radiation, wind, thermal satisfaction), demonstrating the conceptual

importance of the building distribution in the space and the inventive implementation of the environmental elements (e.g., tree barriers, green areas, water basins etc.).

2. LOCALITY INFRASTRUCTURE THROUGH HISTORY

2.1 Street networks through history

2.1.1 Ancient civilization

In general, the historical cities of Europe developed randomly, with all that mess of brought by the narrow streets and that horrible, chaotic puzzle of intersections and squares. Still these days, the power of the Euclidean geometry is vastly inspirational and influential for the architects and urban designers, especially when it comes to the design of streets, towns and cities [27].

The first forms of roads (actually footpaths) occured spontaneously due to the humans walking on the same paths, over and over again. Even though the discovery of the wheel about 7,000 years ago, which gave the possibility for large and heavy loads to be transported, therfe were limitations given by dirt paths that turned into muddy bogs when it rained [28]. Thus, peoples were forced to pave the roads to ensure a proper functioning of the vehicles. As for the Roman Empire [29], the streets were divided into squares according to their specialization. The streets for fast vehicles were two-ways with widths of approximately 7.2 meters. Pedestrian streets had widths of about 1.5 meters. The lasts were the streets for the passage of the animals. In these cities was launched the concept of separation the pedestrian traffic from the vehicles.

However, some of these routes developed into quite extensive networks, when trees and big stones were cleaned from the path [30]. But a paved street has not been found until 4,000 BC in the cities of the Indus Valley Civilization, now on Asian India. The street-networks developed the through history first in the pre-automotive era of the cities, traces of the concept of a hierarchy of streets which formed together a network, that appear in Greek and subsequent Roman town plans. The networks were basically following the gridiron pattern (see Figure 2.1), classified by their size, and consist of one wide street which allowed for two way cart traffic, and then a group of secondare streets, while the third only loaded animals [31].

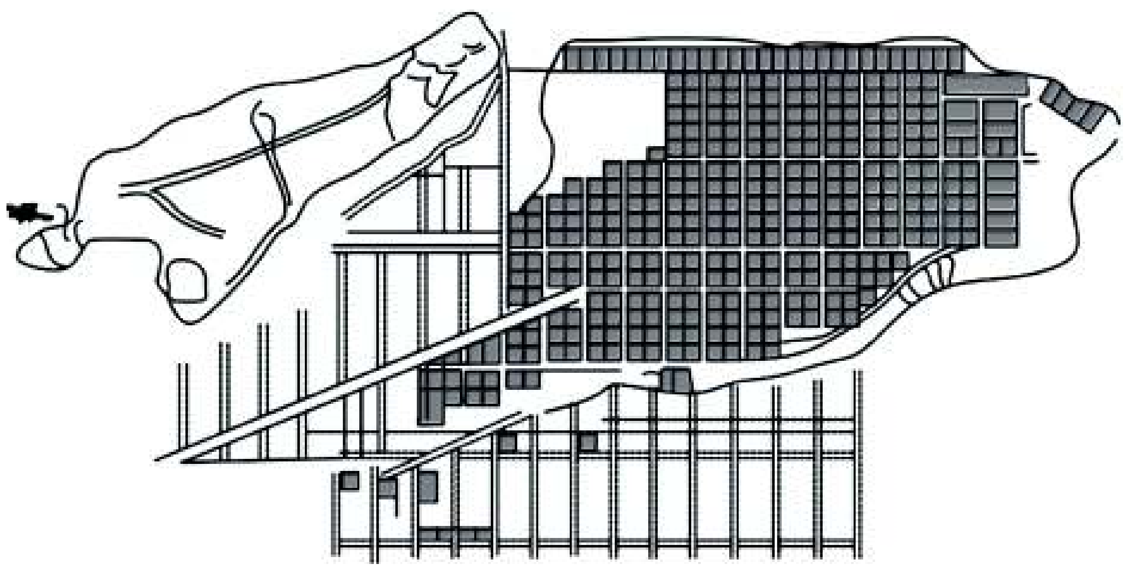


Figure 2.1. Olynthus city plan with its gridiron pattern

The first paved streets have been built in Ur, in 4,000 BC. Greek streets were paved with limestone blocks and had a small gutter for the drainage on one side [30]. By 2,000 BC improvements in metallurgy took place, which made stone-cutting tools to be available in the Middle East and Greece, helping local streets to be paved [30]. A noticeable improvement of the streets structure was created by the Minoans around about 2,000 BC [30], when they built a 50 km paved road which had side drains. The street structure consisted of a 200 mm thick pavement with sandstone blocks, bounded with clay-gypsum mortar, then covered by a layer of basaltic flagstones. This road is considered to be more modern than any Roman road.

Even if there were many ways to build the street network during the Roman Empire, all were based on the following principle: firstly they determined the path of the road before blaze it. Then, in order to build the road they drilled two parallel trenches separated by almost 2.5-4 m. After that, the soil was taken between trenches until reaching a solid base. Then, they filled it with three or four layers of different materials.

First they put a layer of large stones or rubble, and then added gravel or flat stones installed together with cement. Finally, they put a layer of gravel or pieces of stones and compact them. However, many types of pavements existed there, where some gravel roads were just compacted stone, others were paved with stones. The surfaces of these streets have been made from large flat stones, usually taken from the local rocks. The Romans made these streets a little convex at the center to make rainwater flow easily from the center to the channels on each side. However, sometimes final roads could reach 10 meters width with pedestrians' paths on both sides, as shown in Figure 2.2.

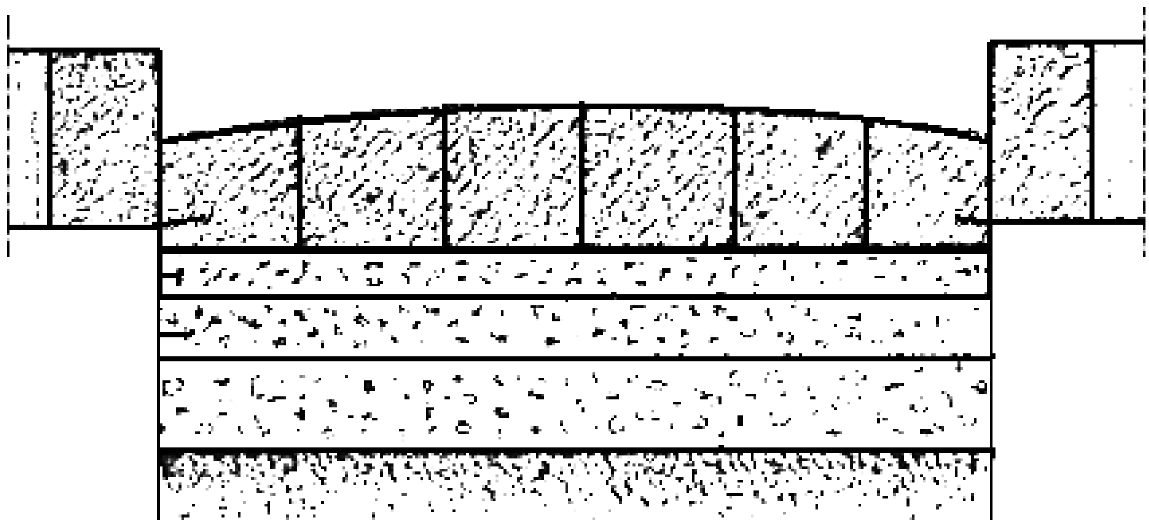


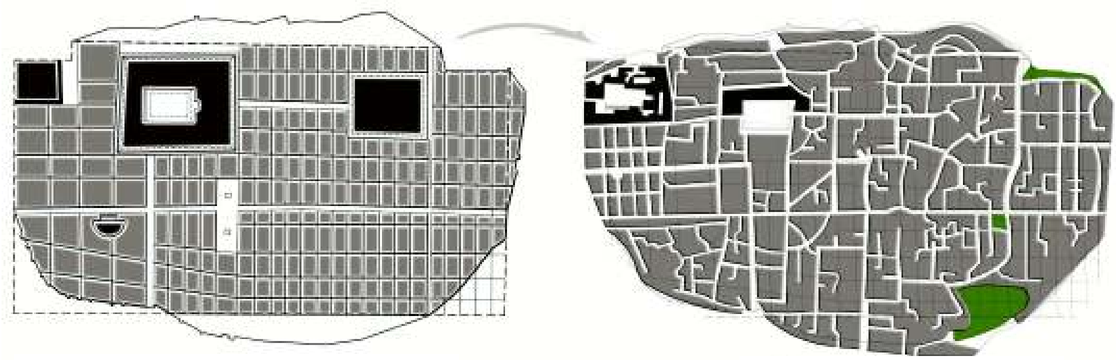
Figure 2.2. Roman street layers

2.1.2 Medieval age

Medieval towns emerged at the sites of the previous Roman colonies, and new ones grew up around a castle or a monastery; or followed the contour of a hillsideriver-bank. As a result, streets were steep, winding, and narrow with an irregular width. The main streets ran to the city gates, which were the only points of access in and out of the town. These main streets were crowded and full of obstacles, preventing a comfortable circulation across town. Nevertheless, in this age became mandatory for every town center to have at least one clear street. Therefore, if any parts of a building interfered the way, it had to be demolished. Thus, the first principles of the street structure had set up in this period.

Then, the form of the roads passed several steps until medieval Islamic world [32]. A clear record of a stricter hierarchical order of streets appears in the Islamic Empire, due the culture of privacy that Islamic society cultivated. We can distinguish two types of street networks in this era. Firstly, it is the one that had developed upon the Roman cities.

For these, we can see how the main wide Roman street turned out to traditional markets; the perpendicular parallel streets had been taken a winding, narrow and twisted forms. Access to the residential areas, there are lanes and alleys that lead to closed-end streets as shown in Figure 2.3 [33]. Secondly, is the street network that existed in the cities, which was designed in this era. This one took into account the traffic separation between pedestrians, animals and soldiers, main roads and serviced roads respectively. Moreover, the most of their plan depended on the radial distribution for the military purpose.



Damascus in Roman and Greek *Damascus in Islamic*

Figure 2.3: The changing over Roman cities

There is no doubt thet most of the medieval age cities were extended over the ancient cities; and their street structure had not seen that development. Even so, if most of the streets were just dirt roads, the main streets started to be paved by stone distributed om a nice ornamental grid.

On the contrary, many roads were built out of stone and paved with tar throughout the Arab Empire. The most developed paved roads firstly appeared in Baghdad in the VIIIth century [32]. Tar was derived from the petroleum accessed from oil fields in the region to be used as a road cover [32]. A step forward, the streets of the Arabic Empire were lighted by lanterns, while the street lamps were introduce to European cities much more later, in the middle of XVIIth century, during Rennaisance.

2.1.4 Industrial revolution

The modern road construction techniques can be traced to a process developed in the early XIXth century. The road is built as a multi-layer roadbed with a soil and crushed stone aggregate, that was compacted.

The roads during the industrial revolution era were developed firstly by John Metcalf [34], who believed that *"a good road should have good foundations, be well drained and have a smooth curved surface to allow rainwater to flow easily into the lateral channels"*. In this age appeared the first street to be paved over a swamp, using series of rafts made from heather and gorse as foundations. However, all the aspects were taken into account (e.g., the technology of road construction, used building materials, and costs)

After that, John McAdam [30] launched the theory of the road building by determining the layer thickness and the stone size. The road should consist of layers [30], the lower is characterized by a 20 cm thickness and 0.75 cm stone size used. Then, the upper one has 5 cm thickness and 0.2 cm stone size. The size of stone in the top layer was calculated to be much smaller than 10 cm, corresponding to the width of the iron carriage tyres. Any material that could absorb water and freeze should be rolled out not to affect the road quality .The road traffic itself contributef by repositioning the broken stone with its own debriss, forming a solid surface that would bear weather and traffic [34].

The McAdam's method is considered as the background of the modern road construction. The most significant, subsequently improvement, was the introduction of tar (originally made of coal tar) to bind the road stones together. Then, the term *tarmac* has been derived from tar and macadam.

2.1.5 Oil age

In the early XXth century, the street-network expanded under the pressure of the automotive. The old network were not able to afford this rapid development. Thus, it was elaborated the street hierarchy concept by Ludwig Hilberseimer [35]. Since the early of the last century, urbanists started paying attention to the importance of street networks, because of the spectacular development in transportation and thus the qualitative expansion need of street networks. But the specific approach, to link the allocation of the land uses to the population growth, through main lines of transportation [36], or seeking the prediction of transportation flows, determining several topological and geometric characteristics of the traffic the channels [37] start only in the sixties of the last century.

Even though, in this period were launched some solutions for the street networks. One of them was the suggestion of hexagonal pattern for the London City. Another one was Le Corbusier [38] proposal for Paris, which is a grid-square as shown in Figure 2.4.

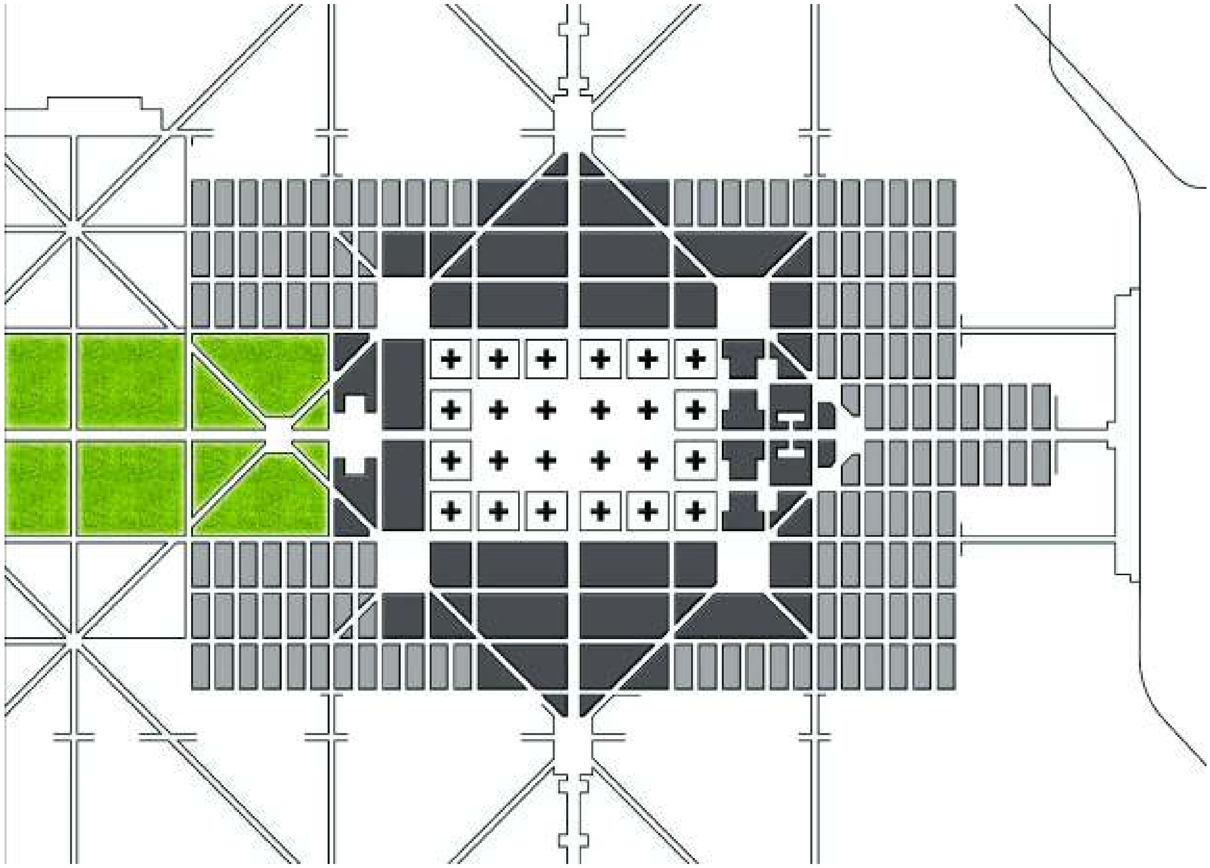


Figure 2.4: Paris networks vision of Le Corbusier

In the last century, the streets hierarchy became a topic fot the research and rational planning, as a major improvement over all different patterns of the grid system. It discouraged drag racing and dangerous high speed driving in residential areas. New master plan of suburbs, coordinated the street hierarchy into their zoning laws, restricting the use of the grid layouts in residential districts [35].

Industrialization has brought a dramatically increasing shift in traffic, once with the appearance of the motor vehicles and the pneumatic tire. Hence, the degradation of the ineligible roads became faster. Therefore, new intentions to improve the streets structure arose by the need for more efficient routes. On other hand, the oil was discovered as a motor fuel and other several products that enter directly into the structure of street. The multi-layer concept was developed in the first of part this century by adding the oil-product *asphalt* as a binder. The contemporary a*sphalt roods* have been able to support the vehicles that emerged [33]. Thus, we can say that the only real change that was introduced after McAdam was the replacing of the binding materials with the oil product *asphalt*.

2.2 Water systems

Since human existence, getting the water was a main problem. Thus, human settlements emerged when a group of people gathered around a well of water. It is not surprising for our actual great cities that are established near such place (e.g., river, lack, spring or any water resource). The far distance between these settlements and the water resources used to be limited to how many people can walk daily to reach them. All these changed when some civilizations succeded to bring the water from a far distance to their cities. Such a work is called water supply system.

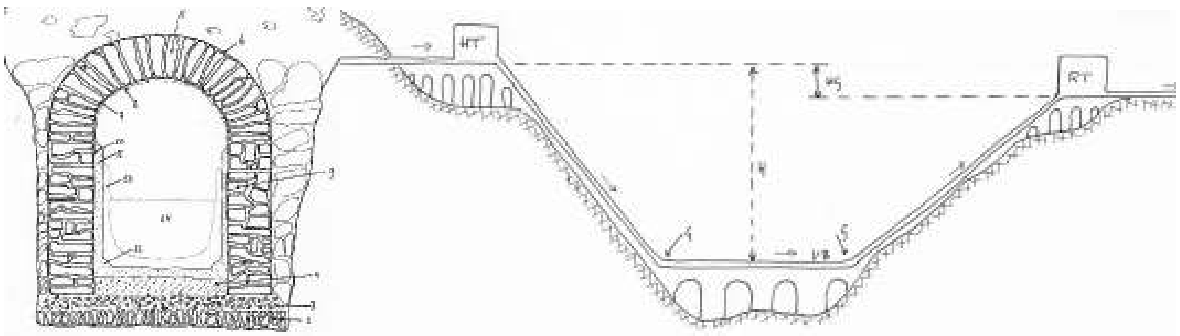
2.2.1 Ancient civilization

The ancient civilizations were decisive for humanity. Regarding water systems, the first example could be the Indus city of Lothal, after 3,700 BC, where all houses had their own private toilet. These toilets were connected to covered sewer networks that ended into the surrounding water or cesspits [39]. The sewer networks were built of brickwork and bind together with gypsum-based mortar [40].

The first underground clay pipes for sanitation and water supply were used by the Greek civilization 'Minoan'. They eveloped a water system that brought the clean water inside the city and took the wastewater out. Alongside there were storm sewage channels to absorb the overflow of the heavy rain [41]. Moreover, they were the first who used a flush toilet, indoor plumbing system for pressurized showers, elaborate heating systems, pressurized piping for firefighting purposes in the City of Alexandria [42].

Dionysius [43] said *"The extraordinary greatness of the Roman Empire manifests itself above all in three things: the aqueducts, the paved roads, and the construction of the drains''.* The water was brought by many aqueducts into the Romans cities to supply their public baths, toilets, fountains and private households. On the other hand, wastewater was taken out the city by a developed sewage systems, ended into the surrounding water bodies, keeping the city clean. The aqueduct were built of stone, brick or concrete (see Figure 2.5.a).

Firstly, the conduits above the ground were ashlar-built. Then, often were replaced by brick-faced concrete. Waterproof concrete used to cover these conduits [44]. Beside the covered trenches and tunnels, different types of piping were also used (e.g., stone, clay, and lead pipes). For cleaning, repairs and air the water, vertical inspection shafts were built at regular intervals, with 0.7 m height above the ground level [44]. When the water crossed a deep or big valley, a siphon was built (see Figure 2.5.b), where the aqueduct water poured into a distribution tank then lead pipes descended into the bottom of it then climbed up to the other side to end on receiving tank, then continue its way.



a. channel structure *b. siphon concpet*

Figure 2.5: New trends of water systems in the Roman Empire

In Petra, around 300 BC [45], Nabataeans developed a system to collect rain water using water channels, pipes and underground cisterns. They developed the shape of the cistern until they reached the perfect cube, with perfect right angles. Then, they covered this prepared surface by cement composed of water-resistant plaster of unparalleled quality. Many of these are still in use, proving the quality of the ancient Nabataean water-proof cement. They also developed sophisticated ceramic pipelines that served developing urban centers, some of these resisting till these days (look to Figure 2.6).

Figure 2.6: Nabataean clay pipes(Petra museum)

2.2.2 Medieval age

In the Middle Ages of the Byzantine Empire aqueducts were abandoned in many cities and the inhabitants focused on the construction of cisterns to collect rainwater instead [46]. Some of the underground aqueducts were built to bring the water inside the walled cities (e.g.,. Daphni monastery near Athina in XIth century). However, most of the Medieval Age cities suffered from the outbreak of diseases and epidemics, due to the lack of water system.

2.2.3 Renaissance

Renaissance did not have a notable development regarding the water systems and aqueduct networks. The households had their own reservoirs, which were filled by water during the winter, or by carrying the water into them from the rivers. In this age water was also distributed to houses by workers by cart-horses.

During the Ottoman period, water was an important issue for the religious practice. Thus, baths and fountains flourished near the mosques, with a high demand for water. That led to the occurrence of many water supply projects throughout the Asia Minor between XVth to the XVIIth century [47]. Many Ottoman aqueducts can still be observed, while many were still in service until the beginning of the XXth century. Numerous arched bridges were the main feature of the Ottoman aqueducts. The use of metal and wooden tensile strengthening elements is quite common and many traces of covered and underground conduits survive today [47].

2.2.4 Industrial revolution

Between the XVIIth and XVIIIth centuries, appeared a great need for large water systems, but their development was facing a number of important manufacturing breakthroughs, that today we take for granted.

As for piping a need for a strong, long life expectancy, and interchangeable pipes was the main water system issue. However, before the XIXth century, pipes had been made of wood and other weak materials. This piping was difficult to connect over long distances and to be repaired once in use. However, all the attempts for an extensive water service, without standardization of the pipe dimensions was not functional [48]. After the Civil War in USA, new manufacturing techniques were developed to standardize the pipe dimensions, allowing the pipe to be readily interchangeable.

With the need of a large amount of water and with the appearance of multi-storey buildings, pumps have been essential in the water supply field. However, wooden pumps existed since the 1,700^{s} and metal piston type pumps, driven by steam, were developed in the 1,800^{s}, but their use was not feasible until the invention of the electrically driven pumps [48]. The new engine was powerful enough to fill the new reservoir, but that did not mean that sufficient water had been delivered to all parts of the city.

2.2.5 Oil period

Certainly, many modern advances were not known in antiquity, such as the use of electromechanical equipment to pump water from deep wells, the use of plastic and concrete pipes in the transporting and distribution water systems, and the effective mechanical equipment for the construction of hydraulic works.

To some extent, there are differences in the apparatus used today and the scale of applications, still there are no differences in the fundamental principles used. Even the lifestyle related to the hygienic standards of a civilization may not be a recent development. For example, flushing toilets equipped with seats resembling present day toilets and drained by sewers has existed during Minoan times [48].

2.3 Building materials

2.3.1 Medieval building materials

Medieval stone walls were built using a similar concept to the antique walls, apparent stone sides and debris infill. The stones were bounded by weak lime mortars. The poor hardening properties of these mortars are an ongoing problem, and the settlement of the wreckage infills is a major concern [5].

Timber has been used also through the whole medievalism. Oak dominated the field of construction considering its durability and general availability. It had been used in a wide range of construction, not just for roofs, but also as structural elements like columns, arches, beams and walls.

Such practices remained till the late medieval period, when the growth of the towns initiated. By the end of medieval age, clay bricks and tiles replaced the stone and slate. Because fire became a general hazard, after the great fire of London in 1666, the building bylaws specified the use of brick for external walls as mandatory. By the end of the XVIIth century, most of the buildings had walls made of masonry with timber floors and roofs. The timber was now protected from direct effects of the weather, so the structural elements were made of softwood. Increased used of metal for connection and tension members was noticed too [49]. The extended use of timber last until the

XIXth century, when iron and later steel, replaced it a major part of the applications, especially the large ones. Little structural work was done using timber, apart from the conservative roofs in the gothic churches and city halls. However, the designers in the arts and crafts movements favored the new materials in their work for wealthy clients [49].

Islamic architects used in their buildings all available kinds of building materials, like stones, bricks burned, marble, porcelain and used wood, iron and copper. The adhesive mixture was plaster. They used the lime in the parts of building that need to be water resistant, like ceilings and canals and drains, as well as to paste the marble. They were using mixture of gypsum and lime in the burnt brick industry.

In the foundations were used kinds of solid stones as granite or basalt. Their depth differ depending on the building, in some large buildings were reach to a depth of a ten meters below ground level.

They invented types of mechanical machinery to lift large gravity by little effort or dragged, including the types of crane. The big stones brought to the top of the building with ropes hanging on the set of pulleys so pulled easily by an ox to the top.

Architects also benefited of chemistry so they made types of paints and dyes, which is characterized by stability and sparkle. Moreover it is known that Muslims are the first to use crystal glass created by Andalusian scientist Abbas Ibn Firnas the year 887 AD, as used in the windows colored glass and stained in geometric forms [50].

2.3.2 Renaissance

The turning point in this era was the introduction of new technologies to produce building materials. Water mills, in most of the Western Europe, were used to saw timber and convert trees into planks. Wood was also used as kind of beamsto carry the bricks and stone domes.

Bricks were used in increasing quantities. In Italy, brickmakers were organized into unions. However, the precaution of the fire risk and the availability of firewood and brickearth resources, made that kilns were mostly placed in rural areas. As long as the brickmakers where paid by the brick, the size of bricks was small, that led to lay down legislation to identify the minimum size [51].

Figure 2.7: Brunelleschi's dome of Santa Maria [52]

Renaissance architecture was directed to saturate the desire of classical trends. These classical architecture brought some problems to builders, so they did not use concrete. Thus, they were constrained to build up vaults and domes out of brick or stone. The major important discovery and development was Brunelleschi's project for the dome of Santa Maria del Fiore (Figure 2.7). The huge dome was built without formwork, just depending on bricks' weight and the way they were set to keep them in position. The dome consists of a double skin linked by ribs made out of wood and chains of stone [52].

Manufacture of glass used to be the major breakthrough in XVIIth century. Undoubtedly, glass was discovered and used before the second millennium BC, but the first transparent cast plate glass was manufactured in France in this century [53].

Iron structures were also specific for tjis century. It was used as floor beams, rods to strengthen the dome and to cover rubble cores. Iron was used in roof carpentry for straps where tension iron was fixed using forelock bolts. The uses of ironwork are found in some buildings of this period, but as they were labor-intensive, thus not used on large structures. So, it was restricted in the roof tiles of the Romans. In northern Europe it was the material of choice for prestige buildings [53].

Some experiments to obtain materials equivalent to Roman concrete were made by mixing lime with other materials mortar, but there was still far from it.

The turning point in XVIIIth century was the use of iron in both cast and wrought. Iron used as columns in several early eighteenth-century churches in London to supported only galleries. In the second half production allowed the construction of major pieces of iron engineering as iron Bridge at Coal brook dale. Large-scale mill construction increasingly used for columns and beams to be floor supported. Many of tools were manufactured in Paris but could not be made in sufficient quantities to be used for building. The use restricted on brick-made, render sometimes patterned like stone and terracotta in the UK [54].

Rock structures existed since the dawn of history. It is the longest lasting available building material. There are many types of rock throughout the world all with different attributes that make them better or worse for particular uses. Rock gives a lot of protection due to its density, but its weight is considered the main obstacle to use it in wide-range.

Stone walls have been built since humans thought to put one stone on top of another. However, in order to hold the stones together, different forms of mortar were, cement is the most familiar now.

Circular huts were built from soft granite rocks through the Neolithic and early Bronze Age. Granite used also throughout the medieval period and modern times. For roofing materials usually used to use the rock Slate if it was available.

Generally, stone buildings can be had attended in most major cities, some civilizations were completely built from stone like the Pyramids in Egypt, the Aztec pyramids and the Inca civilization.

Thatch: Thatch is one of the oldest known building materials; grass is a good insulator and easily harvested. Many African tribes have spent their lives in huts made completely of grasses. Thatch roofs existed also in Europe, but the material once started to be reduced in construction due to industrialization and enhanced transport that increased the availability of other materials. Today, though, the practice is undergoing a revival.

2.3.3 Industrial revolution

The invention of steam engine was followed of new kinds of transportation installations such as railways, canals, and stone roads. These require large amount of construction devices, machine tools, and optical surviving [53]. On the other hand this invention worked to produce some new construction materials in big amounts and make it available to replace the old ones.

As we have said the industrial revolution accompanied with many new materials that were produced and introduced in constructions. The first good example of using these new materials may be 'Crystal Palace' in London, which was the first attempt to be built from cast iron, glass and timber in very fast time. All afore worked to change the concept of onsite hand work for building, to using factory made products. Ever after the development of industrialized manufacturing processes of iron, steel, cement, aluminum and glass, the range of materials used in building structures and finishes have been enormously extended [55]. At the beginning many modern buildings had serious defects, because of the traditional knowledge, the lack of combinations or characteristics of new materials used by designers, and the information of materials and systems were weak or not up to date [55].

Metals had been discovered and used since the early time, but using it as building materials has started with the launching of industrial revolution. The characteristics of these materials can be summarized by thermal and electrical conductivity; strong but deformable under applied mechanical loads; opaque to light "shiny if polished". These characteristics are attributed to valence electrons that are detached from atoms, and spread in an electron sea that glues the ions together [56]. Iron manufacture used to take place along with coal fields as coal could use as the fuel in this process. This led to consume a big amount of wood, worked to damage forest then environment. Moreover coal contains sulphur, phosphorus and other contaminants which interacted with iron to produce impure iron with brittle and impossible to cast. Even pure metals are not good enough for much utilization including structural ones, thus metallurgists used to mix more than one kind in alloy form to improve the desired qualities like steel, brass, aluminum and gold.

Special steel: in 1860 high quality carbon steel was produced by using crucible furnace. This step was followed of many attempts to improve and specialize steels by mixing it with wide range of newly discovered metals. These new materials were discovered and used as follow cobalt (1730-1737), tungsten (1783), chromium (1798), nickel (1804) magnesium (1852) [57].

Aluminum: Hall-Heroult process is still till now the only commercial way to produce aluminum. Generally aluminum refineries are placed close to low cost electrical energy supplies, due to the cost of aluminum is mostly electricity supply forms. As an engineering materials aluminum characterized by several advantages, such as good strength, light weight, corrosion resistance, good electrical and heat conduction, easy to cast, and is 100% recyclable. Aluminum also has used to mix with steel as a deoxidizer to improve the casting of it. So we can say that aluminum used to be the critical additives cast steel till these days. Moreover recycling of aluminum could create energy saving, that recycled aluminum uses only about 5% of the energy [58] [59]. Metals have dominated the position as the most important engineering materials for long time; where steel has been considered the most significant over the past few centuries.

Although metal has dominated for several centuries, the chance to became changed by other new ones such plastic, ceramic and composites is increasing quickly. Development of materials and engineering science keep going on to merge metallurgy with polymer science, mineralogy, physical and inorganic chemistry, glass and ceramic technology, and solid state physics to include all structural and functional materials [60].

Ceramic: The word ‘ceramic’ derived from the Greek word for pottery to represent all materials of clay origin, such as glass, chinaware, porcelain, pottery, brick, cement, concrete, and enamel. Ceramic ‘as fired clay’ considered one of the first building materials where was used in the late stone age around 6000 BC. [61]. Ceramics are inorganic compounds; usually it can be obtained either of oxides, carbides, nitrides, or silicates of metals. the character of these materials are very high strength under compression, low ductility, and act as a good insulators to heat and electricity [55].

Since 1700 modern ceramic science was evolved through European development of porcelain. Great demand of this product led Europe to work to reproduce it in large amounts and good standards. We can say that these attempts were first succeeded at the beginning of 18 century in Saxony, when Bottger and Tschirnhaus developed a furnace to get the required temperature. Finally after years of experimentation they succeeded to reach high quality porcelain by mixing white kaolin and alabaster. Experiments continued to get high-quality materials, leading Josiah Wedgwood to develop ceramic materials through a combination of basalt and jasperware, using chemical methods to control the raw material in his first high temperature [56].

Glass: till the late of 19th century research about glass was inadequate. This significant scientific research once took place into the composition of the glass and the resulting physical qualities. Those three Otto Schott, Ernst Abbe and Carl Zeiss are considered the first researchers who studied the effects of diverse chemical elements to make great improvements in the optical qualities of glass [62]. Schott is also responsible for nearly all of the early developments in 'technical glasses'. Attributed to his discovery of borosilicate glass all developments of a thermally resistant cylinder glass necessary for the new gas lighting systems of the time; thermally and chemically resistant glasses for laboratory apparatus; thermometer glass [62].

The science of glass kept going on till approached in the 1836 the first modern production method for fiberglass by Dubus-Bonnell. Mineral wool was used as an insulation material in 1870. It was invented by John Player when he developed a steam jet process to mass produce fiberglass. [56]

2.3.4 Oil age

2.3.4.1 New oportunities regarding to oil materials

The occurrence of oil fuel was accompanied by the appearance of a wide range of materials that have started to be used in various fields. Building material was not so far to be influenced by this new revolutionary material, but more lots of building materials have made out of crude oil or its products. The influenc has not confined on materials that were made directly out of oil such as *asphalt*, or derivates of it as *polymers*, some materials have made as composition between oil products mixed with other materials (i.e., composite materials). Undoubtedly, oil offered possibilities, conditions, and energy required for building materials to be created. Thus, the new opportunities for building materials can be synthetic summarized in three types: 1- oil materials; 2- derived from oil; 3- composite materials

Asphalt or bitumen is a materials derived from oil with characterizes as gluey black and sticky liquid. The terms asphalt is often used to mean both natural and manufactured forms of the substance. Asphalt is extracted by distill crude oil under pressure and temperature up to 300 degree. It has diverse types differ between themselves by liquidity, concentricity, melting and freezing temperature. The asphalt usually consists out of saturated hydrocarbon, naphtha aromatics, polar aromatic, and asphaltenes [63]. However, sometimes it can be confused between asphalt and coal tar, which apparently have the same black features. Additionally coal tar used to use a binder for road aggregates until 1970 when asphalt has completely overtaken it in this using. Even though large amount of asphalt forming naturally from ancient microscopic algae and other once-living things; the great commercial amount of asphalt is obtained from oil. Another ways may form asphalt is impregnated sandstones which familiar as bituminous rock and the similar tar sands [64]. Finally Asphalt can form in hydrothermal veins where there is a crowd of laterally and vertically veins consisting of a solid hydrocarbon called Gilsonite [65].

The use of it in urban construction could be summarized as:

- Asphalt concrete which is a composite material usually used to surface roads, parking, and airports runway. It consists of 95% mineral aggregate (stone, sand and gravel) bound together by 5% asphalt cement. In addition, it was developed to be used as the core of embankment dam [66]. Asphalt concrete characterized of 100% recyclable, their recycled materials using to repair streets defects and in making new ones. [67];
- Mastic asphalt is a different type than dense asphalt concrete that related to the percent of asphalt cement in its composite which is 7-10%. This thermoplastic material is vastly used to waterproof flat roofs and tanking underground. [68];
- Asphalt emulsion is a melted substance contain up to 70% asphalt cement and less than 1.5% chemical additives. Its use involves in spraying the road surface followed by crushed rock layer. So it is like slurry seal that smooth the surface of roads. [69];
- Other uses include roofing shingles, fence-post treatments, and waterproofing for fabrics. It is also used on making Japan black, a lacquer for iron and steel.

A study field of materials concerned with primarily synthetic ***polymers*** such as plastics and elastomers is called polymer science. Before the discovery of oil was the first attempt of polymer materials to manufacture multi-types of rubber by mixing latex of rubber tree with the juice of the morning glory plants to get different types of rubber [70]. When many repeating subunits united in one large molecule, the polymer is formed. There are two types of polymers: synthetic as plastic and polystyrene; and natural one as DNA and proteins. The term polymer was coined firstly by Berzelius in the 19 centuries when he proposed that substances of equal composition but different properties be called 'isomers'. The following year he proposed the name 'polymeric' for the larger of two compounds with the same relative composition but different absolute numbers of molecules in each molecule [71]. Despite significant advances in polymer synthesis, the molecular nature of polymers was not understood until the work of Hermann Staudinger in 1922 [135].

What we are interested about is the synthetic polymers that derived from oil and used in building materials. There are two types of these polymers, thermo-plastic like nylon, polyethylene, polyvinyl chloride, and rubber. Second is thermo-sets one like epoxy and phenolics which consist of a network of covalent bonds [60]. However, the most famous polymer materials are polystyrene that used as thermal insulation and plastic that inter in wide-range of building materials.

Polystyrene*:* Is a synthetic multipurpose aromatic polymers that made out of the monomer styrene and has the chemical formula (C8H8)n. polystyrene can be existed in two forms rigid or foamed [73]. Polystyrene is generally characterized as clear, hard but brittle, poor barrier to oxygen and water vapor and has a relatively low melting point [74]. However the physical nature of polystyrene is transparent but it also can be colored by adding colorants. Naturally it is solid as a thermoplastic polymer at the room temperature, but start melting if heated above 100 °C then come rigid again when cooled. These characterized helped polystyrene to be cast into molds forming any required shape. Based on structure polystyrene is classified into three forms isotactic, atactic, and syndiotactic depending on the phenyl group and its distribution.

Historically polystyrene was discovered accidently in 1939 in Germany by *Edward Simon* from the resin of Turkish sweet gum tree [75]. The products polystyrene has started to manufacture in 1931 in pellet form. In 1941, Dow Chemical invented a Styrofoam process. The final syndiotactic products of Polystyrene once were synthesized in the early 1980s [76]. Despite polystyrene can be manufactured naturally all the polystyrene that we know right now and we work with, is synthesis begins by heating the natural gas or crude oil in a cracking process. The gas or crude oil pass through several steps from ethylene then mix it with alkylation of benzene to get ethyl-benzene. Then take out the hydrogens of ethyl-benzene to form styrene, which is the polymerized to polystyrene [77].

- ***The use of it:*** Polystyrene is the fourth largest thermoplastic by production volume and one of the most widely used plastics. It is used in applications in the order of consumption the following: packaging, consumer or institutional goods, electrical or electronic goods, building or construction, furniture, industrial or machinery, and transportation. The type of polystyrene that used in construction and what our study focuses on is called foamed polystyrene. It is commonly used for building thermal insulation and acoustical ceiling panels. Recently it has been started to be used in the concrete slabs between secondary beams instead of bricks forming the hollow core slabs. It also used in place of metal pans in the forming of poured concrete floor. For insulation it is usually used as part of a structural insulated panel where the foam is sandwiched between wood, cement or insulated concrete forms where concrete is sandwiched between two layers of foam. In addition foamed plastic sheet has been used as backing for firestop mortar [51].

- ***Plastic:*** The main materials that form plastic come from oil and natural gases, by range of synthetic and semi-synthetic organic condensation, or polymerization products, plastic can be converted into objects. This converted operation is a cracking process to obtain long chains of carbon and other elements that finally forming plastic [78]. Then it can be mixed with other chemicals to produce finished product like PVC soft, tough plastic, and many others. Bacteria, heat, light, color, and friction can also be added [79]. Plastic can be made from crude oil or manufactured from petroleum products that include liquid petroleum gases, natural gas liquids (NGL), and natural gas. The use of plastic in construction could be summarized as: High-density polyethylene (HDPE) plastic used in cabling, pipes, wood composites; Phenolics (PF) or (phenol formaldehydes) as Insulation for electronics; Polyamides (PA) as Nylon materials; Polypropylene (PP) plastic used in Pipes; Polystyrene (PS) plastic to produce foam products and insulation materials; Polyurethanes (PU) like foam products for furniture and coatings; Polyvinyl chloride (PVC) plastic to form pipes, shower curtains, flooring, windows [79].

Other modern building materials are"

- ***Fabrics:*** since century tents including all their types used to be the living place for nomadic groups. In the last century this technology was revived as a major construction technique with the development of tensile architecture and synthetic fabrics. Modern buildings started to be built out of flexible material such as fabric membranes, and supported by a system of steel cables.
- ***Fibers:*** it is a kind of plastic materials that in their semi-liquid state they are flexible and have property of plasticity. They have diverse resistance in heat tolerance, hardiness, and resilience. Their general properties of composition, lightness and tensile strength ensure their use in construction by mixing them with concrete mixture to strengthen it.
- ***Cement composites:*** Cement composites are made of hydrated cement paste that binds aggregate to make building elements. Recently various materials have been added to the mixture of concrete in order to strengthen it as fiberglass, fiber of steel and carbon fiber. However, cement is considered a polluted materials, but recently a lot of studies have been done to make these materials more eco-friendly by treating the emission of CO2 [80].

2.3.4.2 The impact of oil's building materials over environment

Plastics in general act as pollutants; however it has been categorized based on size into micro, meso, or macro debris [79]. The existence of plastic products in environment as strange materials led to adversely affects wildlife habitat and humans [81]. The comparative cheap price of plastic products leads to high levels of plastic used by human which mean more wastes in environment [82]. In addition, it is slow to degrade; plastic pollution can unfavourably affect lands, waterways and oceans through several ways like entanglement, direct ingestion of plastic waste, or through exposure to chemicals within plastics that cause interruptions in biological functions.

There is no doubt that humans also affected as long as we cannot stay far from other species, these affects can be through the disruption of the thyroid hormone axis or sex hormone levels [83]. Even though plastic materials themselves are polluted, the chemical additive during plastic production has potentially harmful effects that could prove to be carcinogenic; some of these materials are used as phthalate plasticizers or as brominated flame retardants [84]. When Chlorinated plastic degrades in environment can release harmful chemicals into soil then to groundwater or surrounded water sources, may also into ecosystem [85]. Moreover decomposition of plastic results the release of toxic chemicals such as Bisphenol A [86]. The most dangerous phenomenon is when biodegradable plastics decompose releasing methane, which is a very powerful greenhouse gas that has significantly impact to global warming [87].

Polystyrene as any polymer takes hundreds of years to be biodegraded and has a high resistance against photolysis [88]. But it degraded by number of microbe in natural environment releasing carbon dioxide. Polystyrene foam wastes forms the major ratio from all plastic debris in the ocean. That leads to become a real danger to marine life by confuse it for food. In addition, it could transfer toxic chemicals to the food chain through settling in marine animals' meat [89]. The danger of polystyrene is not limited on the marine life but to any creature that swallows significant quantities [90]. Polystyrene is considered a serious issue for human health that causes neurological impairment, toxic effect on liver and central nervous system. Furthermore styrene biotransformation causes the styrene oxide that is more toxic component [91]. Generally polystyrene is not recycled materials even more is not accepted in curbside collection recycling programs [92]. However, where it is accepted is not separated and recycled due to the lake of incentive to invest and it is not profitable economically.

It is enough for asphalt to be crude oil production to be polluted materials. However, the main emissions at asphalt plants come from the combustion of fuel, such as natural gas. Even though the asphalt pavements their selves were found to pose no harm to the environment, other aspects were omitted. The increasingly spread of black asphalt spaces at the expenses of green spaces working to rise the temperature inside the cities.

This can be caused such of pollution that may call heat pollution, which has a serious linked relation with global warming.

Concrete admixture impact over environment has been critically addressed in different ways, starting from the processing of its components until get the final concrete structure. Despite concrete is inert chemical material, the processing of manufacturing cement causes emission of dioxide carbon through first calcining of limestone into lime releasing about 0.5 ton of carbon dioxide per one ton of cement [93]. In addition oil combustion to run the rotary kiln releases approximately 0.75 ton of CO2 per ton of cement that means we have 1.25 ton of dioxide carbon released in atmosphere for every ton of cement. Beside that other gases emission like sulphur dioxide and nitrous oxides, resulting from fossil fuel burning for process and transportation uses. Furthermore, some used aggregates can be resource of radon gas. The most serious problem is when uranium mine tailing were used as concrete aggregate, but even some natural stones emit radon [93].

Other concern issue of cement and concrete production is the air pollution by dust, this most visible pollutants have been estimated about 360 pounds of dust emission per ton. The water pollution is not far from the concrete and cement production, washing pollution water that comes from equipment cleaning usually discharges in rivers, ponds and seas. Energy consumption is the biggest environmental issue, where cement production is one of the most energy consumption of all manufacturing process [93].

Anyhow all the building materials should be always accompanied with the context of environmental impact. This context means how these materials' distribution, installation, maintenance and eventually disposition are impacted over environment. On the other hand, working on reducing waste, efficient raw material use, material substitution, recycled content. Increasingly focus on protecting the environment is the key drivers to improving resource efficiency. At the same time using materials efficiently and reducing waste can produce great cost savings.

2.4 Building technology

2.4.1 Ancient civilization

Starting with primitive community, the main factor in building was the availability of building materials. As there were just few suitable roads and vehicles were primitive, thus transportation always was quite difficult and the easiest means was by water. According to that the materials were confined on local resources as comprised earths, wood, reeds, turf and thatch. Stone was reserved for the structure of very important building as it is the heaviest of building materials to transport and deal with.

Earth is considered the first building material that has been used from earliest times. Technology of making this material has been developed through time depending on the type of available earth and climate zone. Generally there are several ways to obtain it to be used in construction. The most famous one is to make bricks from it that by mixing with water to make substance plastic and then cast in mold, the other one is ram dry. Clay is the best one for plastic form that can form the both types, by time the substance was developed empirically where some materials were added to give strength and durability. This building technology required to be based on foundations made out of more permanent materials like stone or rubble. That led to appear the need of foundations first time, in order to keep the house dry and prevent invasion by vermin. It also need layer of plaster to improve insulation. However wood also was used in walls by making panels of wattle, it was not just used as supported elements for roofs, but even more clay house was roofed by tree trunks.

With discovering new ways of transportation and with developing building instrument, stone started to be dominated over building materials, because of its specifications like rigidity, durability and resistance against climate and environmental factors. The structure out of stone started by making supported walls then covered by layers of wood and earth.

The trabeated manner by using pillars had given new ways of thinking to several civilizations which took it and worked to develop it. The Cretans used trabeated manner by using columnar supports which characteristically and unusually tapered downwards towards the base. Egyptian had entered new style of columns characterized by its head *‘capital’* ,This capital was thought as a decorative feature but also a functional one in that its upper surface area was greater than that of the column, so that it better supported the lintel above [94]. Moreover they preferred to use lintels and posts to form horizontal continuous ceilings by using great pieces of stone, more than the one based upon the arch which they regarded as being less stable. However, the lack of both stone and timber had led Mesopotamia to use available local clay to make sunbaked bricks. Because of the characters of these bricks like small size and softness of the materials lintel opening was not able to be done. Due to this fact an arcuated structural system for arched opining and vaulted roofing was developed. The shapes of these arches were changed through both history and civilization. Anyhow this technology of using arched lintel, vaulted roofing, and arched opining had given the possibility to change the face of architecture. The design of vault developed gradually to be imported later in nineteenth century by other technologies where plaster vaults were reinforced by an iron structure. Other new materials like steel and glass fiber were also involved [95].

The Romans developed the vaults to cover square interiors layout by building a domical vault over a square space. The way of building this type was by using groined vaults intersect in one point, forming four separated webs between them.

2.4.2 Renaissance

In the renaissance the dome became the dominant shape to cover the square layouts. The main problem was how to transfer the square section to cylinder upon that the dome could be supported. The problem was solved by using squinch or pendentive.

Even domes were revived in the modern age as curved shell to cover large spaces. The new materials like plastic, steel and reinforced concrete have helped these roof shells to be built up.

2.4.4 Industrial revolution

Between 1850 and 1900 concrete was gradually employed more widely for building purposes. However in the modern age and exactly starting from twentieth century reinforced concrete has become the dominated building materials. The invention of steam engine and then the discovery of oil have made revolution over building technological in both transportation and building instruments. The theory of reinforcing concrete with iron to increase its tensile strength was advanced in late XVIII century. The need to rapid construction led to appear the prefabricated elements. This technology has succeeded once when elements could be standardized and three dimensions have been set up.

2.4.5 Oil age

The features of this age have been marked as the launch of great start in the world of knowledge. In addition, it has characterized as a first nucleus that led to the enormous surge in various technical and scientific fields that had a clear impact over urban thought and production.

In general, the relation between technology and architecture has become so important in last centuries, technology process has had a significant impact over architectural creativity because of globalization and openness to the world. In light of this new technology many tremendous architectural mutations have been occurred, moving humanity from one stage of great technology development to another. The discovery of new building materials, multi- structural system, and automatic, developed and high-speed means of implementation have had a great influence over urban planning. Hence, urban planning in general and architectural design in particular have been affected by this great technological development that happened in twentieth century. The development of construction technology was not in one area or two of architectural areas, but it has become in all aspects of architecture. That has led urbanists, architects and civil engineers to start using all the new developments in the building materials and structural systems, which became meet all modern architecture requirements, where the modern means of implementation has become a time and effort saver with better perform.

The technology developments are in constant renovation, so it is possible to the building materials, structural systems and means of implementation in use today to do not be after a period of time through updated them by others.

2.4.5.1 The impact of oil over the building industry

As it has been said, the invention of steam engine was to revolutionize the machine tool and engineering industries. At the same time, gave the possibility to replace craftsmanship in building by the mass-production of materials. However, the idea of making part of the building in a workshop ‘factory’ then assembling them in work site was not that new, may be dating the medieval ages but just with buildings made out of wood.

The lack of need to large number of buildings led such constructional methods to develop slowly during the later nineteenth century. However the acute shortage of buildings that happened directly after First World War was pointed to the need of quick constructions. All that has been said led to the growth of pre-cast concrete, especially when standardized steel window frames, structural steel framing and pre-cast concrete panels for walling and roofing were being manufactured. These concrete elements were delivered to be assembled on site by lorry. Moreover completed houses with bath, kitchen and their installation were made in factory and moved to the site to be temporary houses. Firstly the cost of this construction methods were expensive but the mass-production level required after the war in so many European countries made the project cost-effective.

The most essential thing that accompanied this technology is the need to standardize the dimensions of structure elements, thus a system to set an overall three-dimensional unit of measurement was required. Based on this need, the system was developed, known as modular design, ensures the precise fitting of all building parts of whatever material and wherever or by whomever manufactured [94]. Later, further development in this domain has achieved under name of building systems which means modular coordination and functional planning. In this building all building aspects like structure elements, heating, lighting, ventilation, capacity, load bearing requirements, building materials, and site characteristics were taken in consideration [94].

The advanced stage of reinforcement concrete and with the development of pre-stressing, concrete became the omnipresent twentieth-century building material. After the Second World War, and with the big need to build massive and fast constructions, many large firms have depended on on-site pre-casting methods. This new technology has helped to economize in transport and handling.

During the twentieth century many technical advances have taken place in the manufacture and use of materials which have made new building methods possible like glass cladding. This new way of structure has made a revolution in construction technology, introducing the curtain wall of steel and glass, hanging in front of a steel-framed structure and separated from it.

Furthermore, advanced technology has helped to appear other building materials like float and solar glass, laminated wood and particle board products that have been used in a wide-range. Even though plastic had been made since the early of the twentieth century, its applications in structure needs was not fully developed yet. However, the experimental work and manufacture demonstrates their satisfactory potential by mix it with other materials like the combination between polyester resins and glass fibers. Anyhow different plastic has been used in variety aspect of building as cisterns, piping and roofing panels.

2.4.5.2 Transport and buildings instruments for building multi-storeys buildings

As known historically builders have had very little equipment prepared for construction site. Long time ago heavy work and lifting has relied of human power or with animal’s help and very rarely with water power. These days, we just need to be able to choose the right equipment on the market and of course with right financial prediction. The technology has changed the way to build, for example: the possibility to pump concrete has provided designers and executed company new opportunity to construct tall reinforced concrete structures.

2.4.5.3 Formwork and scaffolding systems

Formworks and false-works used during constructions, playing an important role in all types of construction projects, both in regard of achieving a good final quality of the concrete or having a smooth and effective construction. In the construction of high rise buildings an effective and efficient formwork is of great importance since small misalignment in the structural members. False-works is a term used for all temporary structures needed to support a structure during its construction until it is self-supporting [96].

Traditionally formwork has often been made out of wood that was built in place, and then often was disposed after the work is finished. Building new formworks for each type of shapes will be very expensive and the erection time will increase. Therefor the modern formworks are modular type, and adaptable to different thicknesses and widths. Some modules are easily handled by single workers but others we need cranes to be handled [96].

2.4.5.4. Cranes for climbing formwork

Jump-forms have been used for long time and usually are useful if formworks are used for consecutive casted concrete which have the same cross section. Once the formwork has been stripped it can be lifted with crane and then hooked and secured at the next level. This process saves time because it is not necessary to assemble and disassemble the formwork of each floor.

These systems are relatively cheap if they do not require any climbing machinery but because they are lifted by cranes, other crane-dependent work may be interrupted or suspended. This slows down the project progress and may also increase expenses by having pending processes. The sizes of the formwork modules are limited by the crane capacity. We have also structural geometry restriction regarding the shape of casted concrete elements. Lifting process of the climbing framework it must be supervised by qualified staff.

Due to these disadvantages crane operated formworks are seldom used in modern high-rise construction. Crane-operated formwork are however highly competitive when it comes to lower high-rise buildings.

Thanks to the lower investment cost of buying or renting this system, compared to self-climbing formworks, it can prove to be a better and more economical solution [96].

2.4.5.5 Automatic climbing formwork

In order to unburden the cranes and thereby allowing them to perform other tasks of self-climbing formworks, they were developed automatic climbing systems (ACS). These formwork systems have much in common with crane-operated formworks, but hydraulic systems that are used to push the formwork upwards as the work progresses. This system is completely independent from cranes and offer an efficient platform and safety work.

At the top there are platforms for work, serving for preparations of the next working stage. These provide suitable fitting of the reinforcement bars in the concrete. When the forms are retracted there is also a service room for cleaning the surfaces and treatment with anti-adhesive agents [96].

At the stage of building skyscrapers, a self-climbing formwork first raises the core followed by the floors and secondary structure some levels below protected by another set of climbing system. In the figure a climbing hoist and an externally free standing crane are also visible.

The two largest formwork manufacturers that provide these formwork solutions today are Peri and Doka. Other framework system was used by MEVA [97].

2.4.5.6 Sliding formworks

Instead of having the formwork climbing one floor at a time, we could use sliding formworks. Sliding formworks which lowly climbs so that the concrete is casted at the top of the formwork to the bottom of the form, but not until the concrete has achieved such strength that it can be self-supporting [98] [99].

Sliding formworks have advantage such casting joints are avoided due to the continuous pour. This formwork system also makes it possible to achieve a fast progress of the erection of the concrete structure [96].

2.4.5.7 Pumping systems

The world record in vertical concrete pumping is 606 meter, and was set at the Burj Khalifa project in Dubai [100]. An issue when constructing a high-rise building is to get concrete to the highest levels during the construction of such buildings [101]. One way to solve this issue was to replace supporting concrete structures in the top, with steel structure.

The distance and height was a real challenge, we need high pumping pressure, and the flowing time of concrete was long and because of the weather, concrete needs to be cooled during the casing. These issues set difficult requests on the equipment that are used for casting, especially the concrete pump and the pipes [101].

2.4.5.8 Massive wall brackets hold the concrete

Because pipes are still full during the concreting, we need to support the weight of the risers for every delivery line, by a massive mount after each transition to the vertical. These U-shaped mounts have been welded with heavy steel plates which have been concreted into the walls and can support the weight of this riser. With a pumping riser's height of approx. 570 m, the weights involved are very big, if we count the pipes and couplings and the weight of the concrete come to more than 50 tons!

For each three meters of pipes pump lines are fixed by floor supporting plates between two storeys, so that they are released in the vertical and horizontally are fixed [101].

2.4.5.9 Hydraulic lifting device makes it easier to replace pipes

In order to replace the individual delivery pipes, special lifting devices were developed. The system consists of sleeves that are connected with the coupling of the pipe section above. Then two anchors are routed through the slab above and supported by it. The complete line section is lifted by hydraulic drive cylinders that are operated by hand pump [101].

2.4.5.10 Prefabricated elements and there advantages in front of cast concrete

The precast structure as other structure elements has achieved some advantages and disadvantages, as clarified below in Table 2.1 [102].

2.4.5.11 Prestressing and its advantages

Prestressed concrete elements principle is very easy to be obtained. Pre-compression has to be applied to control the stresses resulting due to external loads below. The neutral axis of the beam tension develops due to the external load which is more than the allowed limits of the normal concrete. The pre-compression applied may be axial or eccentric [102]. Prestressed concrete structures can be classified in various ways depending on the features of design and constructions.

Tab. 2.1: Advantages and disadvantages of precast structures

Advantages	Disadvantages
very rapid speed of erection.	very heavy members
good quality control.	camber in beams and slabs
entire building can be precast-walls, floors and beams, etc.	lower continuity and stiffness
high quality because of the controlled conditions in the factory.	functional flexibility is restrained
economy of timber scaffolding	required special mechanical devices (lifting, cranes)
economy of manpower, low manufacture time	design is more complex for different stages: manufacturing, transport, lifting, positioning, final state
no weather problems	very small margin for error
the joints are settled by design	connections may be difficult
prestressing is easily done which can reduce the size and number of the structural members.	because panel size is limited, precast concrete cannot be used for two-way structural systems.
	economics of scale demand regularly shaped buildings.
	need for repetition of forms. yhat will affect building design.
	joints between panels are often expensive and complicated.
	skilled workmanship is required in the application of the panel on site.

Pre-tensioning: In which the tendons are tensioned before the concrete is casted, tendons are temporarily anchored and tensioned and the prestressed is transferred to the concrete after it is hardened.

Post-tensioning: In which the tendon is tensioned after concrete has hardened. Tendons are placed in sheathing and after this stage we inject concrete under pressure. Table 2.2 below shows the advantages and disadvantages [102].

2.4.5.12 New opportunities of Height and Ultra-Height Concrete

As a concrete field innovation, ultra-high performance concrete (UHPC) provides a new technology to expand a precaster's business with new products and solutions. The material's combination of superior properties having effect for structural engineer who can now design thin, complex shapes, curvatures and highly customized textures – applications which are difficult or impossible to achieve with traditional reinforced concrete elements[103].

Tab. 2.2: Advantages and disadvantages of prestressing

Advantages	Disadvantages
the use of high strength concrete and steel in prestressed members results in lighter and slender members than is possible with RC members.	the availability of experienced builders is scanty.
in fully prestressed members the member is free from tensile stresses under working loads, thus whole of the section is effective.	initial equipment cost is very high.
in prestressed members, dead loads may be counter-balanced by eccentric prestressing.	availability of experienced engineers is scanty.
prestressed concrete member possess better resistance to shear forces due to effect of compressive stresses presence or eccentric cable profile.	prestressed sections are brittle
use of high strength concrete and freedom from cracks, contribute to improve durability under aggressive environmental conditions.	prestressed concrete sections are less fire resistant.
long span structures are possible so that saving in weight is significant & thus it will be economic.	
factory products are possible.	
prestressed members are tested before use	
prestressed concrete structure deflects appreciably before ultimate failure, thus giving ample warning before collapse.	
fatigue strength is better due to small variations in prestressing steel, recommended to dynamically loaded structures.	

Some optimizations have been introduced like adding high carbon metallic fibers. This additive materials make it achieves compressive strengths reach up to 200 MPa and flexural strengths up to 20 MPa, while architectural one can achieve compressive strengths up to 117 MPa and flexural strengths up to 20 MPa. Afore mentioned put it to be used in a wide-range of architectural and structural applications. For architectural UHPC applications, Polyvinyl Alcohol (PVA) fibers are used [103]. We can also reduce or eliminate passive reinforcement due to the properties of. It is also highly flexible and we can precisely repeat elements [103].

UHPC has got a lot of advantages, like reduced global costs as formwork; labor; maintenance; erection speed. Its applications are bridge, beams and slabs; urban furniture; solid and hollow wall panels; louvers; stairs; large format floor tiles; pipes and marine structures [103].

New challenge in the field is the manufacture of precast UHPC elements. However, precast made of UHPC is a fundamental change to traditional manufacturing processes, through introducing many improvements regarding batching methods, casting techniques, molding expertise, and handling techniques [103].

2.4.5.13 Technology of absorbed carbon

However, concrete has originated from earth, and seems to look like inoffensive material just like mud, the fact is that concrete is considered the world's third largest source of carbon dioxide. The process to product concrete release at least 5% of the CO2 that pump into the atmosphere annually. However, recently researches to make concrete carbon-neutral or even carbon-negative have been started, by using different technologies. Novacem Company is claiming carbon-capture by using magnesium silicate as its product's base [104] instead of limestone that used in traditional Portland cement. The silicate is converted to magnesium oxide through a low-heat of low-carbon producing cement. Therefore, when the cement hardens within a concrete mixture, it actually absorbs and stores atmospheric CO2. This product as Novacem said can capture amount of CO2 approximately equal to 70 percent of the amount of cement used. Moreover, regarding the costs this products are supposed to be comparable to Portland one, especially it is even recyclable [104].

2.4.5.14 Contemporary concrete and eco-friendly enhancement options

Concrete seems pretty inoffensive compared to other fields (like in the chart presented in Figure 2.8), but taking into account how much energy is required to produce the concrete components and process like heating, mixing, and transporting the concrete, it can easily be observe that the use of traditional concrete in green buildings is not effective at decreasing the carbon footprint [104].

Carbon footprint is represented the quantity of released carbon dioxide through fossil fuel combustion. It is often expressed as tons of carbon emitted per year [105]. Concrete industry has been classified as the main producer of greenhouse gases emissions, mainly due to the high environmental footprint of cement. It is estimated that during produce one ton of cement emit approximately one ton of CO_2 [106]. The world's total production of cement in 2008 was 2.84 billion tons, which positions cement together with fossil-fuel burning and gas-flaring in top position with other emitter industries[107].

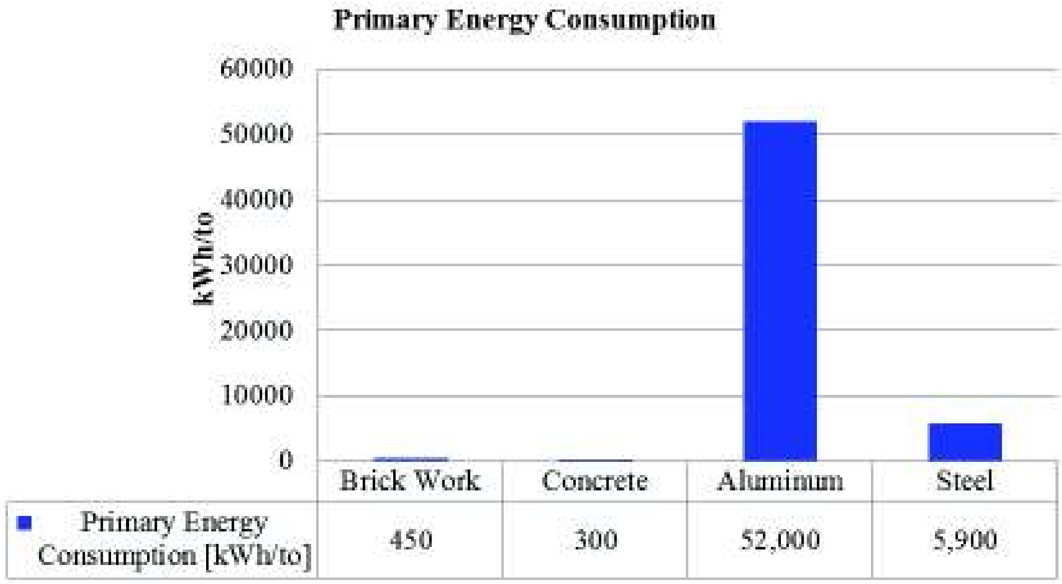


Figure 2.8: Primary energy consumption [104]

These days concrete industry has begun taking some procedures to reduce the carbon footprint by replacing Portland cement with fly ash or slag, enhancing the mix with chemicals that allow working with less water. Further the introduction of coarse aggregate cooling systems help to find ways to more innovative solutions including carbon retaining [108].

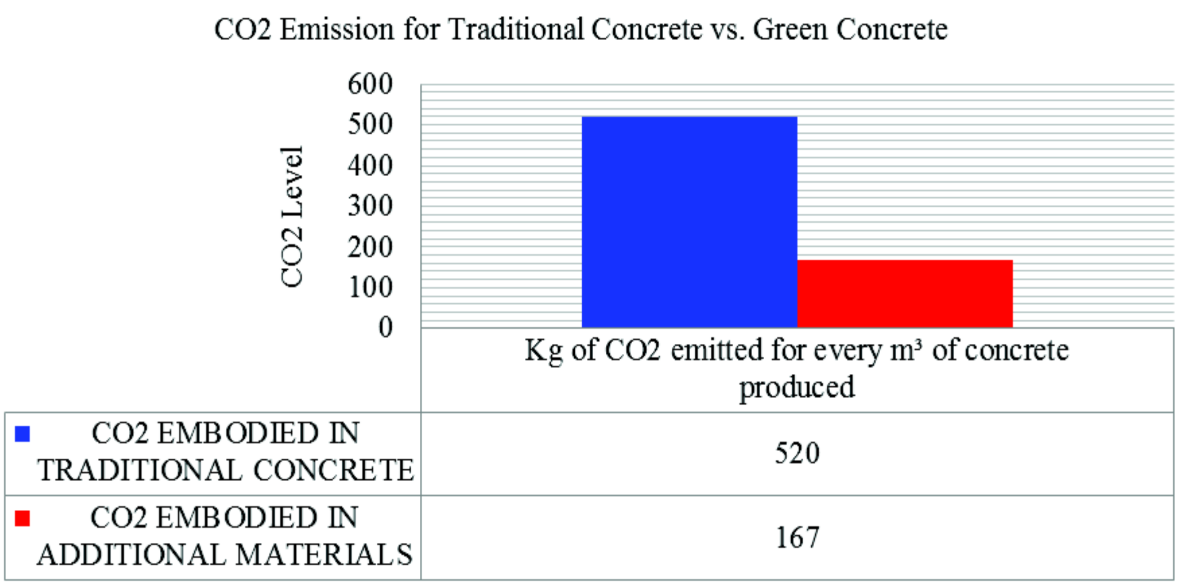


Figure 2.9: Emission for traditional concrete vs. green concrete [104]

Technology is trying to transfer concrete from being a polluting material to become an indispensable element in sustainable construction projects (see Figure 2.9). For instance, a recent study regarding the installation of railway sleepers shows that concrete sleepers produce six times less GHG emissions than timber ones. This is of foremost relevance in Qatar and the GCC area where timber is a scarce commodity and the prospect of a joint GCC railway system will demand the installation of a considerable number of sleepers [109].

3. CITIES SINCE POST-CLASSICAL HISTORY

3.1 Overview over the medievel cities

For the medieval age, the following two types of cities will be considered:

- Cities that existed prior to the Middle Age that extended and developed, specific to the European continent (see section 2.1.1);
- New born cities, that occured especially in the Near and Middle East, where the Islamic civilization reached the the top of its prosperity.

The above mentioned cities are the background of the Renaissance cities, that marked a turning point in the evolution of the human society in general, and urban development in particular.

3.1.1 European cities

This era in Europe is called Dark Age, being a transitional period between Roman Civilization and Renaissance, while the society in Western Europe was controlled mainly by the Inquisition of the Roman Catholic Church.

Urbanism has not completely disappeared during the age after the decline of the empires in the west. Some cities survived as human settlements, where others became the governmental centers of the invading peoples, but generally they failed in the economic sense and they had to be rebuilt slowly. By the end of the Middle Age, a large number of cities and towns had emerged. Counting them is an impossible task because the boundary between town and village was often vague and uncertain. In central Europe, alone their number must have run into the thousands [25].

Whether arbitrary and spontaneous planning were the ways of creation the European cities, the old-fashion approach to them was not the classical antiquity style. All towns were to a certain degree engaged in agriculture. Each morning citizen-farmers led their wagons and carry their tools to the surrounding fields, returning each evening to the security of their urban homes. A strict limit was set to the extent of this agriculture's development by how far would they be prepared to travel. The European cities in the medieval age have established and grew up as [25]:

- ***Organic towns:*** Generally, the term organic refers to the settlements that have born spontaneously, without any previous plan, just as a reaction of the human needs to settle;
- ***Planted towns:*** This term defines the towns that had previously occurred with some urban features. Most of them were the intentional and conscious invention, for the own profit of the territorial lords. Moreover, these initial cities could not flourish without the market, where farmers from the villages could bring their products for sale and where they might get the few goods which they could not make themselves. A fair might also be allowed to attract traders from very much further neighborhoods and dealing in more unusual goods [26]. Therefore, these towns are considered the middle stage between planned and organic towns.
- ***Planned and unplanned towns:*** Despite the majority of the human settlements were unplanned, in the sense of the layout of the streets, the construction of houses and public realms was partially controlled by the local authorities, in accordance with an overall plan. So, the urban plan was not completely absent. There is evidence that city development was not totally unplanned, and buildings were spontaneously distributed in the space. Therefore, every town had centers that defined the purpose of its establishment. Sometimes this might had been a natural feature or obstacle, like a river crossing or a difficult topography. Other centers had a castle, church, or natural place of security.

On the other hand, as urban settlements grown by the slow gathering of the adjacent villages, the master plan of the cities did not followed a single pattern. While many cities developed by spreading, other remained compact. Regarding the agriculture, in some towns was more important than to other. In other zones, the plan layout depends on the need of security, so in a hostile environment towns were more compact and surrounded by walls. All above led us to observe that the old city plan, like the Roman cities were deformed, buildings were intruded into the straight streets to change them, creating small detours [110]. However, the form of the medieval age cities in Europe generally followed these following forms:

- ***Multi-focal cities:*** This pattern existed in many European towns, one remarkable example being Kraków (see Figure 3.1). This pattern derived from the typical institutional centers like a *castle, cathedral, monastery, or market*, where every part emerged by gathering the houses around one of these centers. So, this type of towns originated by assembling some urban blocks gathered around their centers, and started to grow up till formed the whole town [25];

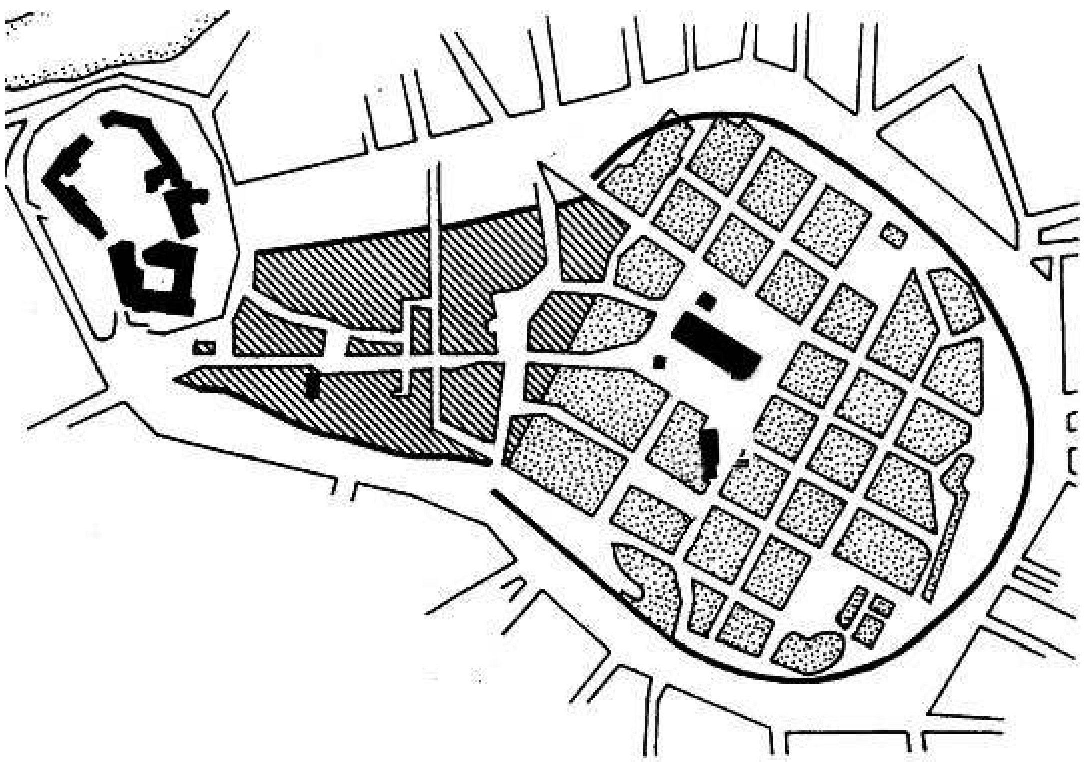


Figure 3.1: Kraków medieval town

- ***River cities:*** During entire history people were keen to establish their settlements near natural resources, and rivers are one of these attraction points, actually a necessity. Therefore, a great number of European towns occurred and developed on the river sides, especially in the western and central Europe. These cities firstly formed on one side, but the need of land led them to grow on the other side too [25]. This growth would not succeed without bridges. In some cases the towns emerged around a bridge that became and important point. Generally the features of these towns were more likely close to be two towns linked by a bridge. Budapest is the most beautiful expression of this type of city (Figure 3.2);

Figure 3.2: Budapest, uniting Buda and Pest along Danube (contemporary engraving)

- ***Fortress cities:*** As the middle age was a lawless time, citizens were exposed to lose their properties and lives not only due to the common thieves, but also from the depredations of ill-disciplined armies. Therefore, security was a major factor in the creation and growth of most towns. Thus, the function of wall was to set a limit to the urban expansion and to set the security up. Walls were functional and people had got used to live in the utmost congestion within the walls, rather than face the dangers of life in the open country beyond them [25]. The city of renaissance, Florence is the most representative city of this type.

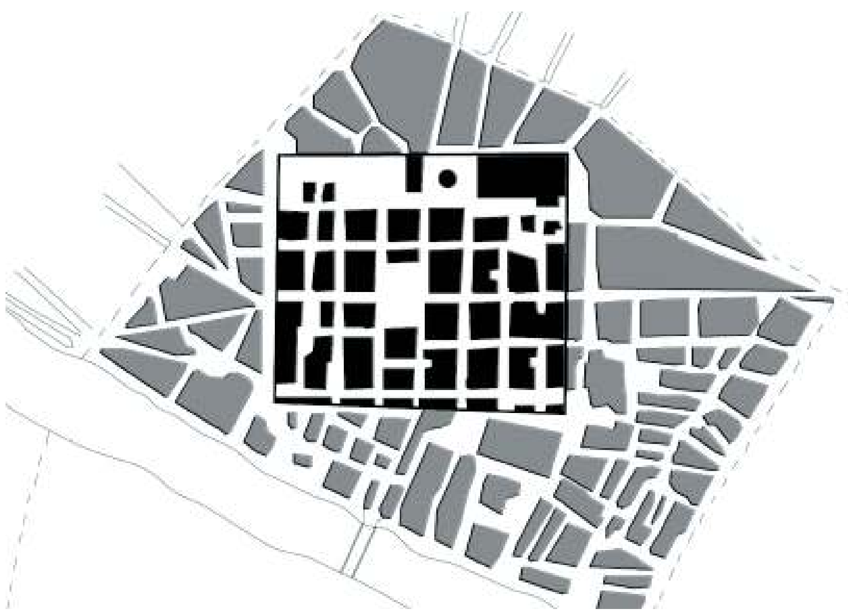


Figure 3.3: Florence expansion between the roman and medieval age

3.1.2 Islamic civilization cities

Islamic civilization had focused on the city and urban planning since its beginning. Architects and urbanists worked at that time on the concepts of new cities to be originated and influenced, directly and indirectly, by the Islamic religion. Therefore, these new patterns of planning cities were affected by the new concepts of Islamic civilization, particularly the way of coexistence and dealing within the urban settlement. All above led to reflect these concepts on the way of forming the geometrical patterns and link it with urban planning concepts. Moreover, these cities were a result of mixing and interaction between the Islamic civilization and its direct and indirect influence of the region civilizations, such as the Arab civilization, Mesopotamia and Nile Valley Civilization. These cities were actually the result of the evolution of several successive civilizations in a given residential area.

3.1.2.1 The concept of Islamic city

Islamic city is a total physical manifestation of the Islamic civilization that reflects the nature of Islamic. Therefore, the Islamic city is a cultural place, that interaction between people on the basis of sacred values which are respected by all. These cities were not just geographically and residential places, but also socio-economic and political systems gathered in a work of art and a beautiful communication tool.

Therefore it expresses the historical geographic religious spiritual city, where physical laws blend with spiritual values. In other words, the urban fabric and the configuration space were formed as result of the interaction between the urban environments with the concept of Islam.

3.1.2.2 The formation of Islamic cities

As the majority of medieval age cities, Islamic cities have almost the same way of cities' planning. The mosque, the Emirate Palace and the main markets formed the center of these cities. The early Islamic city, marked by multi-city facilities like bathrooms, schools, hospitals, corners and inns, all of them allocated in the marketplace. Even more, there were specialist markets systems so we find blacksmithing markets, perfumery, carpentry, traditional industries. Around the center, the rich class people were gathered along the main wide streets. These houses are characterized by a vast space and multi-rooms. Around these houses formed the slums (i.e., poor neighborhoods) which spread along the narrow twisted roots. The religious and environmental factors impacted over the characters of the streets. Therefore, the street networks were graded in terms of widening. As an example, the main street in Basra city was 60 arms (42 m), where others 20 arms (14 m) and the narrowest 7 arms (5 m). As a look over the Islamic cities, we will figure out the similarity of their planning with other western cities, like Paris. The main difference could be that the compact urban fabric and the privacy of the houses design. Even these cities were surrounded by walls and trenches to protect them. Around these walls, villages were distributed where people worked in agriculture [111].

3.1.2.3 Factors of impact upon the Islamic cities planning

The Islamic city is affected by several factors that led to develop its planning and the formation of the architectural elements of its constituents:

- Islamic conquests in the developed countries and the interaction between the new civilization and the great ancient ones;
- Religious and political factors control the social life and have an impact on city planning too;
- The arts of Arab nations that settled in the Arabic island and their closeness of urban nations, and the impact of these civilizations over the Arabic art and architecture in the pre Islamic age;
- The effect of the remnants of earlier civilizations of different regions of the country on Islamic architecture, such as the emergence of first architectural style in Syria where Umayyad state established their state, Umayyad state architecture was affected by Byzantine art one. In Baghdad were the Abbasid state emerged, architecture methods and techniques have changed to be influenced by Persian elements;
- Excerption from other nations art that became under Islamic control, but kept their local architecture. Moreover, using craftsman from different cultures and what accompanied that of their impacts over Islamic arts;
- Diversity of building materials and the difference of their types in different regions;
- Difference in weather and climate, temperate Mediterranean coast, profuse rains in the winter, very hot and sunny in the summer. The rarity of rain is specific in the majority of Arab countries. In Andalusia, abundant rain, snow in the north and some mountainous areas are frequent [112], [113].

3.1.2.4 Planning bases of the Arab-Islamic cities

The traditional Arab-Islamic city is characterized by a unique planning bases, which was inspired by the climatic and religious factors. These factors can be summarized as follows:

- **Hierarchy:** urban spaces of city were organized in clear hierarchy from the general to the specific. Therefore we can observe that city planning started from general space of it, then through the traditional fabric of trade shops to end up with residential condominiums. These residential units were organized as collection of spaces gathered around open interior private yard. This way of planning was accompanied with gradient in the levels of movement axes in the city. So every part of the movement system was suitable with the characteristics and personality of the space that exists in [114];

- **Diversity:** we can observe that at the level of unit and within it. Space changes, growing up and getting smaller, sometimes extends straight or curved, Includes stop, containment and transmission stations from space to other. Diversity exists in all the components of the traditional city in hallways, streets and facades of buildings around them, till the small formations. This diversity does not mean a different style, but occur within the style of simplicity and equality that cities characterized by. So there were not innovative or atypical elements. Moreover they did not design any building according to various strange architectural styles. Diversity was happening within the urban elements and its small formations [115];
- **Scale:** The traditional Arab city reflected the physical response of the requirements of human, stands in the forefront the relationship between the container and content scale. The human scale of city's spaces has played an important role to determine the sense of the receiver to how harmony and consistency of urban elements and its ability to be perceived and understood. The human scale is one of the important principles in traditional Arab city planning; city was designed in line with the human scale so that the separation between the resident and his city does not happen [116]. Alleys and streets expand their dimensions with the possibility to meet safe and comfortable pedestrian traffic. All public spaces 'courtyards, open markets and a mosque' in their three dimensions are with human scale, while facades details are with proportional dimensions with human scale. All that being said, the relationship between traditional city and the human characterized by intimate relationship unlike modern cities;
- **Compact fabric:** The one of the most important concepts that characterized Arab city, where continuity of space and its extension to include the whole city as if one connected space; coherent entity which is difficult to divide it internally because of the difficulty to separate its interrelated parts. Form and Function are linked organically through interdependence and interaction not through the collection of parts [117]. The idea of city planning is not based on specific divisions of land use, or designated areas for each class of the society, but work as a single unit with a single center where main roads return to it [114]. The space of Arab city is not always subject to the terms of symmetry. The internal spaces of the city link together organically and continue without interruption to form urban fabric, through the integration of functions makes house, neighborhood and markets interrelated

elements. These linked elements constitute a shape ruled by extreme centeredness. Thus city become a big house to the unit and subject to precise functional system includes a spiritual and physical activity.

3.1.2.5 New cities

The new Islamic cities have been classified based on the function they were established for:

- ***Military cities:*** they are cities started as military camps then developed to turn to residential cities as Cairo, Basra, Kufa and Kairouan. There are two types of these cities ones the cities that developed from camps established in area close to former city like Cairo which existed close to Roman fortress of Babylon. Others were established in relatively isolated areas like Kufa and Basra. These camps have grown and maintained their development. They quickly turned from military centers to urban centers to become populated area till these days [112].
- ***Fortress cities:*** these cities started as Citadels on border or inside the country to emphasize the influence of the State and to protect it. Then those citadels were grown to become centers of important cities like Rabat in Morocco and Monastir in Tunisia
- ***Princely "administrative" cities***: these cities emerged as a result to the increasing of political influence that was created by ruler to express the political power and to be the capitals of new satellite cities. As an example, city of Baghdad (Figure 3.4) which were set up by the Abbasids [118].

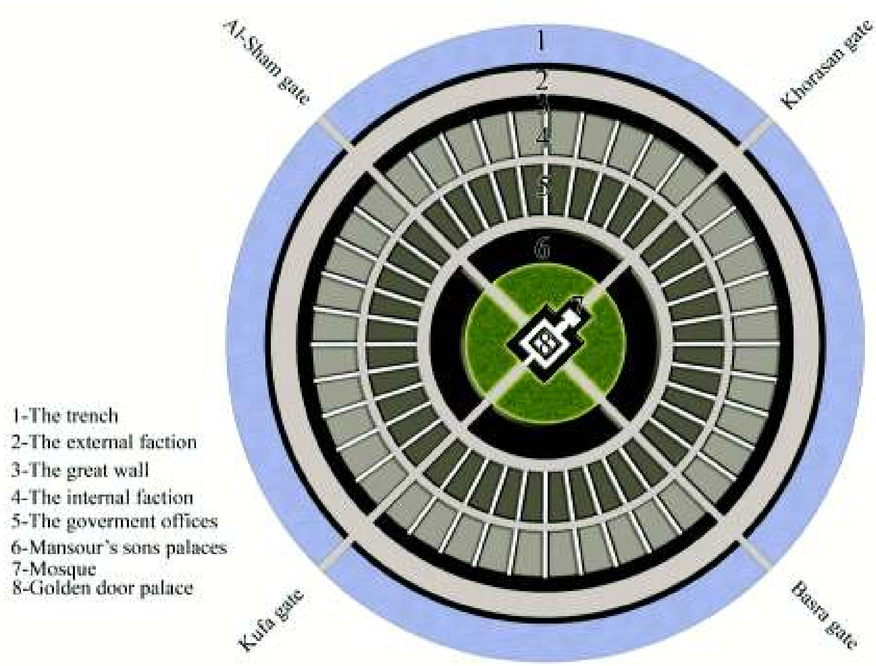


Figure 3.4: Round plan of Baghdad medieval age

- ***Holy Shrines cities:*** they are the cities that express exactly Islamic religion and its thoughts and concepts. It has represented all Islamic city properties in planning that is in harmony with the principles of the Islamic religion and to be translated in distinctive urban structure. They were established around tombs of imams and religious scholars which were the center of great and important religious cities like Karbala, Najaf, Samarra (Figure 3.5) and Kazimiyah [119].

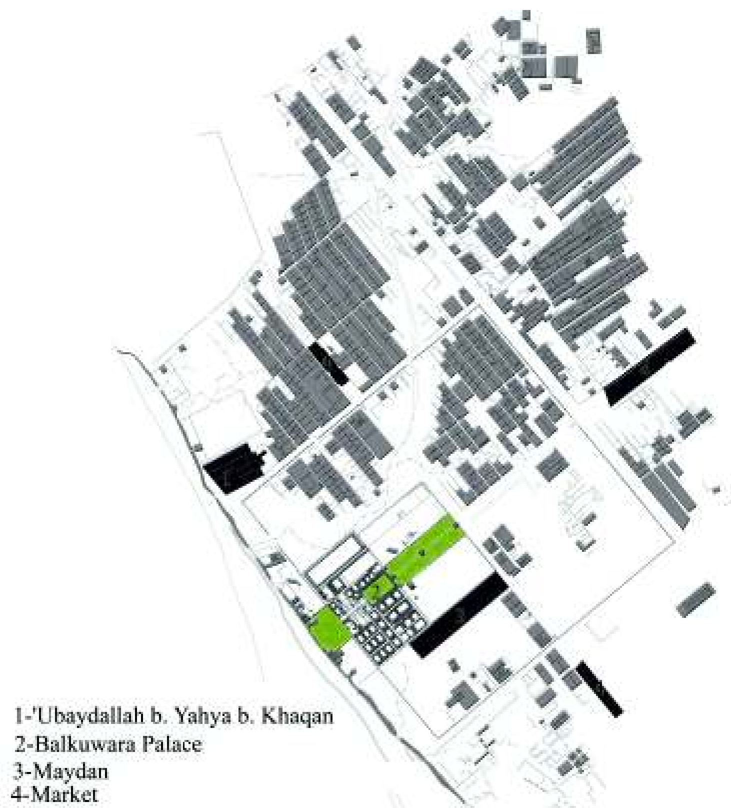


Figure 3.5: Samarra in medieval age

3.1.2.6 Existence cities

In old cities like Damascus and Aleppo, Islamic civilization worked to change the features of these cities, in line with new ideologies and visions of human relations within the urban space of city. As for Damascus "which is considered the oldest Inhabited capital in history" it had developed and expanded in the Greek, Roman and then Byzantine era. Street networks took the form of chessboard pattern like the rest of the Roman cities, which is characterized by wide straight streets that penetrate the city [120]. With the advent of the Islamic civilization and its entry to these cities, they have been changed their urban face. Temple of Jupiter, who became the church in the Byzantine era turned into a mosque that became the city center. The main streets have been converted into commercial markets. Behind this center had distributed residential neighborhoods, straight streets have been replaced by another twisted narrow. Streets get narrow whenever we being from neighborhoods to units, in residential cluster streets turn out to be narrow closed-end lanes. City of Damascus (Figure 3.6) was surrounded by wall contain gates. With the development of the city in the medieval age, new neighborhoods outside the fence were appeared [120].

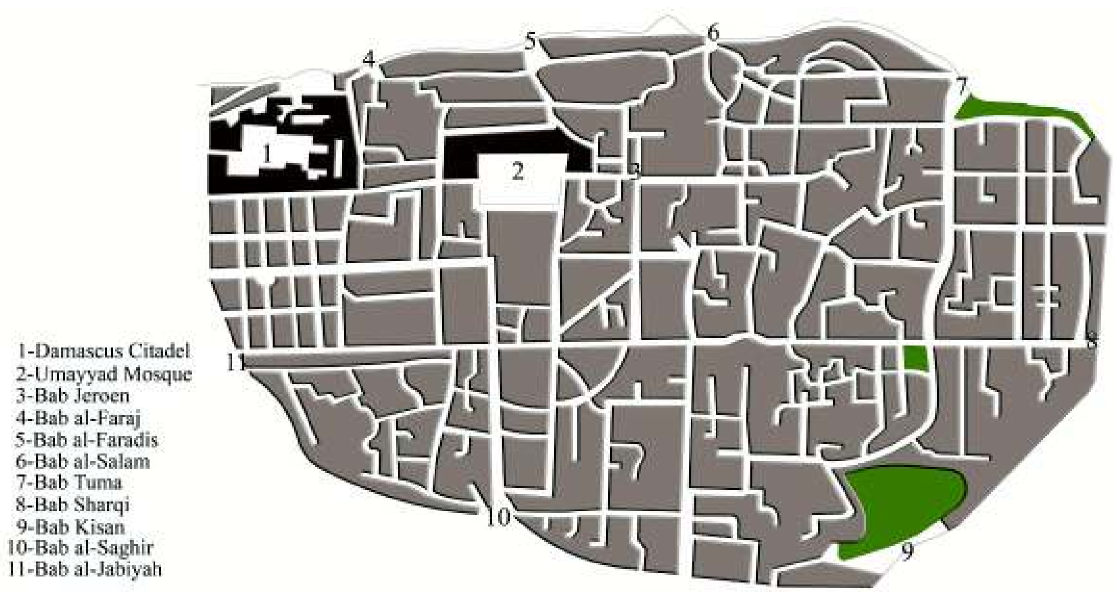


Figure 3.6: Old city of Damascus

3.1.2.7 Islamic cities from the western point of view

Western civilization was often critical with the Islamic city. Next, a few representative opinions are presented:

- *Gustave von Grunebaum***:** he considers Islamic-city as an automatic or spontaneous random city, it had been done without planning and had grown on their ownand he criticize the lack of stadiums and theaters as Romanian ones [121];
- *Lammens:* he said that cities like Alhira, Fustat and Kairouan were unplanning and undeveloped cities that because were not planned by central power but by the inhabitant themselves [121];
- *Creswell:* he believes that cities of Basra, Kufa and Fustat are characterized by narrow spontaneous misleading alleys and overlapping spaces, surrounded by tent and huts create unused land [121];
- *Lassner:* The urban distinctive growth in military cities like Basra and Kufa had done quickly and without any real realization of the basic elements of urban planning.
- *Kubiak:* Described tribes which left the Arabic island and conquered Fustat. He saw that this civilization was less developed than the existing civilization in the conquered area. So from his point of view the Arabic civilization at that early time did not have

any idea about city planning as the Roman did. He said it was impossible to build up a military city with straight streets and as checker pattern and make the inhabitant obey the rule [121];

- *Brugman and Dunne Heyworth:* they talked about the inheritance in the Islamic-religion especially about the inheritance law of land. They said it works on dividing and fragmenting the land in uneconomic way, creating so small and unusable land. In the other words inheritance law is the worst enemy to real estate.

The Orientalists' criticisms depended on the comparison between the Islamic cities and Roman ones, ignoring the growth and creation factors of these cities, as emphasized in Table 3.1.

Tab. 3.1: Comparison between the Islamic principles and the orientalists' criticism

Aspect	Islamic point of view	Orientalists criticisms
City Planning	They planned it staring from the culture and environmental aspects	They saw it was so compacted and spontaneous planning
Inhabitance role	The inhabitances participated in the planning. The city were built up for people to be comfort	They said that inhabitance planned it in a primitive ways. The state has no role
Military planning	They considered the narrow twisted allays is a way of self-defense. Their purpose was to make the enemy or the strange people get lost when they enter in.	They considered that the straight directed streets that end up in the center and lead to the fortress of the city is the best way of military planning
Environmental aspects	They planned the city in a compact way to create as much as they can of shadow and to decrease the transformation of heating by make the city as one entity	They consider the Romanian city with wide straight streets is the best way of land used ignoring the Environmental variation
Culture perspective	They planned the cities depending on the Islamic culture of privacy, where the house opens on the inner yard	They did not considered that privacy, they did not study the reasons of that way of planning
Inheritance law	They consider that dividing land is the best way of equality between sons	They consider that this law is the worst enemy to real estate, crating uneconomic and small unusable land
Development of civilization	They believes in their civilization at the same time they were opened to impacted and influence over and by the other civilizations s	They consider the Arabic civilization is a less developed than the other ones. And they worked on change the face of those cities in unplanned way.

3.2 Renaissance and Industrial revolution

Looking back through history we can deduce that when civilization flourishes in the area another one deteriorates. Thus after the emergence of Islamic civilization the western one represented of Rome and its Colonies started to fall, reaching the medieval age or what so-called dark age. However, starting from the fourteenth century a cultural aesthetic movement began to appear in Italy forming bridge between the Dark Age and modern one, this movement has known as Renaissance.

In this age new ideas have emerged about art, humanism and sciences. At the same time, the flow of revenues from the major geographical discoveries and the exploitation of gold and silver mines of the Americas have helped to develop the methods of governance.

All mentioned afore have helped rulers to regain the order and applying the law, eliminated feudalism, formation of public opinion, growth of local languages, and the emergence of national spirit have had profound impact over the establishment of the modern European states.

3.2.1 Factors growing the cities during the Renaissance

The next for factors were decisive during Renaissance [122]:

- ***First:*** The progress of the medieval city began once with the Renaissance. The upgrading of the warfare introduced new requirements for the urban defense, the medieval fortifications becoming ineffective. Thus, the city fences became obsolete and new solutions to increase the protection of the city were needed. The Renaissance cultural and intellectual movement spread and demanded reforms, with impact on city planning too. The rich aristocracy and the merchants, the church and the rulers, reached a superior potential to show their power and desire for prestige. Thus, architecture became a respected and appreciated art. The classic architectural styles, based on heroic scales, influenced the important architects and city planners, developing theories about the city development based on a superior knowledge and aesthetical need [2];
- ***Second**:* The expanded networks of trade associated with the rise of European colonialism shaped the course of urbanization. Two distinct trends were apparent. At the regional scale, expanding networks of maritime trade and the new wealth brought back from colonial exploration and exploitation strengthened the links between European cities and their surrounding hinterlands. Other trade and

exploration networks also brought back knowledge and unique perspectives on cities and urban design from various parts of the Middle East and Asia. With Europeans' discovery of Americas led to emerge growing global networks of colonial power. Expanding networks of the sea trade and the new wealth brought back from colonial countries strengthened the links between the European cities and their surrounding suburbs;

- ***Third**:* The rapid urbanization of European society created densely-packed cities vulnerable to fire and plagues, dangers that crossed all lines of class and privilege and thus justified public intervention in sanitation, construction, and other aspects of city life. The many rounds of rebuilding in the aftermath of catastrophe often created precedents that still shape the character of cities, and even broader social-political arrangements, to the present day. Other trade and exploration networks also brought back knowledge and unique perspectives for the cities and urban design, especially from various parts of the Middle East and Asia;
- ***Fourth:*** City growth and patterns varied with the particular mix of trends in Christianity and political control. James Vance suggests that sixteenth-century Europe developed two patterns of cities princely, hierarchical settlements modeled on Rome and administrative control through the Catholic Church, and new secular merchant towns that grew from the replacement of medieval economic relations with new trading wealth [2].

3.2.2 Factors growing cities during the Industrial Revolution

3.2.2.1 Economy

The civilizations, since the dawn of history, carried out on the basis of that the village is filling population needs of food and clothing. And what increases on its need, it is replaced with consumer goods from the city center, which mediates a group of villages and which is the administrative center and the commercial market. The city production of these goods was enough to satisfy the needs of the residents of the villages which located in its circle only. All means of production where manual and the streets network was unpaved and appropriate just for animal transportation.

The impact of the economic factor started to be visible once with the widely use of the ore materials (see Figure 3.7), like coal, iron and the derivate coke [122]:

- The establishment of an open market for goods;
- The monopoly of the mining areas as a source of raw materials generated new cities nearby;

- To get more workers in order to meet the need for additional workers in the busy seasons was important for the industry to arise near a large populated center;
- The factory became the center of the new urban agglomeration, and even utilities, such as water supply, often came in late as an emergency concept;
- The population density increases along the rail.

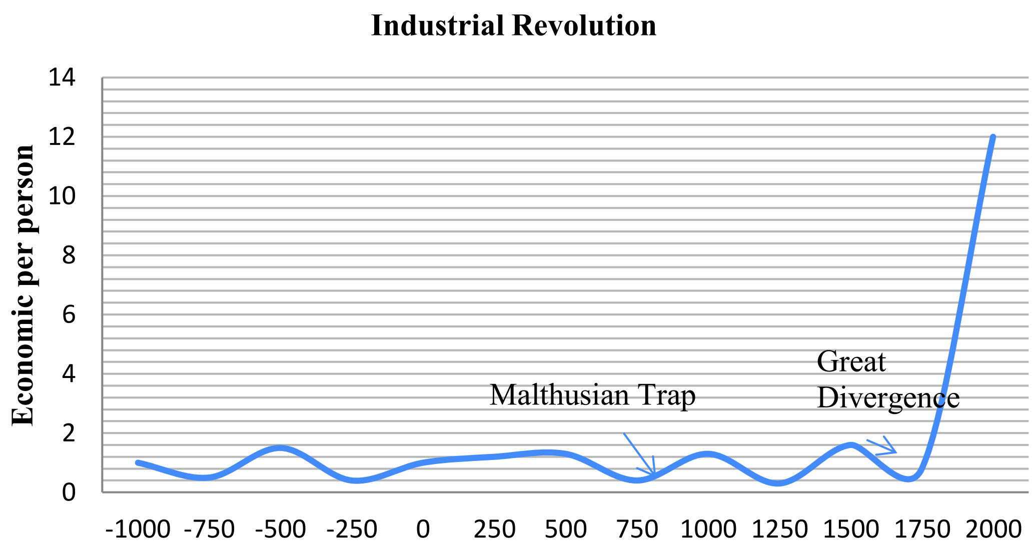


Figure 3.7: The critical point in economic history [123]

The invention of the steam engine helped to make the distances closer, resulted in the reduction of the production cost. Thus, the markets were expanded and connected, giving birth to National Economies.

3.2.2.2 Social

The spectacular increase of the population density was caused by:

- The bleeding of a large number of peasants from the countryside to the industrial cities, where factories need more workers;
- There were no laws governing the construction of housing and urban planning;
- A new trend of immigration was the migration of business into new cities, which coincided with the relocation of the workers between the cities, thus rebuilding the industrial city to suit the constructivism capitalist class in the community.

The industrial urban centers became between the XVIII and XIX centuries characterized by overcrowding. The urban population increased up to 400%, the number of the cities with more than 500,000 inhabitants increasing spectacular all over Europe [124], as shown in Figure 3.8.

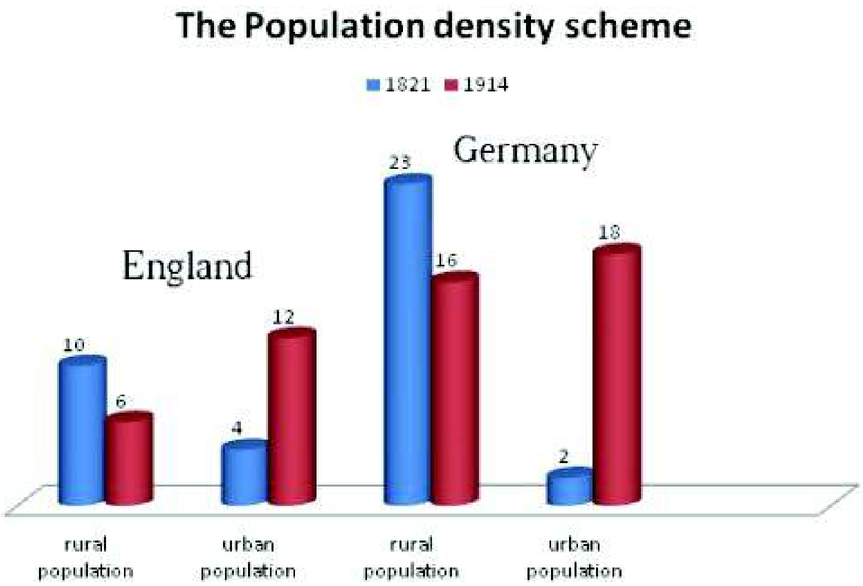


Figure 3.8: Evolution of the population during Industrial Revolution [122]

3.2.2.3 Politics

The colonial expansion policy, which industrial countries carried out, helped them to flourish there trade and discharge their goods in markets such as Egypt, India and the American colonies. The political background for the new model of urban agglomeration was based on three main pillars:

- The syndicates were neglected and the working classes were kept living in an insecurity ambiance;
- Establish a relatively open market to ensure the competition in labor and trading of goods;
- Keep the foreign colonies under the state of control, meaning to be suppliers of raw materials for the new prosper industries and markets able to absorb the surplus of production.

The emergence of the concept of capitalism, as set by Adam Smith [125], to transform the business processes to a system has foundations and regulations leading to an increase in the size of the factories, attracting around it many workers' housing and services. [122]

3.2.2.4 Environment

Environment was completely neglected in the urban development during the Industrial Revolution. Deforestation, due to the extensive use of timber and occurrence of new settlements and roads, affects the amount of groundwater and the moisture in the atmosphere. Moreover, forests support considerable biodiversity, providing a valuable habitat for wildlife. Forests are the most important stores of organic carbon, where can extract carbon dioxide, helping to purify the air from pollutants, contributing to the biosphere stability. This lack of interest for the environment was an important support for the arbitrary growth of the cities, with dramatic consequences for the years to come [126].

Population growth is a natural phenomenon, but the increase of the urban population is the result of economic and social pressure. This was accompanied by increase the spread of the city at agricultural land and forests surrounding the city. And by the time stopped working in many of farmland in the countryside due to the migration of people to the industrial cities. And unorganized increase of factories which created without environmental study led to the pollution of the atmosphere of the city which caused epidemics and diseases. For that they started thinking of planning Urban Structure so that it contains all the required services for the economy and biological activity in a way that entails providing a good place suitable for both living and working [122].

We can say that the motive environmental could be one motivation behind the creation of new cities in many countries of the world .The new city with characteristics and features distinctive urban .The most important of which is the presence of green belt surrounds the city and with overlapping in the surrounding countryside; with attention to the availability of large area of green land and recreational-use inside it; taking into account the wind distribution in order to prevent environmental pollution of the city. Therefore it can be said that the provision of a healthy urban environment less polluted could be a motive for the construct these cities for a better urban environment.

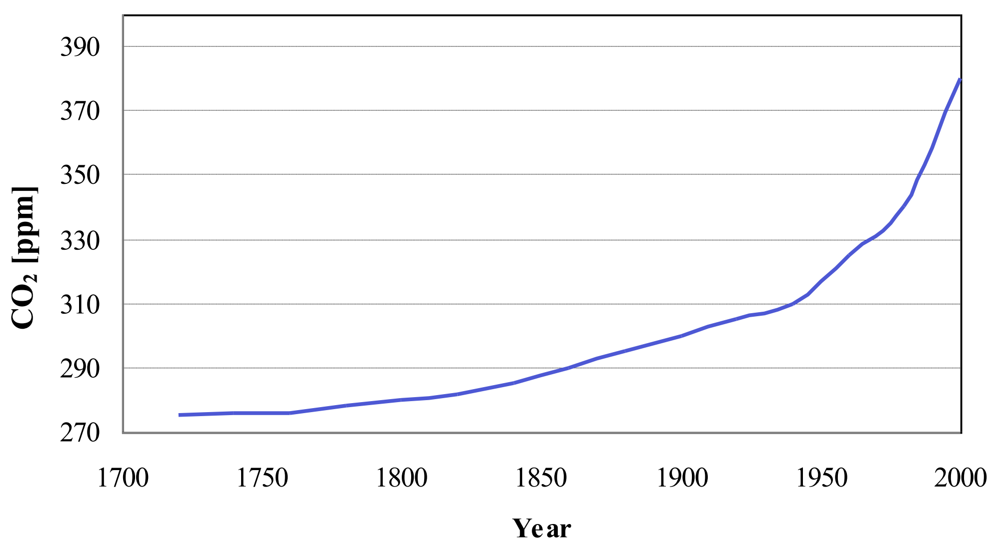


Figure 3.9: The emission of CO_2 between 1700- 2000 [127]

3.2.3 Planning the city

3.2.3.1 Formation and configuration

All significant cities in Renaissance have in their configuration the Royal Palace and its courtyard, other aristocratic buildings, trading and public buildings, streets (especially the Main Street) and squares which form the identity of individual city. Behind these, the ordinary residential buildings form the slums. During Renaissance, the form of the cities resulted in relation with streets network style into three typical patterns [128], as shown in the next sections.

The city in the Industrial Revolution do not have a particular form and do not rely in a single layout type, even if the straight line became the dominant path in architecture, and consequently rectangularity, meaning actually the gridiron pattern. Even if the gridiron system was dominant, the city also developed randomly and the streets network appeared relatively complex. However, this period suggested with the clarity the basics of architectural urban planning of the cities.

The gridiron pattern is a network of streets that confine between themselves islands or blocks, usually of square or rectangular shape? There is a main axis in the city along the public realm, palaces and the public square. This street features is wide, prestige and large scale comparing with the human scale. The planners focused in this age on straightening the main axis street, which ends with public squares or palaces. Behind this main street there are residential neighborhoods which are splitted by the ordinary street. Those streets are less wide than the public main axis street, and less significant in prestige and services. These narrow streets were crowded and with no utilities. Therefore, the streets often became a hotbed for diseases and epidemics [122].

During the Industrial Revolution this pattern developed in a network of streets that limits urban estates. The residential buildings are aligned next to each other, generating an atmosphere of monotony and excessive symmetry. This planning was implemented in the neighborhoods of the workers, around the industrial areas that require speed and economic construction [129].

There are two distinctive configurations in the gridiron system [122]:

- The orthogonal networks distributed randomly (e.g., Leeds), as shown in Figure 3.10;
- The regular orthogonal network, a clear horizontal systematization (e.g., New York), as shown in Figure 3.11.

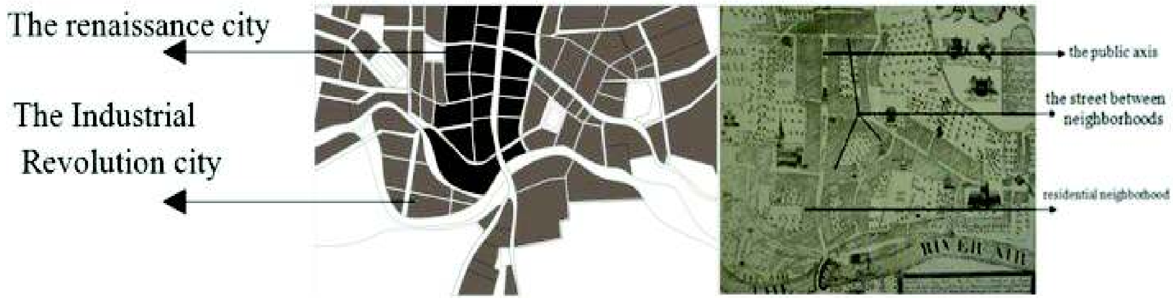


Figure 3.10: Leeds city between Renaissance and Industrial Revolution [122]

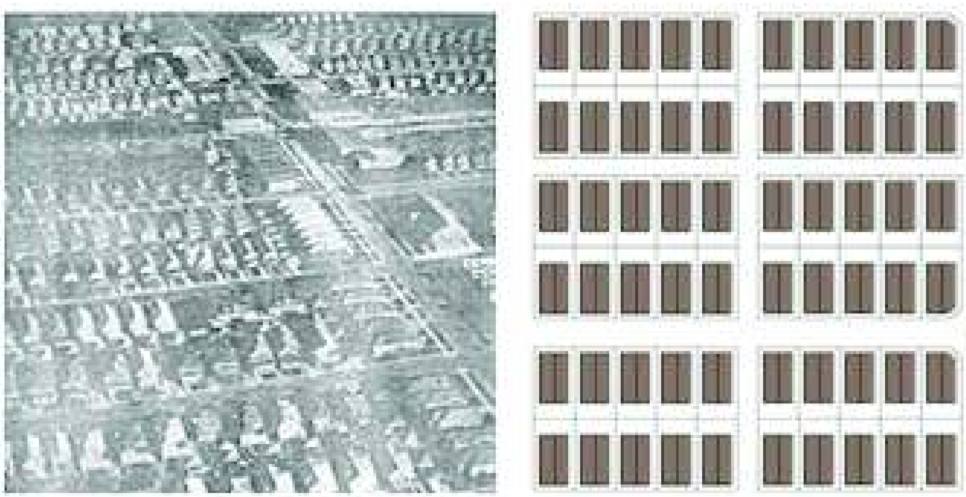


Figure 3.11: New York City between Renaissance and Industrial Revolution [122]

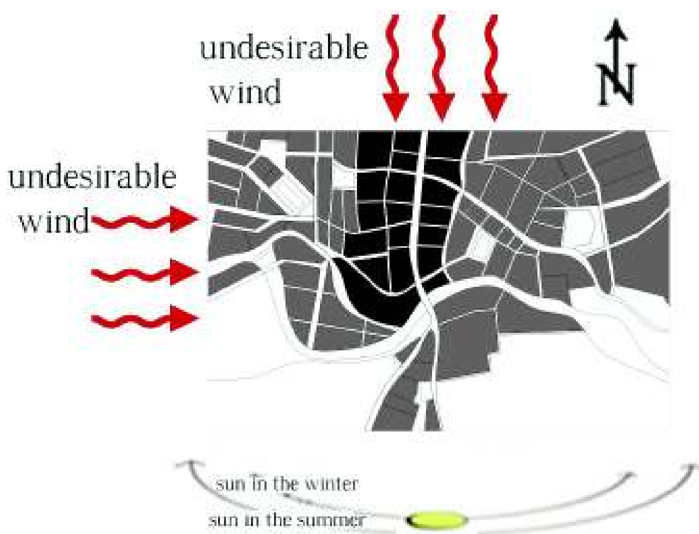


Figure 3.12: Wind and sun impact over Leeds city

Considering the climatic and environmental aspects (Figure 3.12), the first configuration takes into account the optimal orientation of the sun and wind movements, whereas the narrow street inside neighborhoods didn't let the sun enter to the buildings and restricted the wind movement. It didn't respect the nature and the orchard around the city and the streets are opened inside the orchards and farmland.

The advantages of the second configuration (see Figure 3.11), are:

- Ease and simplicity planning and speed in the creation of cities;
- This characterized of formation is economic, because the streets opens straight perpendicularly to each other;
- Creates the premises for the easy extension in all directions;
- Suitability to contain the different distributions of the land use;
- Takes into account the optimal orientation of the sun and wind movements along the public main axis (Figure 3.13).

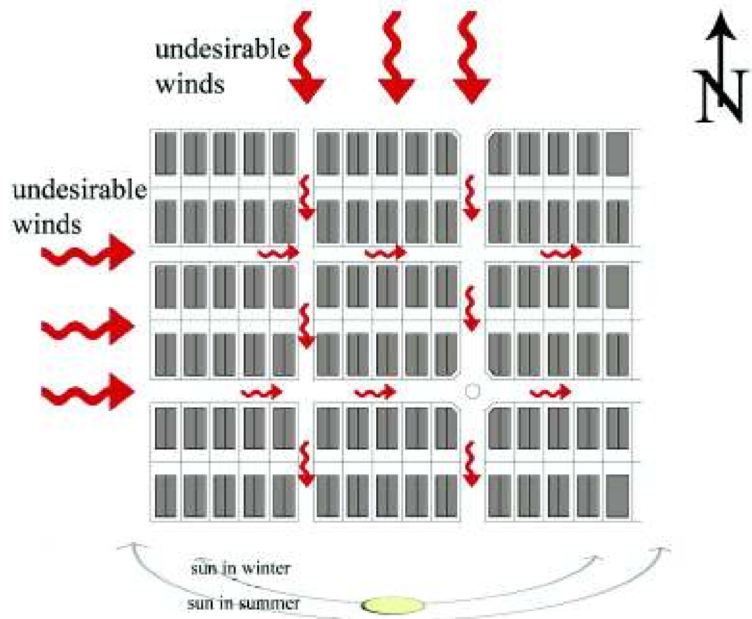


Figure 3.13: Wind and sun impact over New-York city

The disadvantages of this regular configuration are:

- Repetition, boredom resulting from the large number of intersections;
- Disrespect to the natural topography of the land;
- The narrow streets inside the neighborhood do not let the sun enter to the buildings and deviate the wind flow, generating turbulences;
- Do not respect the nature around the city and the streets are open inside the natural surroundings of the city;
- Influence indisputable on historical urban centers, where suffered from morphological changes of opening streets for the passage of vehicles and greatly with varying

degrees of sympathy, resulting in the loss of the traditional urban fabric, and change its properties. Especially opening streets do not take into account most often the important historic or architectural value of the buildings because of what the engineering properties of the streets necessitated of Straightness and perpendicular intersections.

This formation allows optimal orientation of neighborhoods for the direction of the sun and the wind, but in that era were not studied aspects of climate. And often the factory was in the center, which leads to air pollution in residential buildings were buildings lined next to each without taking into account the spaces between them to get solarization and ventilation.

Neighborhoods spread around the coal mines and industrial areas at the expense of forests and the surrounding nature and, of course, these areas not taught to preserve the environment from pollution.

<u>The radial diagonal pattern</u> is characteristic for the cities that had existed before in this shape, usually defensive cities. In this pattern the public realm, palaces and squares are in the center. The main streets go out of this center to the outskirts of the city, and are characterized by greatness and wideness, with buildings carved on its symmetrically sides. The center is surrounded by an annular street that separates the center by the private buildings of the important people of the city. The annular streets are less wide and important than the main street, but ensure the communication route between the city neighborhoods. Behind the neighborhoods surrounding the city center, there are located the neighborhoods for the general citizens (e.g., workers and ordinary clerk). These boundary neighborhoods (i.e., slums) are characterized by overcrowding and the lack of services, narrow, unpaved and unhealthy streets [122].

Paris (see Figure 3.14) is the most characteristic city for this pattern. The planning started in the medieval age considered the walls to surround the fortress city, which were destroyed at the beginning of Renaissance.

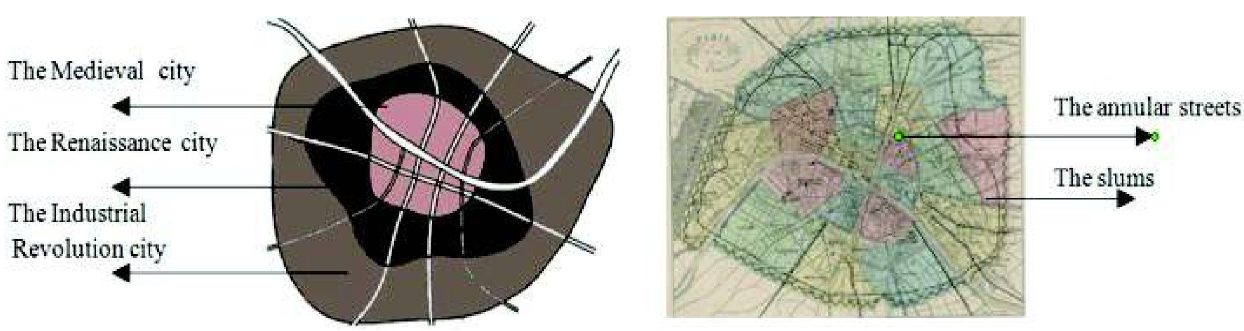


Figure 3.14: Paris city between Renaissance and Industrial Revolution [122]

The advantages of this planning can be summarized as:

- The existence of several intersections and trails that surround the city;
- Efficient radial streets for the transport within, in and out the city;
- Circular motion, which does not encourage the traffic penetrate the areas, but to rotate fast around them;
- Maintaining the historic fabric of the city in the heart of the city;
- The orthogonality between the streets is natural because all streets tend to end in the center of the circle;
- Mitigation of the pressure on the main streets, due to the large number of streets linked to the center;
- Respect to the nature around the city, because the streets are going around the orchards and farmlands.

The disadvantages are:

- Difficult growth and increased pressure upon the internal streets;
- The division of land uses in an inflexible manner, which does not allow to easily changing the land-use, generating dissimilarity in the activities;
- Pressure on the center, especially at rush hour, because all main streets end in it;
- Does not give sufficient flexibility for the growth of the city because annular growth often meets natural obstacles;
- Difficulties in finding future solutions to this kind of formation;
- The planning does not take into account the optimal orientation of the sun and wind flows; the main streets buildings have proper ventilation and solarization, but the narrow streets, inside the slums do not let the sun to enter and restrict the wind.

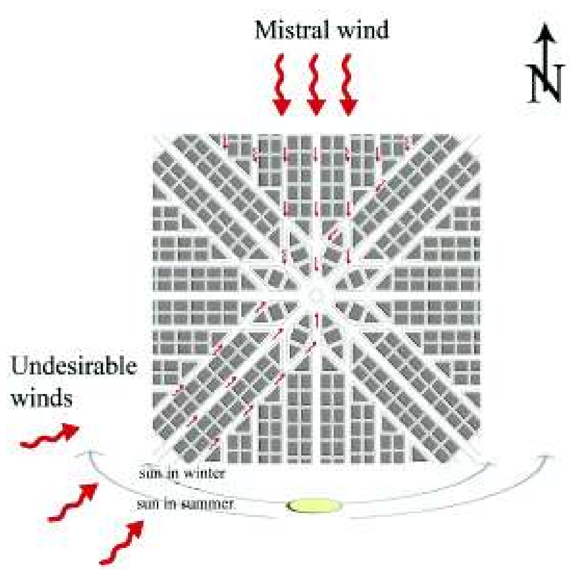


Figure 3.15: Climate aspects over Paris city

This planning does not take into account optimal orientation of the sun and wind movements, whereas the building that viewed on main street had a good ventilation and solarization, but in narrow street inside neighborhoods didn't let the sun enter to the buildings and restricted the wind movement (see Figure 3.15).

However, the pattern respects the nature and the orchard around the city and the streets are going around orchards and farmland, and the buildings were made by sustainable materials.

This model is an extended form of the Renaissance city, that has not been studied climatic and environmental aspects because the aim of this formation was the defensive.

The axial-linear pattern concept developed where the city has a longitudinal direction owed to natural determinants as coastal cities, or cities that are spread longitudinally around the rivers (see Figure 3.16). It consists of a public axis, wide and luxurious, that runs along the city, parallel to the natural border. The public buildings, palaces and squares are distributed around it. The streets that form the neighborhoods were opened perpendicularly on the main public axis. The residential neighborhoods spread behind these second rank streets in terms of wideness and importance. The residential buildings in these neighborhoods are separated by a network of narrow streets, disposed orthogonal to the secondary axes, with no utilities [124] [122].

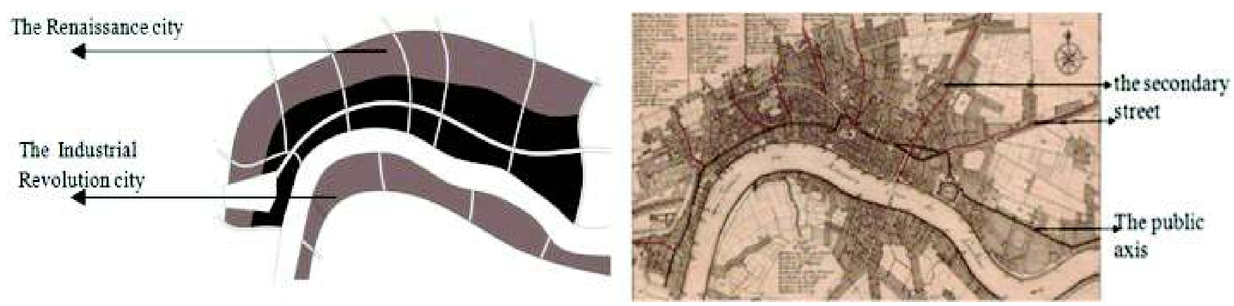


Figure 3.16: London's neighborhood in 1700-1850 [68]

The city extends longitudinally on the east-west direction, which leads to all neighborhoods facing the south and north, and north parts are never exposed to the sun during the day.

The streets which open on main axis constitute crossings for air, leading to good ventilation to these neighborhoods, especially facing the axis leading to reduce the humidity (Figure 3.17).

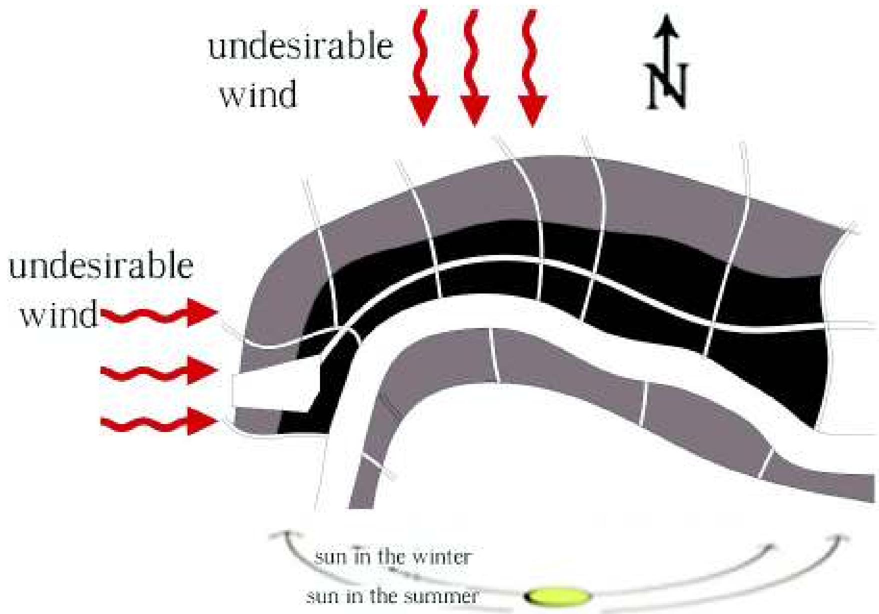


Figure 3.17: Climate aspects over London

City extends according to natural determinants that leading to the preservation of the environment surrounding. This kind of planning gives flexibility that lead to respect the components of environment

On the other hand, it will cause pollution for environment if rivers and seas use in sanitation and as a garbage dump.

The advantages of this planning are:

- Axial clear direction in the motion major and minor paths;
- Flexibility and unlimited growth for the neighborhoods of the city in all directions;
- The center extends along the main axis, leading to its growth with the city growth;
- The streets which open on main axis constitute crossings for the air, leading to good ventilation to these neighborhoods, reducing the humidity;
- City extends according to its natural determinants, that allow the preservation of the environment;
- Flexibility in planning, ensuring respect the components of the environment.

The disadvantages are:

- Extra loads on the main axis (e.g., traffic density and transport) at rush hours;
- Frequent intersections with main axis, which leads to a slower traffic;
- Increased pollution of the environment if the rivers and seas are used in the sanitation and/or as garbage dump.

3.2.3.2 Properties of the urban block growth

The definition of the urban block is a cluster surrounded by the so-called *free space* and presents the ability to expand. The expansion is often done at the expense of the agricultural land. It limits of existing buildings and these limits can be in line with the urban space.

Annular growth presumes the urban block expansion around the city center to outside. Consequently, this means increased pressure on the central region. This type of growth cannot be complete if there are natural determinants hindering it. It often leads to the imbalance of the architectural elements of the city. As an example, we shall consider the city of Paris, as shown in Figure 3.18. In Paris the neighborhoods spread around the former ancient wall of the city during the beginning of the Renaissance. But the problems arose when the slums started to occur around the city at the end of this age, determining the normal growth of the city.

During Industrial Revolution new overcrowded neighborhoods appeared suddenly, quickly and without prior study. These neighborhoods restrict the city and prevent it from the natural evolution [122].

Figure 3.18: Early expansion of Paris city [122]

In axial growth the urban block grows with axes and streets, and the development is characterized by a clear direction. The city can grow in several directions, and the growth is flexible because there is no axis defined. The growing block does not exerts any pressure on the center, because the center grows with the growth of the block .As an example, the City of London, where new neighborhoods began to spread in a horizontal way, perpendicularly on the main axis parallel to the river Thames, as shown in Figure 3.18.

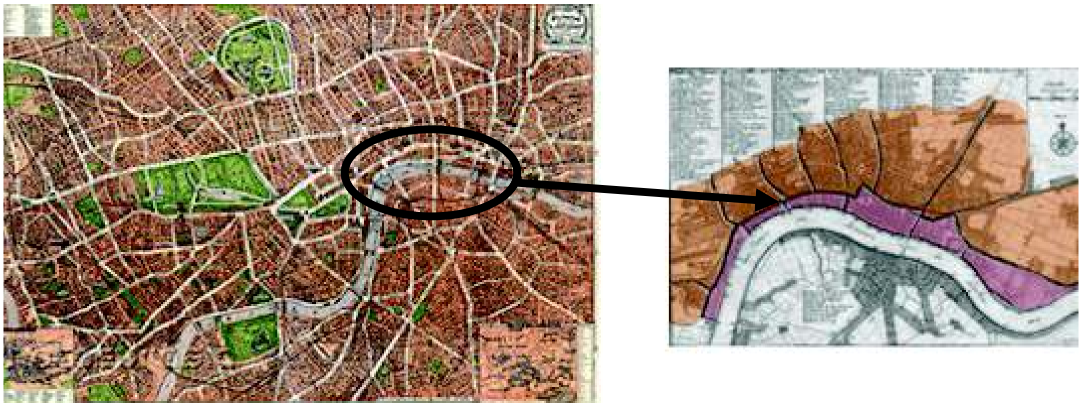


Figure 3.19: Neighborhoods of London 1750-1850 (London city council)

Dispersed growth (Figure 3.20) is linked to the lack of planning in urban growth, and it is often entitled the random or cancerous growth, despite if sometimes it is compatible with the environment, when is called organic growth .This growth results in poor neighborhoods for workers that began to take place with the beginning of the Industrial Revolution around cities and industrial area [126]. These neighborhoods, often illegal, appeared in the most industrial cities and are characterized by overcrowding, unsanitary and the lack of basic services [122].

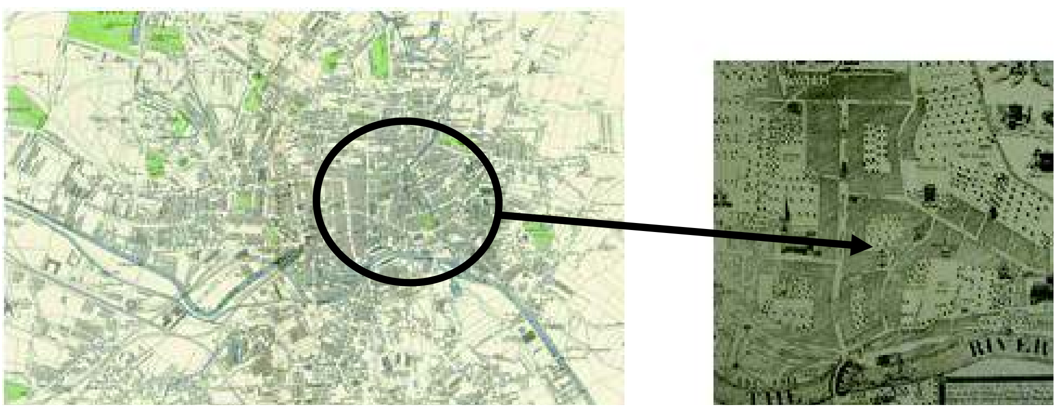


Figure 3.20: Leeds expansion (Leeds city council)

3.3 Cities during oil-age

3.3.1 Factors favoring cities grow during oil-age

Since the appearance of oil, it has worked to modify factors that affected over cities. Hence, our cities have been rapidly changed due to emergence of several revolutions. Therefore, urban designing has faced a radical reshuffling of a number of its principal underpinnings. For a better understanding of the main characteristics of current changes, we try to identify the effects of oil on urban structures; through an analysis of the different evolution phases of the cities through time.

3.3.1.1 Demographic factors

Population growth is a natural phenomenon, but increased urban population is the result of pressure economy. The subsequent changes in the global economy due to the application of new economic rules have resulted to huge migration of rural poor into degraded urban living conditions. That has been said, led to emerge what so-called slums *(poor neighbourhood)* around economical cities [21].

Demography is an important key to cities' development. Human population, their sizes, compositions, distributions, densities, growth, and other characteristics, as well as the causes and consequences of changes in these factors is the basis of all planning activities and developmental processes [130].

Discovery of Oil has led to the depopulation from countryside to cities, which has become the centre of Business that caused to emerge megacities. Population of these cities and its growth rate had exceeded the capacity of area, infrastructure and services to bear this burden. Oil accelerated the shift in human population from one billion in 1800 to two billion in 1930 (e.g. population growth in UK; as shown in Figure 3.21). This massive growth in human carrying capacity has been made possible by the consumption of vast stocks of non-renewable resources [131].

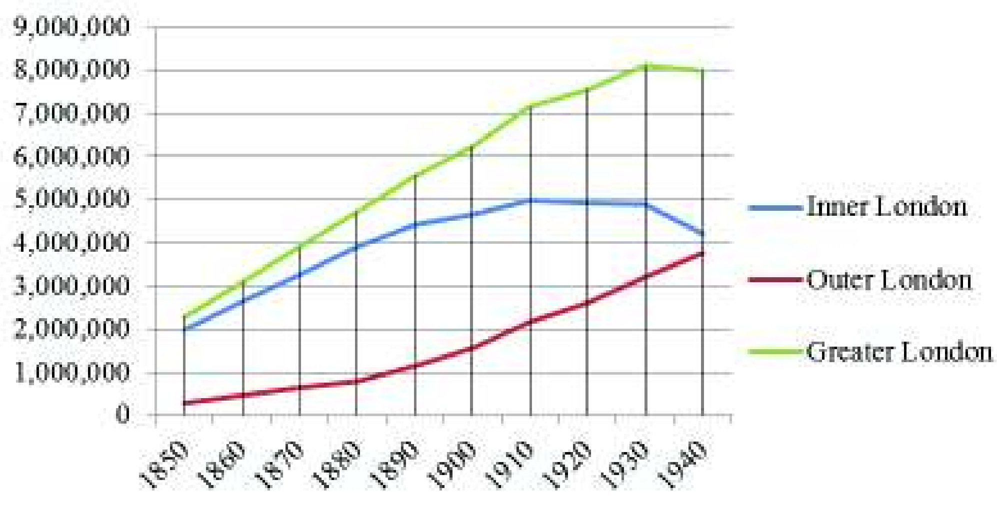


Figure 3.21: London population through oil age [130]

All of the above pushed the urbanists to start looking for solutions through create new cities. These cities were as a solution to redistribute the population and reduce the pressure over the cities. Furthermore, the movement of people to the oil-cities has led to grow it up, or emerge new cities.

3.3.1.2 Economic factors

After a long age of coal used, and with industrialization spread, oil has started to surpass it as the most valuable energy source (Figure 3.22). However, global oil peak has the potential to shake or even destroy the foundations of the global industrial economy. Hence, we could say, the history of twentieth century makes more sense when interpreted as the struggle for control of oil more than the conflict of ideologies. In highlighting, the forefront of energy resources most teaching and understanding of history underestimates the importance of energetic, ecological, and economic factors [131].

Looking back through history, whenever available resources have expanded, the conflict has increased [132].A major work in urban planning has been to analyse how and what effects of economy development, local product and reproductions. A common focus is on gathering sources and supplies for keep the development of cities. In other words, the impact of the economic factor started to be visible once with the widely use of the oil in the various sections of industry.

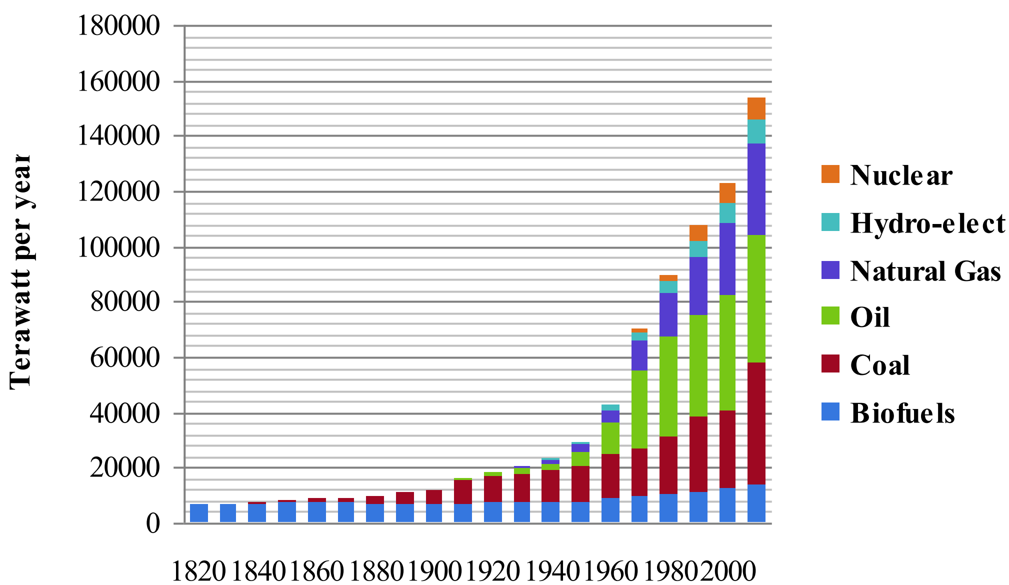


Figure 3.22: Primary Energy Consumption 1820-2000 [133]

Moreover, the economic factor have been used to develop underdeveloped areas. Build up new cities in such regions has been role in its development and prosperity. But the question that rose up here: Were these cities are to be found if there is no economic pillar depends on? Has had the oil this impact? Of course, oil has worked since it appeared to be at the forefront of materials for a power sources, and enters in composition of a lot of material on which the city depends for its success. There is no doubt of close link between oil and economy. Oil has been worked since its discovery on changing the economic policies of countries. This reflected in the movement of people to lead to [131]:

- Emergence of settlements near oil wells for families of the workers there.
- Emergence of new neighbourhoods around the cities of oil as a result of the evolution of the economy.
- Population migration to oil-countries for work, led to emergence of new cities to accommodate this increase.

In the same time oil has entered in a lot of construction materials and worked to develop it, that helped cities to grow up vertically not just horizontally. That has given urbanists and engineers such wide options to extend cities.

3.3.1.3 Political factors

The coming to power different regimes and governments resulted in a radical shift in the direction, approaches, and concepts used in city planning. Therefore, the cities were not completely able to define and solve their own planning problems. In fact, it became subject to the imposition of national ideology and national government control. When was said [132] "*as the struggle for control of oil rather than the clash of ideologies",* that did not mean the great struggles between ideologies have not been important in shaping cities, especially capitalism and socialism.

First emerging the concept of capitalism and colonial expansion policy, which industrial countries carried out, helped them to flourish there trade and discharge their goods in markets. After that socialism then communism regimes had come to keep important manifestations in the overall process of economic, social and political. And to change influence profoundly the spatial constructions and over the face of cities [131]. Over and above, the transition from a centrally planned to a market based economy offered significant opportunities to increase the economic prosperity and social well-being of urban residents through more democratic governance [134].

The third period saw the collapse of the Republic. City planning, as a major governmental activity, became virtually non-existent. Continually expanding unemployment, ruinous taxation, fixed capital costs, investment were crucial causes.

Still, the problems of city planning were not the high priority for the national government. The cities had to continue to plan for themselves without significant national input as net results of that. Anyhow, the national government focus on urban problems once began when the cities became virtually bankrupt during the depths of the depression [135].

3.3.1.4 Environmental factors

Environment is all that outside of human entity, and all that surrounds it from the assets, air, water, earth and what surrounded it from animate and inanimate objects. They are elements of the environment in which they live and practice his life and activities. The most important characteristic of the environment is such a delicate balance between its elements, until pollution entered it.

Over the last decades the climate-damaging concern has turned out from being a worrying issue of some climate scientists to one of the primary topic of environmental awareness. Moreover, the impacts of fossil fuel burning and other sources of coal burning has become the decisive hypothesis under the blows of environmental degradation. Rapid economic growth in developing economies, addictive consumer economies in the long-affluent west, and ongoing population growth are driving emissions ever higher [131]. Meanwhile the evidence of actual climate change is accelerating, with the alarming rates of Arctic sea-ice melting being the most dramatic. On the other hand, air pollutants like ozone, airborne particulate matter, carbon monoxide, nitrogen oxides, sulphur dioxide, and lead are considered the most impacted materials over environment and even over human health. Alongside, and climate change alters the concentration and distribution of air pollutants. In addition the temperature of the earth is on the rise in the phenomenon called global warming. This phenomenon is fundamentally a result of human interventions like oil combustion, emission of transport and industry, greenhouse gas emissions from energy supply, and agriculture [136].

On the other hand, when most of cities have grown up, this development usually take place at expanses. The important of forests lies in the amount of groundwater, water in the soil, and the moisture of the atmosphere. Forests are considered the main support of biodiversity where provide the suitable habitat for wildlife. Moreover, forests are important stores of organic carbon; they work to purify air from carbon dioxide and pollutants, thus contributing to settle down the biosphere and diminish of greenhouse phenomenon. Tropical deforestation contributes as much as 90% of the current net release of biotic carbon dioxide into the atmosphere contributed to Global Warming. This change represents between 20% - 30% of the total carbon flux because of humans factors. Deforestation is an important potential source of carbon by the lack of absorption, so it is clear their contributed to Global Warming (look at Figure 3.23). Besides that, Forests are also valued for their aesthetic beauty and as a cultural resource and tourist attraction [126].

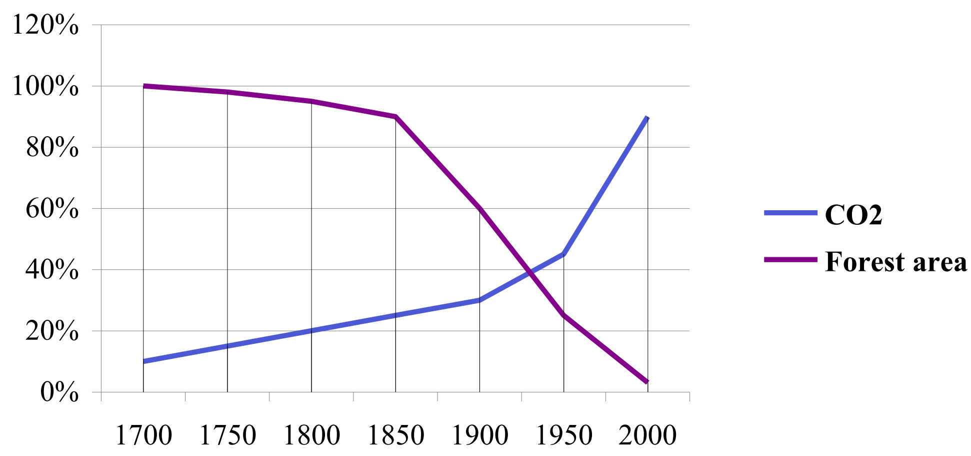


Figure 3.23: Relation between deforestation and CO_2 emissions

In addition, this urbanisation has brought in its wake massive problems of water supply and sanitation, resource flows and solid waste management; with serious sanitation consequences and the management of movement; with chronic congestion and air pollution. It is generally recognised that greenery filled public areas provide comfortable and pleasant living environments for urban residents; feeling comfortable in relation to physical environments in densely populated areas. However, there is a controversy as to whether substantial positive health outcomes result from living in localities with greenery filled public areas [131].

All above led to start thinking in eco-friendly cities "We can say environmental motive has could be one of motives behind building up new cities"; New cities with their characteristics and architectural features, which is the presence of green belt surrounds and overlap it; with attention to the provision of large green and open areas within it. Moreover, should take into account the direction of the wind in order to prevent pollution of the environment of the city as a step to reach healthy urban environment, and as a reaction of Megacities.

3.4 Oil and the city

3.4.1 Impact upon the conceptual development

3.4.1.1 Definition of conceptual development

There is no specific definition of development, almost every writer have a different definition of it. Moreover, the meaning of development always linked with other expressions that give it its specific meaning. But first we have to distinguish between the development as a state or condition-static and development as a process or course of change-dynamic [137]. Thus, it is a multi-dimensional process involving reorganization and reorientation of entire economic, social, and environment system. In order to push the quality of all human life conditions forward with preserving the resources.

The concept of development means the use of all available resources to move city forward, but recently and with the lack and overexploitation of these resources, appeared what it calls sustainable development. That means working to achieve lasting satisfaction of human needs and improve the quality of life. Moreover, help to stop destroying the surrounding environment to survive, attempts to get renewable low-cost energy to be accessible to everyone, dealing with environmental problems requires solutions sensitive to local social and ecological conditions. In other words save the environment to save our lives and our future generation lives.

3.4.1.2 The relation between oil and urban development

The International Energy Agency (see Figure 3.24) says that: *"the demand of oil will be increased 45% by 2030, at the same time there is no clear evidence that new oil resources could meet this need are already discovered or it will be"* [138]. Regardless the peak oil phenomenon is accepted or not, whether new studies of ability to make oil " petroleum" are applicable, we have to admit the price of oil keeps increasing[139], [140].

That means the cost of all extracted, manufactured, grown and transported goods are impacted by oil. Thus cities that were made to be the place of human activities, their development will be surely affected. Moreover cities rely heavily on oil to meet energy needs for heating, cooling, and transportation, will undoubtedly be impacted.

The exaggeration of transportation means led Enrique Penalosa to say *"are we building cities for cars or for people?"* [141]. Building materials like plastic pipes using in sanitary or streets upper layer *asphalt* should be rethought to be replaced.

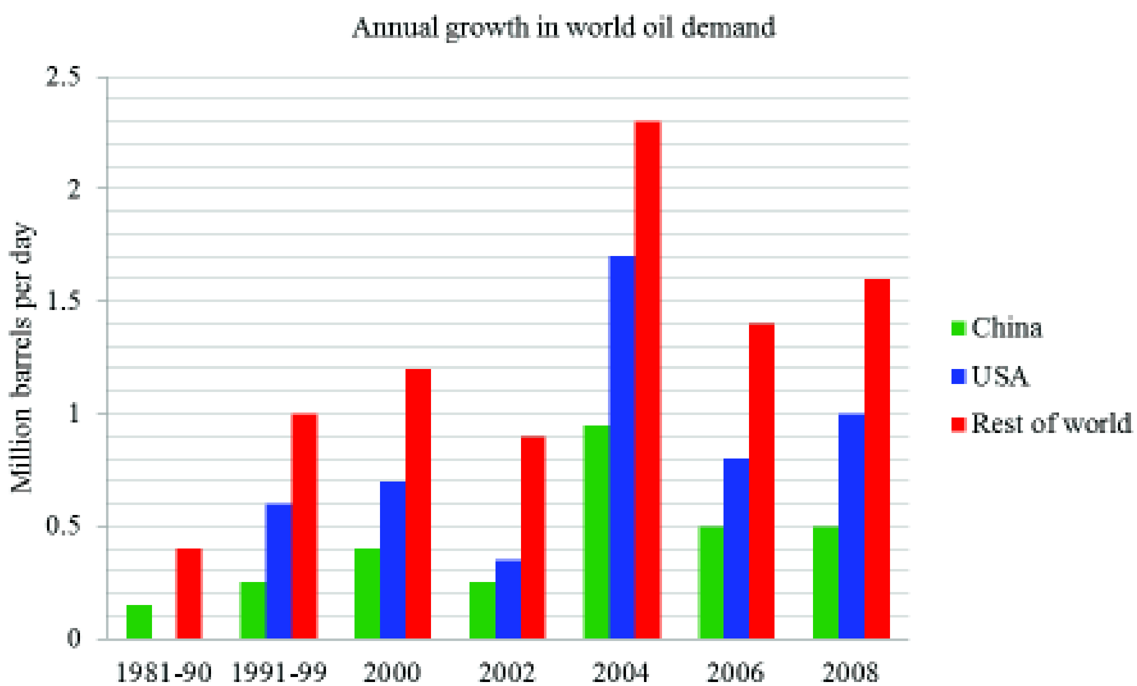


Figure 3.24: Annual growth in world oil demand (U.S. EIA)

All have been said and the talk about the impact on environment and biodiversity yet to mention, which means habitat conversion, degradation and fragmentation; air, water and soil pollution; soil erosion and sedimentation of waterways; deforestation; soil compaction; contamination from improper waste disposal or oil spills; loss of productive capacity and degradation of ecosystem functions. The predicted future of cities under peak oil issue may, according to Newman, these will lead to several different reactions from cities. These include the possibility of collapse of cities, the decentralisation and dispersion of cities into what may be termed *the ruralised city*, *the divided city, or the resilient, sustainable, solar city* [142]. In other words, oil worked to drive the wheel of development forward that accompanied with wide-range of oil productions, resulted in rapid development of cities components. This development in time unveiled huge number of problems, starting with global warming, environmental destroying, lacking and continuing growing need of resources, which threaten the human existence upon various ways.

3.4.1.3 Relation between urban development and climate change.

Cities account to consume almost two third of world's energy at the same time two third of CO_2 emission [143]. Moreover the ecological footprint is severe in cities, as we also running out of land for agriculture, watershed sustainability and recreation due to urban sprawl that take place at the expanses of agriculture land, forest, open space, and water land, with a concomitant loss in the economic, recreation and ecological resources [144], as shown below..

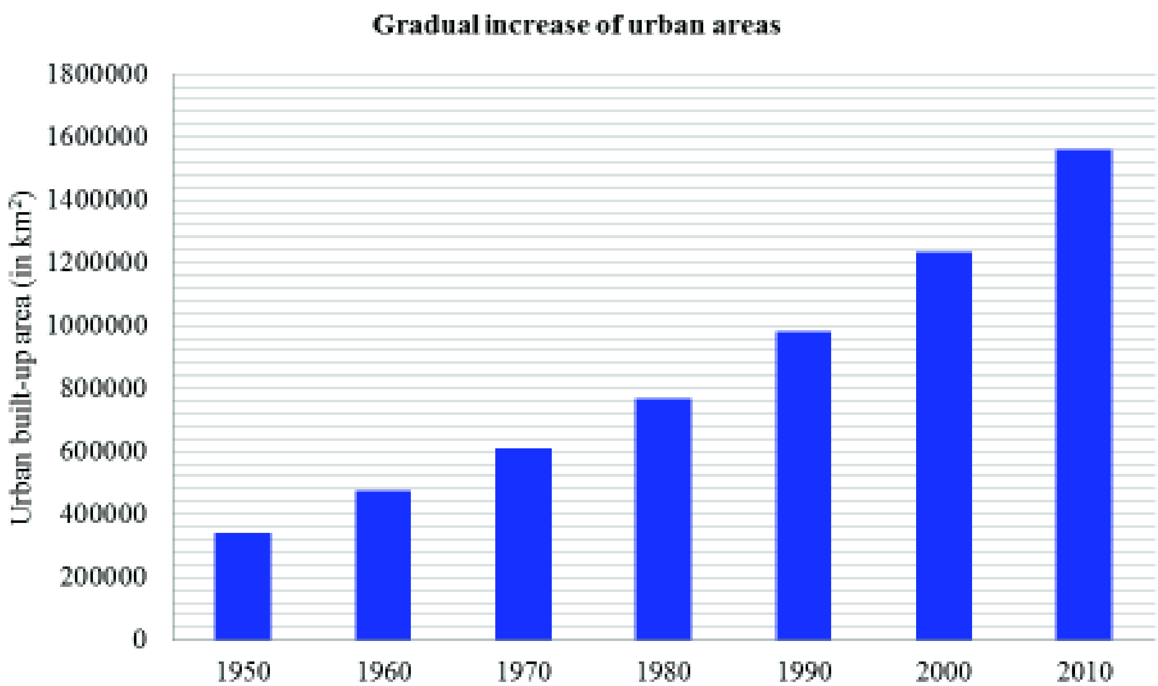


Figure 3.25: Gradual increase of urban areas [145]

Thus, the relation between city and global climate change is close to be reciprocal influence, where city's activities works to make a deep traces over surrounded environment then climate, the last one comes back to undermine the urban public health and infrastructure system. All afore has argue governments and urbanists to start thinking of urban green growth.

3.4.1.4 Green growth

Is catchall term referring to resource protection and practices emphasis the concepts such as, resource efficiency and the need to protect the natural systems upon which humans and other species depend [146]. It also includes waste management and recycling, pollution prevention, and clean efficient energy. Growth is a similarly complex concept. As economic perspective growth means wealth creation and increasing, where in environmental concept is to keep the circle life of biosphere and environmental components going on.

The concept of green growth is a harmony between the economic growth and environmental sustainability, as presented in Figure 3.26. It is the formula that through it we keep the wheel of economic going on at the same time save environmental resources. So it is important to steer economic growth in different direction and knowledge that environmental policies that do not support economic growth are not sustainable in long-term. Moreover urban areas have to conduct environmental policies that can enhance these new sources of economic growth [147]. The correlation between economic and environmental concern, the implementation of green growth at the local level addressed social issue in a more direct way.

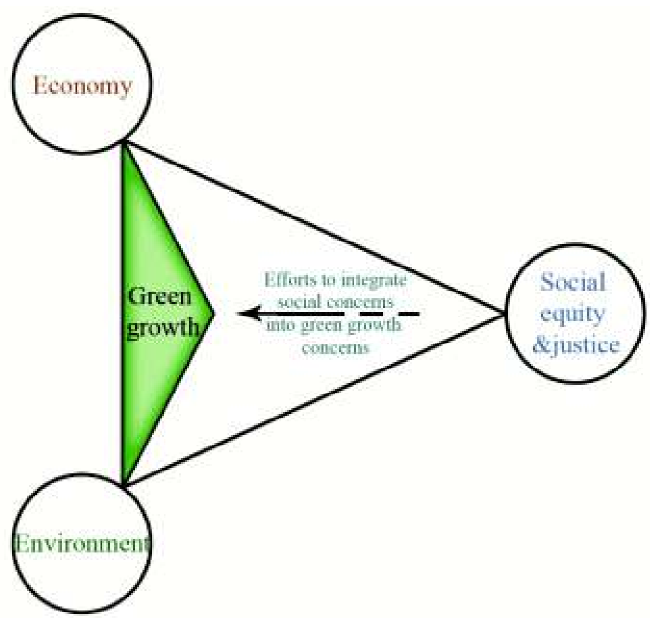


Figure 3.26: Green growth and sustainable development concept [147]

Governments are looking to green growth as strategy to emerge the global financial crisis and deliver both economic and environmental gains. That could be achieved by the environmentally-focused economic which include wide-range of green "sustainable" solutions starting public transportation, green buildings, research and development into advanced bio-fuels and alternative energy technology, treatment of inadequate water supply, eco-infrastructure, and green economy which means "economic activity that preserves and enhances environmental quality while using natural resources more efficiently" [147]. However what is seen as green today may not be considered green tomorrow, as tastes, technology, knowledge of what constitutes acceptable levels of pollution, and optimal levels of resource.

3.4.2 City planning before and after oil

Urban design fails between the professions of planning and architecture. Urban planning deals with large-scale organization and design of city with the massing, organization of buildings, and the space between them. However, architecture deals with design of the individual building. This lack of cooperation between urban planning and architecture on the one hand, and with other sciences from another hand, resulted in an environment characterized by high uncertainty. Moreover Urban growth continues to create unhealthy and dehumanizing environments (air pollution, stress, isolation, lack of community, etc.) genuine planning is desperately needed to mitigate the adverse elements of oil and to reach healthy urban public.

3.4.2.1 Formation and configuration

Before the revolution of transportation and infrastructure the cities were limited by the distance that people can go on foot or by horse cart. The invention of machine and because of the congestion inside the centres of cities people tend to make their own houses in area around actual cities that has led to create what it calls now the suburbia. By the time the cities extended along the streets that link these suburbs with cities' centres forming metropolis cities. These cities have kept growing making new suburbs with new growing along access till we got mega cities.

Urban planning in oil-age is quite different from earlier periods in many ways, including organizational principles, the nature of urban, layout and planning. Moreover, the shape of cities has changed under the growing of transportation. And the cities mostly have had more than one kind of planning. In fact, we cannot say that city have a pattern but we can say it is consist of group of neighbourhoods which each one has its pattern. Although in the past cities have faced topography obstacle or natural ones, in the oil age the technology of construction has overtaken these obstacle making the growth of cities possible in all directions [131].

That being said has pointed out clearly that in this age it is not about the formation or the method adopted in the planning, but how the urban blocks have grown configuring the final form.

3.4.2.2 Urban growth blocks properties

Example for the ***longitudinal to radial pattern***, London had extended longitudinally along Thames River in the Renaissance and early of Industrial Revolution. It had consisted of main street parallel with the river and the secondary streets open on it. And then the shape of city started taking the radial pattern under effect of new neighbourhoods that started arranging around the old cities and working in changing its shape (see Figure 3.27).

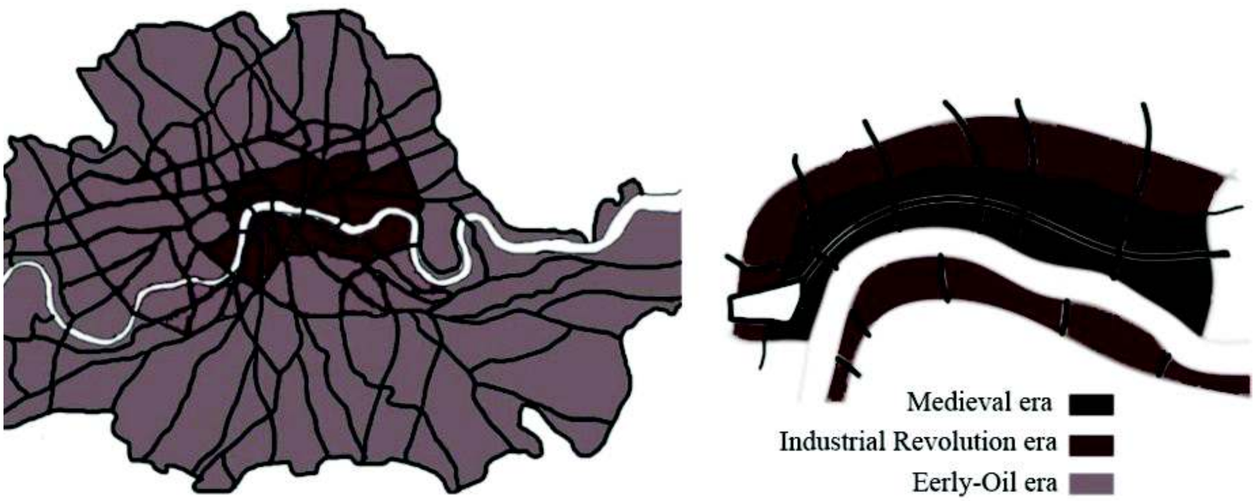


Figure 3.27: London between Oil and age Industrial Revolution [131]

The original city has grown up on the site of the present city of London. It is built upon a series of slight undulations, only rarely sufficient to make the streets noticeably steep, as well as other natural features were impacted by the growth of the city. Plan of London depicts how it is made of a large number of neighbourhoods, each one sharply separated from all adjacent districts. It consists of elegant neighbourhoods, but close by these, appalling slums located [148].

This sharp growth in the city had led urbanists to start thinking of solutions for stop unplanned growth. Consequently, in 1865 John Leighton had set a system to prevent public people to expand the city by their own. Thus, he published a plan proposing to divide London hexagonal neighbourhoods. It aimed at preventing overcharging by cab drivers. However, the growth of urban transport, *although is not without its problems*, made the move to the suburbs easier. Indeed, the growth of the metropolitan population was almost entirely confined to the outer suburbs. The proposal is to emphasize the identity of the existing communities, to increase their degree of segregation, and where necessary to recognize them as separate and definite entities. And again, the communities themselves consist of a series of sub-units corresponding to the neighbourhood units. The city was considered as a tree with two principal levels. The communities are the larger units of the structure; the smaller sub-units are neighbourhoods. This proposal was strict so there were not any nested units. However, some exceptions to identify the borders of these great areas were lost where open country stays unbroken by streets or close-cluster of buildings [21]. Unfortunately, the reality was not as the proposition and the communities sprawled, as shown in Figure 3.28.

Figure 3.28: Hexagonal solution of London between planning and executing [131]

The ***radial to astral pattern*** is almost oldest cities pattern planning. It had been existed in old cities of Roman and Greece. This form is characteristic for the cities that had existed before in this shape, usually defensive cities. In this pattern the public realm and important buildings are in the centre. This centre is surrounded by annular streets that separate the centre by the adjacent neighbourhoods and between neighbourhoods themselves; with ensure the communication route between it. These cities usually growth in an annular way presumes the urban block expansion around the city centre to outside.

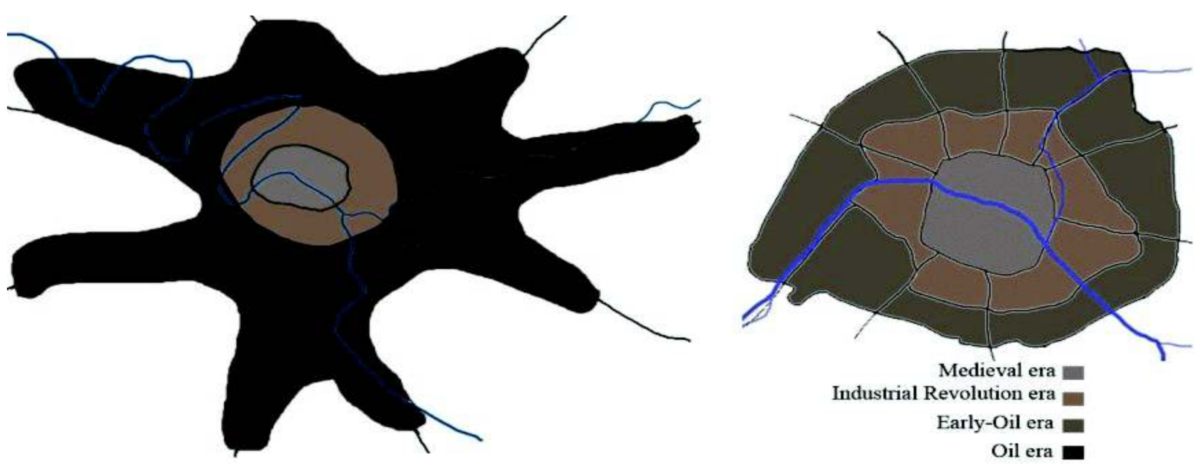


Figure 3.29: Paris city planning between Industrial Revolution and oil age [131]

Paris (see Figure 3.29 above) is the most characteristic city for this pattern. That was happened when the city extended gradually, especially during renaissance and at the early of Industrial Revolution. But what happened in the age of oil, and what accompanied it of infrastructure developing, especially streets network led to appear suburbs around it and link it with main city. But after while some sets of buildings started appearing along these streets, forming new neighbourhoods, changing city shape from radial to astral [131].

3.4.3 Oil age and urban heritage

Although a century of efforts has passed, our knowledge of how cities have been developed and how the oil impacted over them is still absolutely incompetent. However, cities are considered a complex system that grows from the bottom up, where their size and form following specific criteria that result from intense competition for space. An integrated theory of how cities evolve, linking urban economics and transportation behavior to developments in cities components has not made that progress. This provides new insights into the resource limits *(oil products)* that facing cities in terms of street-network, transportation, sprawl and related questions of sustainability. This may has the potential to enrich current approaches of city planning and replace traditional way of dealing with new strategies city plans that benefit all city dwellers.

Archaeological heritage is represented the age and origins of cultural background, defining the history and tradition, linking the certain ethno-cultural space with other states or cultural spaces. Hence, for preserving archaeological heritage we need an efficient management with frame of activities focused on preserving, research, and conservation to get back the cultural resources to future generations. Historic buildings can be the cornerstone to rebuild many of our cities. put these buildings in use again working to rehabilitate them in correct sustainable way can enhance the sense of community, drive the local economy forward, acting to enter important improvements on wide-range. Historic buildings generally form the centre in many cities, giving them their own characters, causing profound impact over local residents and communities.

Archaeological heritage is considered great balance, unparalleled and indispensable resource that gives us a rich image of the history of society, expressing the local, regional and national cultural identity. Historic buildings and places are important for their genuine cultural traditional value, where people work, live and enjoy everyday activities. On the other hand, our duty is to keep this building standing for those generations who come after us to do not lose their social afflation. Thus, many of these historic places existed for long time ago and handing them on in good condition is our responsibility to give the chance for future generations to enjoy them too. Conservation involves caring for historic buildings and places and managing changes to them in a way which retains their special characteristics. It is important, therefore, to understand the following basic principles of architectural conservation practice so that any changes undertaken do not damage the special qualities of a historic building or place [149].

Oil has had a profound impact on various aspects of development processes, which has made a jump in the economic areas. Large urban scale development has continued to threaten the existence of heritage buildings in the region for a long time. Many heritage buildings are being demolished to pave way for the construction of wider roads, schools, hospitals, shopping malls and parking. Some of these buildings, especially those located in the central business district, have been under threats of demolition from the public and private developers seeking more lucrative ventures only [150]. Moreover the pollution that oil has left it on climate and environment, such as *'acid precipitation,'* has made a direct impact over the structure of the historical buildings.

With all that being said, we should guide the direction of development processes, which must occur in architecture, to save our historical cities and turn them up to sustainable ones. Otherwise architecture would be a victim of tampering and distortion that may be exercised to lead up in the end to destruct the records of cultural community. all mentioned above must direct us to find a state of civilization balance, that combine between doing changes over old buildings to match renewable human needs with changing time on the one hand, And maintaining the heritage value that embodied in these buildings on the second hand. That what so-called architectural rehabilitation [151].

All above were bits until the discovery of oil in commercial amount. And what accompanied of the arbitrary expansion of street-networks. Moreover modern road-construction techniques can be traced to a process developed in the early 19th century. It is built as multi-layer roadbeds with a soil and crushed stone aggregate that was then packed down and then add the oil-product “Tar” as a binder. The contemporary roads (*Asphalt roods)* have been capable to support the vehicles have emerged. Moreover we must emphasize the fact that the street-network may be one of the critical issues in urban planning toward approach sustainable cities. These cities that are in seek to improve their infrastructures to become more eco-friendly by increasing the life quality and reduce the costs. Even more than that, they have to make a commitment to design the future, so offering an integrated program to achieve the desire and demands of the community, in order to protect and preserve the Earth's natural resources through the built environment.

3.4.3.1 Define our cities

Through time the reuse of historic environment by giving it new life has demonstrated as one of the basic economic and social factors to revival our cities. The integration of heritage buildings in renewal urban planning has shown the success of these urban neighborhoods where people can enjoy their life in positive places .Such regeneration may be a good opportunity for conservation and development to work alongside, transforming the built environment to the communities that live in [152]. Our built heritage is the best thing that remains from the past, where provides massive clues that define our initial cities. Moreover, these buildings make up the centers of our great cities, which worked to shape the actual ones and give them the growth shape (as shown in Figure 3.30). On the other hand, historic buildings give a sense of place, while the fabric and design add a distinctive identity to townscapes that raise the quality of the built environment.

Figure 3.30: The old cities of bucarest and cluj as a center of actual cities

3.4.3.2 Economic effects

Despite the cultural and environmental value of the archaeological heritage may help to enhance these areas to be as visitor destination which can generate widespread economic benefits through tourism and leisure [153], the economic factor has played critical role to accelerate town centre declining and historic urban damage. On the other hand, heritage resources are considered key of factors to attract foreign capital to invest in these sectors, which leads to develop these areas. Even more these attractions are working to raise land prices and encourage the real estate markets. It is recognised that tourism and recreation development has the possibility to damage and destroy these authentic buildings through excessive visitor numbers, inappropriate development and other forms of various impacts. The role of the planning system is to ensure that the growth and development of tourism based on archaeological buildings is compatible with proper long-term conservation. The contribution of conservation as an element in the wider process of physical and economic regeneration should not be underestimated [153].

3.4.3.3 The impact of oil over our heritage of historical buildings

A style that had flourished in Europe during the XXth century as an architectural style, then its structural basis were set later between XIth and XIIth century, known as Romanesque style. Despite Romanesque style had a lot of similarities to the Carolingian forms, it was noticeable as an important period due the following: relief that the world did not ended at the turn of the millennium; upsurge of cities and trade; extension of the Pope's authority.

The main architectural pattern of Romanesque style was the churches because they often housed the relics of saints and martyrs. Moreover, these churches were always the destination of pilgrims that usually would travel large distances to visit, believing in curative and sanctifying powers that such relics were supposed to have. In order to make churches absorbs the large number of people; the inspiration to create massive cathedrals has come up. Therefore, an important church would not only contain the relics, but would also have enough space to accommodate the visitors. The Romanesque structure is characterized by: Thick and large walls supporting stone roofs; simple design but huge; Similarity in the internal and external appearance; small windows to do not weaken the load-bearing walls; vaults [154]. It is considered the important achievement in the medieval period. It has significant development in the Romanesque period, where several types were evolved like barrel vault, the groin vault, and the rib vault. Vaulting in Christian buildings had used to be limited to smaller buildings, till Norsemen burnt some wooden churches. Then the time was to replace the wooden roofs that covered larger structures with stone masonry [154].

The question that came up is how oil could have impact over historical buildings? May there is no direct influence but the big dependence on fossil fuels in energy, transport and housing is increasing the gas emissions keeping bad traces over climate that has potentially not able to be undone[155]. That being said has pointed clearly out the impact of oil over climate. The impacts of climate change on the historical building in general and Romanesque heritage are wide-range. The global warming phenomenon works to rising sea levels and increase storm events that have threatened historic landscapes, structures, and archaeological buildings in the coastal zone. More frequent intense rainfall events will cause flooding in historic settlements and erosion of archaeological sites. Historical buildings are being endangered by increasing the level of rainfall causing water penetration into masonry, resulting the risk of dampness, condensation and mould growth, sometimes may reach to structural collapse.

The real risk that threatens our heritage is acid rain. It is considered as one of the most serious environmental problems that have been happened because of oil materials emissions. However, we are becoming more aware that many of our Romanesque buildings and monuments are located in the areas of highest acidity. In addition, the resistance of these structures has been reduced by many factors such as chemical attacks due to air pollution and vibrations causes by traffic. Traffic vibrations are arising from road and rail traffic and its effect on historic buildings have become a real threat. The effects can be divided into three components: source, transmission path and receiver. The source represents rolling wheels; where transmission is the waves generated at the source. Then receiver in this case is the historical buildings. After vibrations enter the building through the foundations, they may grow up from 2 to 5 in propagating to higher storeys. Soft and saturated soils transmit vibrations more easily than sand; even rocks transmit it also [150]. Streets that have been paved inside historical areas to bear this sudden growth of vehicles are considering the main resource of vibration.

Protection of many ancient *'and frequently precious'* buildings coming from the past is not an easy question. Unfortunately, the Romanesque churches rehabilitation problems are much more difficult to solve than those related to modern reinforcement concrete or steel structures, due to specific conservation criteria *(integrity, compatibility, reversibility and durability).* An additional problem for existing churches is that their characteristics, material properties, construction aspects, and state of integrity, are frequently not very well.

3.5 Critical perspective upon the born of new cities in oil age

The effect of oil has led to emerge lots of new cities. Not only in the areas that has Oil like Arabic gulf area, but also areas that affected by Oil. These new cities that were planned at one time, *"diagram cities as Spiro Kostof term" [124]*, use a strict geometric layout, whether orthogonal or non-orthogonal in plan. But most of examples date to the Industrial Revolution and oil period was orthogonal.

3.5.1 Form and Growth

Above was mentioned that most of the new cities had a grid pattern, or in another term *orthogonality pattern*. This pattern describes the use of right angles in the layout of buildings and cities. Orthogonal city planning is a special case of two principles, coordinated arrangement of buildings and formality. Even if it planned as an orthogonal pattern, however, it is still inadequate to conceptualize the Orthogonality principle in presence absence terms. There are degrees of Orthogonality, just as there are degrees of coordination or formality. An integrated orthogonal plan occurs when buildings are aligned orthogonally with respect to one or more large-scale features. As an example Chandigarh which was designed by Le Corbusier [2]. It designed to be the first Indian city where water, drainage and electricity would be available to even 'the poorest poor'. Just like other modernist city. The basic component of the urban form was a concept for living, neighbourhood unit *the secto'* as shown in Figure 31.

Figure 3.31: Chandigarh city planning as it planned and the new slums appear [156]

Le Corbusier replaced the city plan which had been suggested by Mayer 'a fan shaped' with meandering roads and neighbourhood units, 'superblocks' with a geometric matrix of generic neighbourhood units, 'sectors' and roads. The new city plan, be placed on any flat piece of land. It was conceived as *Garden City* where high-rise buildings were excluded, keeping in view the living habits of the people.

The primary module is a sector, which its size is 800 x 1200 m. Each sector is a self-sufficient unit, having shops, school, health centres and places of recreations and worship. Shopping was conceived as the nucleus of the social life of the sectors, in the point view to allow for a set of different urban relations and connections. Shops were usually arranged in a linear configuration along roads that interconnected the sectors to allow for social interaction [157]. Even The development bears similarities in terms of the planning principles like hierarchy and connecting of green spaces *from greens at city level to semi-private to private green areas*, public buildings and basic building typology.

The new plan allowed for such of infinite expansion.

However, with all flexibility and planning, we can clearly see how some slums have started taking place in unplanned area and at the expanses of green lands. Leading to Destroying the modernity, and if it keeps spreading like this way it will change the form of the city.

3.6 Arabic cities and oil

Arabic peninsula used to be just a desert zone inhabited by tribes of Bedouin. This situation has changed once in the middle of 20th century due to the discovery of oil. The Bedouin tribe used to be the main component of all the peninsula society including Saudi Arabian, UAE, Qatar, etc. Bedouin means desert-dweller, the harsh climate force those people to this kind of life that came as environmental adaptation. The lack of resources has obligated these tribes to keep moving ocean where pearl diving and fishing the main forms of livelihood and searching for drinkable water and dates farms that exist in oases like Al Ain one in UAE. Nomadic tribes also used to roam in desert searching for grazing areas for the camels and herds [158].

UAE was just another zone of peninsula's desert inhabited by proud and resourceful nomadic Bedouin tribes [158]. As modern century revealed Abu Dhabi was one of the poorest emirates that did not have enough resources or advantages, it was built up of hundreds palm huts *'barasti'*, a few coral buildings and the Ruler's Fort. At the same time, Sharjah was the most populated and powerful [159]. The region remained a quiet backwater of pearling until 1930's when the pearl industry was broken down by the Japanese invention of the cultured pearl. This change had created significant hardship for the local population with the loss of their largest export and main source of earnings. Forty years ago, Dubai used to be a trading port, providing the safety to whom crossing through Straits of Hormuz [160].

As mention above peninsula's cities used to be deserts, urban compact fabric as social and environmental treatments; some houses that were made out of local materials like palm and clay, the majority used to live in tents as moving house that they had to keep moving searching for water and food resources. Then oil was discovered in that area and the story has begun and new face of cities has started to appear.

The searching for oil was started firstly in Kingdom of Saudi Arabia in 1933 when King Abdulaziz Bin Abdulrahman Al Saud signed concession agreement for oil exploration with Standard Oil of California. At the beginning the results did not meet the expectation but the company keep drilling and searching till achieved their goals by 1938.

Later, the prospecting company has found that this discovery is the first of many, finally revealing the largest source of crude oil in the world [161]. This discovery would change the future of kingdom at various levels, especially at the economic one so kingdom’s oil revenues would become the main source of wealth, thus this resource has been enough and no longer had to rely on the incomes of pilgrimage to Mecca. Undoubtedly, this discovery would change the role of Middle East in the international policy forever. Gradually, the oil started to be discovered in the zones around the kingdom.

As for AUE the first oil concessions were held in 1939 by Sheikh Shakhbut Bin-Sultan Al Nahyan. However, oil was not discovered till 14 years later. At first, oil revenues were not enough to invest in development, but later the situation have been changed when Sheikh Zayed bin Sultan Al Nahayan replaced his brother. Oil exports from Abu Dhabi began in 1962, turning the poorest of the emirates into the richest. Although Dubai was interested to build its reputation as the region’s busiest trading post, the oil was discovered later in the mid of 60^{th}, helping it to make what it intend to [158].

3.6.1 Influencing factors on emergence of Arabic oil cities

3.6.1.1 The economic aspects

The development of the Arabian Peninsula cities has gone hand in hand with the discovery of oil and its revenues. Moreover, we cannot talk about unified economic system in these countries before oil. As for Saudi Arabian, the state was consisted of several regions where everyone had its resources, for example the western area "the Hejaz" depended on agriculture, some long-distance trade, and the pilgrimage revenues. On the other hand, date farms and other cash crops dominated the Eastern zone [162].

The events that followed the discovery of oil in Eastern area helped the kingdom to build their economic system. These events can be summarized in: the establishment of the Kingdom of Saudi Arabia by unite several provinces, second the need to rebuild Europe after World War II and the need to cheap, reliable sources of oil. Moreover the amount of revenues that have flowed into the treasury of Saudi Arabia has changed the state to become the widespread agent of economic change, replacing the traditional economy with one that depended primarily on the state's outlays [162].

Developing the oil sector was crucial to domestic political stability, and it was the kingdom's importance as an oil producer. Thus, in order for Saudi Arabia to face this challenge, it had set plan to expand capacity for its oil industry [162]. Therefore, the main policy of Saudi has been to keep its position in the international oil market. Thus it has increased its production of oil as shown down in Figure 3.32. All other attempts to diversify the economy have not succeeded yet, and have proved more difficult than earlier Saudi planners had imagined. All mention before, the government could not afford to neglect the oil sector, the primary engine of economic growth.

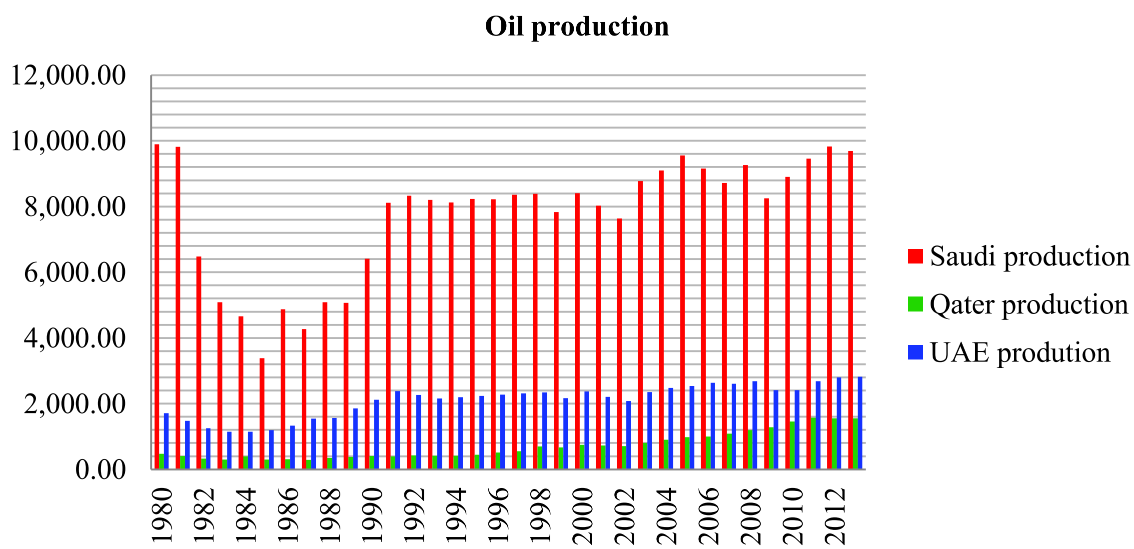


Figure 3.32: Saudi Arabian, UAE, and Qatar production of oil through history (EIA)

After 1980, the price of oil had a sharp shift as shown in the chart Figure 3.33. This oil price has given the kingdom the potentiality to relieve all the financial constraints. This economic prosperity created large financial surpluses in both the private and government sectors of the economy that enabled the Kingdom to start the investment in the construction and infrastructure areas.

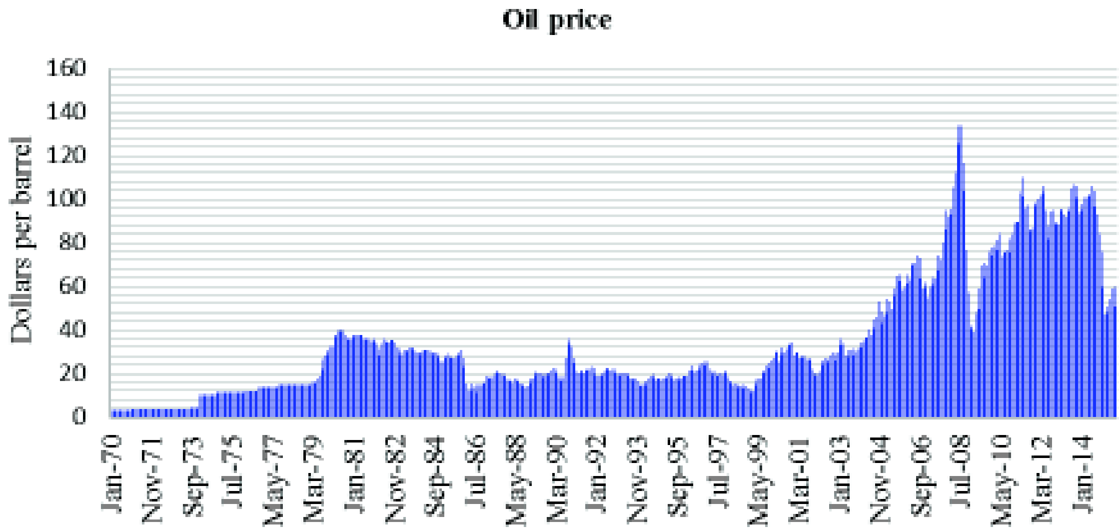


Figure 3.33: Price of oil since 1970 (Federal Reserve economic data)

Emirate used to be desert land consists of several groups, living on what they can be produced in their local environment. So emirate before the discovery of oil had not had an economic permanent system. Indeed, Dubai in the Nineteenth Century was a British protectorate that its economy was depending on fishing village and pearl diving. However, even these sources were no longer sufficient after the invention of cultured pearls. As for Abu Dhabi the main resources used to be the date farms as “Al ain oases”. Till 60th of the last century there were no electricity, and running water and tarmac roads. However, in 1966 marked the discovery of oil and the country began to modernize at a slow steps [163].

Despite the amount of oil that has been discovered in emirate is lesser than the production of Saudi, this production has helped the country to build its economy system and to become one of the richest countries and one of the highest per capita incomes of the world by following certain strategies. There is no doubt, the discovery of oil has brought big mount of revenues to the treasury as shown in chart 10. This amount of oil production has helped it to build its reputation as trading port and to develop it. But, on the other hand, in response to the running out of oil reserves and to keep the developments and revenues wheels forward, Dubai decided to diversify its economy, making real estate one of its backbones. [164].

Even though emirate has ten percent of the world's total known oil reserves, contributed as 90% in Abu Dhabi and 10% in Dubai, The reserves are expected to last just ten years in Dubai, where in Abu Dhabi may last another 100 years.

May be by fortune, but most likely by foresight of the UAE leaders, the UAE economy is no longer depending on just oil and gas. Today oil form just 30 percent of country's revenues, the rest come from trade, tourism and real estate. Therefore, all mention above clearly point out the deep and critical impact of oil revenues "economy" over the urban development.

Qatar was not inhabitant till the middle of XIXth century. As UAE, it once started as a consequence of tribal conflicts with other tribes leading it to move to the area that known today as Doha [165]. The Livelihoods before oil were just pearl trade that thrived in this zone till 1930 when the collapse was happened due to the invention of cultured pearl [166]. Thus, there was not a clear face of economy system and people live on what produce per day. However, Qatar has not devoid of some Persian immigrants working as craftsmen in boat construction, and East-African slaves engaging as fishermen or in the pearl industry. In addition, Bedouin tribes in some seasons come and settle in zones around Doha, selling their animals and animal products [165]. Oil had been discovered in 1937 but its investment did not start till after World War II. Oil revenues began to flow into treasury just after 1960. These revenues were used to develop the infrastructure in emirate like roads networks and airport.

Oil and natural gas are the main resources of Qatar's economy where they form 70 percent of total revenue and more than 60 percent of gross domestic product. Oil has put Qatar to rank among the highest income in the world per capita. Long-term goals include the development of offshore petroleum and at the same time diversifying the economy that can be helped by its position as third-largest reserves of any country in the world. The main goal of government right now is the investment in industrial fields as a part of its plan to diversify the economy. All afore, has worked to change the face of Qatar, especially its main city Doha to put itself on the road to urban development and modernization.

As it has been said, the economy has been the main factor to change the urban texture in the Arabian Peninsula, where we can clearly see how oil revenues have kept the investments forward. The need of foreign labourers creates the need for more housing, so need for new construction. However, some countries like Saudi has not succeed yet to diversify its economy system that there is no need yet because of the reserve of oil, other like UAE has been succeed to diminish the dependency of oil till 30% in order to be ready to replace it. That led it to use the oil revenues in build a strong economy then no longer need to oil. Main while Qatar moving in the both side for its economy system, they are working to diversify it and diminish the need of oil, at the same time they have huge reserve of oil and gas putting Qatar to be the richest country on the world, leading the near future to reveal the huge amount of investments in the urban fields.

3.6.1.2 The demography

The economic aspect is significant to develop cities, but the demographic factor has used to be main factor for urban sprawl. However, looking at the demographic history of Arabic oil cities like Dubai and Doha we can clearly see how these cities has emerged as fishing villages or nomadic tribes that have moved here as a result of the conflict with other tribes in Arabic peninsula.

There is no doubt, an extremely harsh environment determined geographical separation of peoples and obligated them to keep moving searching for life conditions. Certainly, without settlement cities cannot be existed, permanent habitation in that time could exist only where there was water. Although the Bedouin 'the original people of these cities' were known for their resourcefulness and independence in the face of a harsh environment, but the long distances between water sources hampered these tribes to settle.

As shown in chart from Figure 3.34, Dubai population increases slowly until 1980. The main reason behind this slight increase is the harsh climate that did not allow high average of age. In addition, infant mortality was high due to the health conditions; other reasons like conflicts with other tribes may restrict the high increase.

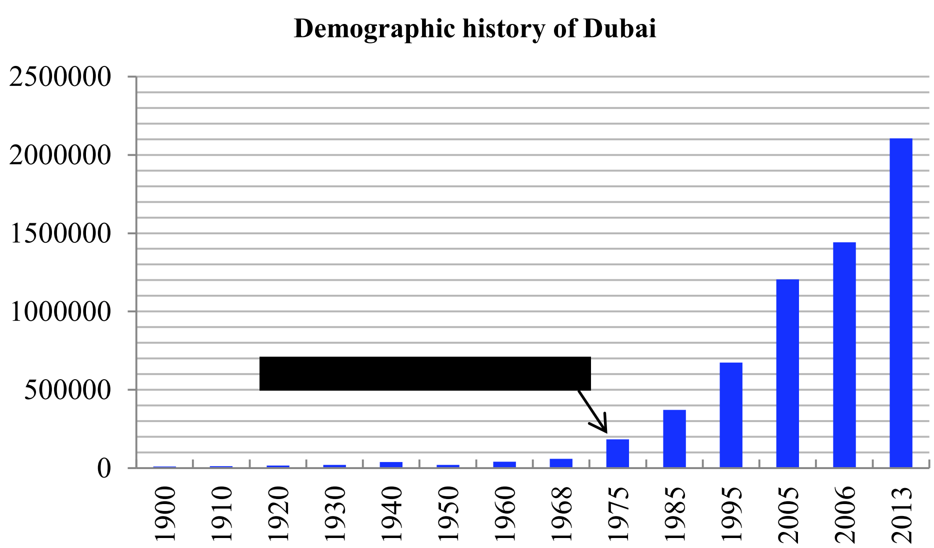


Figure 3.34: Dubai demography (U. N. population estimates)

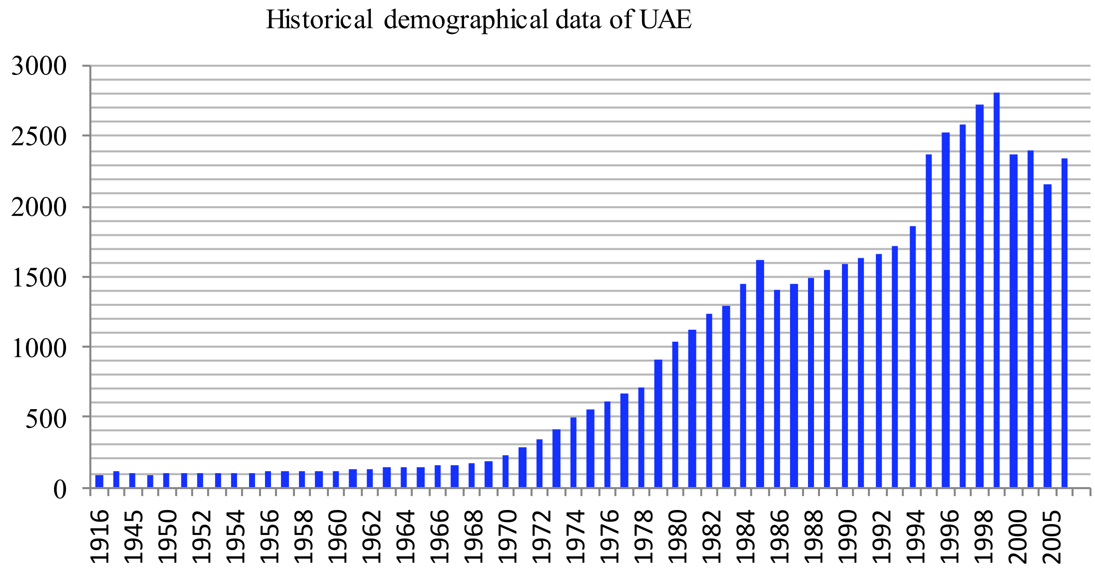


Figure 3.35: Population of UAE (U. N. population estimates)

The discovery of oil has given these areas new opportunities, working to improve the life conditions, hence the change in the demography. The main explanations for the increasing population are: Recently Dubai has been experiencing a higher birth-rate, decline in infant mortality and higher average duration of life, which are results of the improvements in health care facilities and technology [167].

However, the decisive shift in population happened starting of 1975 when the need of labours has led to flow thousands of migrants as shown down in Figure 3.35. As from here, this increase has caused big demand of housing and infrastructure to absorb this huge flow of job seekers.

As mentioned above and illustrated in Figure 3.36 more than 80 percent of UAE's population are from foreign countries have come just for work. Figures 3.35 and 3.36 are showing us that in the last 20 years UAE has slight increase in the original population, at the same time high increase of the emigrants that the majority are men and their age is between 20 and 40 years old.

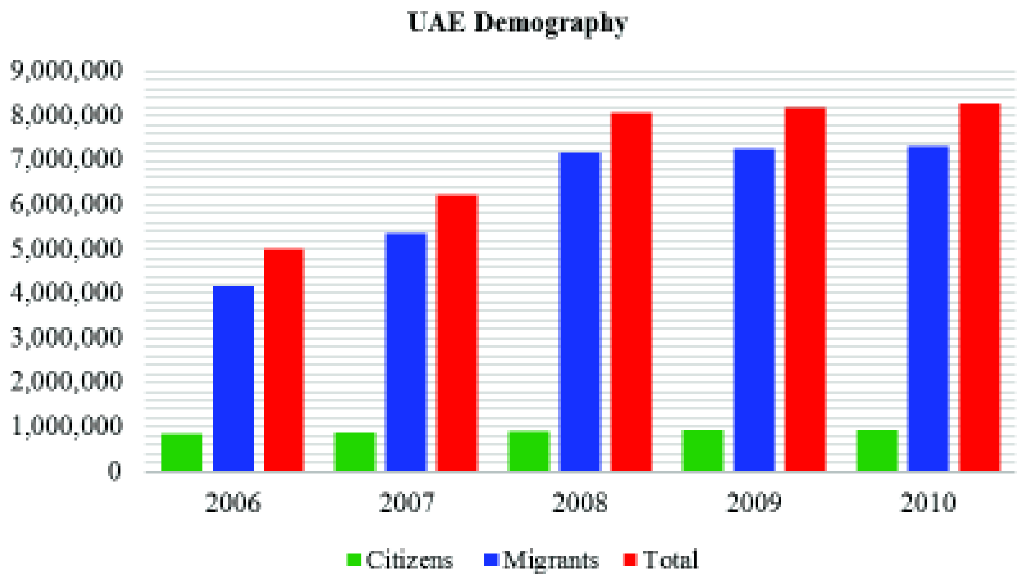


Figure 3.36: UAE demography (U.N. ESCWA)

However, as mentioned before, the discovery of oil led to the industrial prosperity, prompting the population to migrate from rural to urban areas forming the big cities. In Qatar situation the oil worked to transfer the fishing villages to development cities as shown in Figure 3.37.

The population of Qatar has not increased gradually but it suffered several setbacks depending on livelihoods availability. Generally population growth especially since 1976 was too low and they felt the need to be raised, and more, in 2009 it deemed population growth 'satisfactory' and seeked to maintain it. On the other hand, some villages that have not turned to city yet are facing depopulation where governments searching for actively lower the frequency of moves away from rural areas. Anyhow these country like Qatar are not far from having population problems due to emigration issue, where was declared that is too high and should no longer be remained at its current levels.

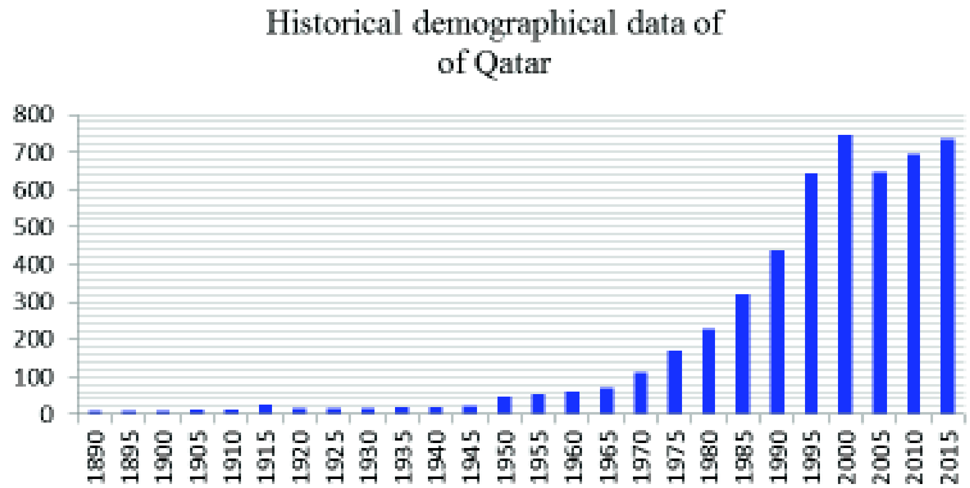


Figure 3.37: Qatar population (U.N. ESCWA)

Population is such a key of importance for the future of these cities, leading the governments to set policy to achieve a balance between population growth and the requirements of sustainable development, with ensuring a decent life for all the people. The main problem that is facing these cities may be the high population of immigrants. Therefore, they are in need to improve the capabilities, expansion of their choices, and their fuller participation of their original people in society. In other words, cities that foreign people form more than 80 percent of their total population, how would be their form if those people left suddenly because of the running out of Oil? And what the solutions can be? Is resettlement of immigrants and give them the right to apply for citizenship and trying to engage them in society is one of those?

3.6.1.3 Environmental impact

It is obvious that since the beginning of the XXIst century, environment has become the most critical issue facing the world today. Environmental problems have characterized heavily in scientific warnings, political agendas, public concern, and media attention. The Arab world is part of this problem when it comes to this topic, taking into account that Arabic countries are in the top of the list of oil-producing cities [168]. What cities have done through implanting the desert and creating huge amount of green areas is considered significant step toward sustainability. There is no doubt that, desalination plants compensate for the lack of freshwater transferring the desert to green space [169].

On the other hand, the environment and climate of this area characterized by harsh and hot dry. Moreover, these zones are subject to frequent sand and dust storms, which can severely reduce visibility, effecting health problems for respiratory system. Moreover they have strong tides and occasional windstorms that hinder ship movements near the shore [169].

Dubai and follow Doha has started lately an ambitious plan to raise their international standing by building a number of artificial islands. These islands are a growing concern for environmentalists, because of their impact on the local marine ecology [170]. These cities should be conscious of rising sea levels because of global climate change, due to the contribution of these cities on the environment pollution through the extraction of oil. Earth Island Journal says: *"How ironic that the very people who drive rising sea levels through their businesses, which emit much of the world's greenhouse gases, will undoubtedly be some of the first to experience the devastating effects of climate change"* [170].

Furthermore, great change in the marine environment is leaving bad traces over marine life. Drilling and backfill to construct in the gulf has resulted a lot of alluvium that works to damage the marine habitat through burying coral reefs, oyster beds and subterranean fields of sea grass. Although increase the temperature and salinity have been the main factors in reef habitat degradation, but that does not mean new pressure from dredging does not work to aggravate environmental degradation [170].

However, until these days governments and even people have refused to admit the profound cost of economic and their luxury life over environment, natural resources has been used unsustainably, undermining economic development and poverty reduction efforts [170]. Undoubtedly, the rapid rate of urbanization is accompanied by pressures on the environment, and there are no indicators that this high pace is concomitant with equally high rates of human development and infrastructure provisions [168].

On other words, the need of fast construction, with limited and short time of planning has created cities that are far as urban fabric than its climate demand. These led to high-consumption of energy to make these spaces run, releasing a huge amount of CO_2 as shown in Figures 3.38 and 3.39.

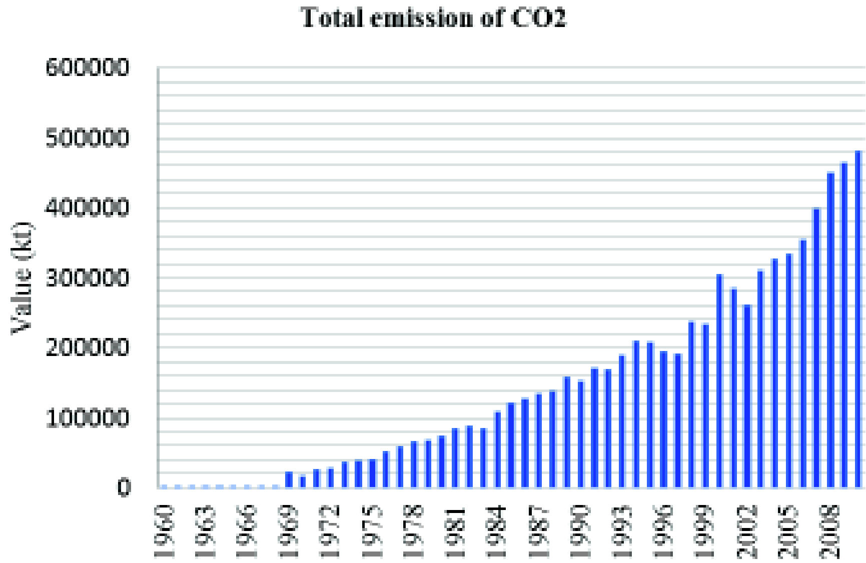


Figure 3.38: CO_2 emission in UAE (IndexMundi)

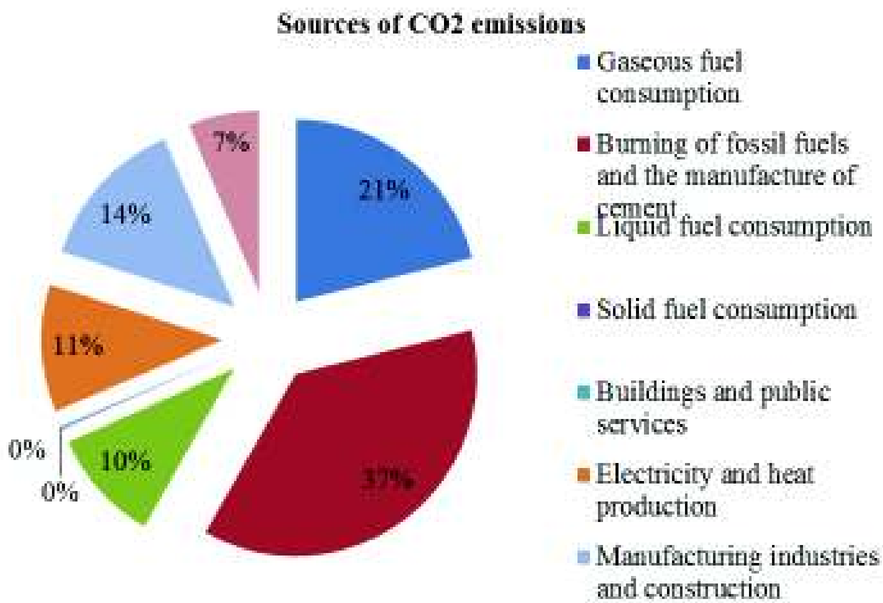


Figure 3.39: Sources OFCO_2 emission in UAE (IndexMundi)

In addition, another concern will appear soon enough, these concerns are linked with seismic movements. These earthquakes are not anymore a natural activity, but it is an action of repositioning crustal layers at the areas of big empty wells after extracting the oil.

Certainly, recently these country start feeling the importance of saving environmental resources, water ones, diminish the pollution, marine life, land resource degradation, and biodiversity. The high rate of need to rapid construction has created approximately 75 % of buildings and infrastructure at direct risk of climate change impacts. Therefore, building materials that used for buildings and roads should be taken in consideration the risk of rising temperatures and climate change [171].

This area of Arab world has seen unpredicted growth, providing both economic and social prosperity to their people during the last decades, thanks to the oil revenues. However, is this economic development without environmental cost? Can these resources form sustaining livelihood and quality of life for future generations?

It therefore remains to be seen if the modernization that worked to keep bad traces over the environment and climate, may work to create a sustainable environment to live!

3.6.2 Critical observations over cities planning

Urbanization is considered a recent phenomenon for gulf countries. Until the discovery of oil these cities used to be villages or centres for pearls trading forming small towns. Anyhow, along the coast line of the Gulf there were just a handful of villages and such dense urbanization had not observed yet.

The desire to construct and develop these villages to great cities has been characterized by impulsive and lack of patience, led to not to give enough time for study and design, affecting the quality of the built environment. The demand to increase the large-scale projects has led to huge and distinct buildings, which may enough for the moment, but surely these building were not taken in consideration the understanding of the past, so we do not know how it will work in the future. However, some attention has been given to construction industry, to date the focus has been over the buildings individually rather to concentrate on the urban fabric as integrated space [172].

As late as the 1960s, they used to build their town houses out of coral stone that were brought from sea bed, and roofed it by palm fronds and mangrove poles, these type of buildings called "windtower" and were linked with people with greater means. Thus just few houses would have had more than two stories. As for villages the houses "barastis" were huts built up of date sticks and fronds. The economic and environmental aspects did not allow these towns to have cars so there were no roads. Moreover there were not schools, running water, electricity, and healthy system. However, some see that changed was not as good as the most important changes they expected, but they admitted that the health and education have had the most important changed.

3.6.2.1 New modernization and Arab cities

By 1920 the most of Arabic world was occupied by western country. The cities pattern and buildings form have influenced by the new colonist. The dynamics of economic changes has created changes over social life, leading to radical transformation of traditional urban fabric of Arabic cities. Whilst the development of Arabic urban texture and architectural spaces used to be linked with natural evolutionary process, the new urban pattern was not, due to the speed and massive scale of new construction.

With industrialization era and what followed it of modern movements, the urban form had not stop to be a concern issue, but the way of thinking has changed. Therefore, the concentration to create huge constructions in number and pattern, has omitted the contextual values and interrelation between human and buildings on the first hand, and between buildings and open spaces on the other hand. In addition, the big numbers of cars have required a massive network of traffic arteries, which worked to interrupt the correlation between urban components. On the other hand, the urban form of most traditional Arab cities follows rules which are diametrically opposed to those. The formation of the Arab urban structure based on social and environmental treatments that depends on gathering process of organic micro-spaces into larger units [173], [174]. These social and environmental treatments are represented of the integration between the public realm and pedestrian movement with the components of the urban structure, producing a coherent urban environment. The public spaces in these urban complexes used to be linked with specific architectural units like Mosques, Suk, and Khans. From these prominent points, streets were extended, penetrating the organic urban structure and were often turned into narrow internal corridors. That being said, Arab cities were designed as closed universe reflecting their culture value, creating degree of privacy, ensuring that every section of the network matched the character of the space and the social needs of its users [173].

The majority of modern planning interventions have been done without respecting the traditional urban system, copying the western approach and applying it without taking into account the built environment. Resulting fragmented urban fabric by unstudied road systems that worked to divide the cohesive fabric into isolated blocks. These isolated blocks have started to be implanted of number of modern buildings that began to overwhelm on ancient structure. As mentioned above, local traditions have been replaced by western architectural style, and Occidentalism urban and planning techniques start to dominate these cities. Moreover, modern environmental planning techniques and concepts have taken place, ignoring centuries of experiences until reached these Arab cities their authentic traditional pattern. As a result, lots of traditional urban texture has been left to decay, where western modern style patterns have been emerged to replace them [173].

The traditional urban planning of the gulf cities came as a reaction of hot and humid climate. Buildings were constructed close together in order to create narrow streets, which were shaded most of the day. The main traditional architectural features are the courtyards and the wind-tower. However, modernization in urban development has destroyed much of the local urban character. Most cities turned to international planning ideologies that paid little or no attention to local traditional structure and such a good example for that could be cities of Dubai and Doha [173].

There is no doubt these cities can face the globalization by good and suitable strategies. These strategies can be the key of importance to direct the consequences of economic and human development in positive way. The challenge is just to find balance between the function of cities as engines of economic growth and their parts as factors of social change.

Generally the form of urban planning in Arab cities used to be linked with Islamic culture and social value, taking into account the environmental aspects to dwell with the harsh environment and to resist in the desert climate. Over and above, the growth of economy seems to demand a parallel concentration in the cities constructions. This conflict between traditional environmental treatments and modernization will be illustrated in case study of form and growth of Dubai and Doha.

The form of Dubai city can be significantly divided to two eras, before and after the discovery of oil. Before oil and till 1971 Dubai has been shaped by various imported ideologies like Arab, Persian and British. Dubai has emerged at the beginning from small villages called Al-Bastakiya and Satwa, where today these villages form the oldest neighbourhoods of it. Take a look at this urban fabric of the initial city of Dubai, can clearly observe the random and cohesive planning, as shown in Figure 3.40. However, Al Bastakiya is renovated and preserved, but focus was on the individual buildings rather than on the whole fabric leading to lack of cohesion. Meanwhile, Satwa was converted to be a slum that densely populated by illegal immigrants, with its urban fabric and buildings that suffering from the destiny to be obliteration [173]. In other words, the modern city of Dubai has developed orthogonally along the coastline ignoring the entire traditional pattern.

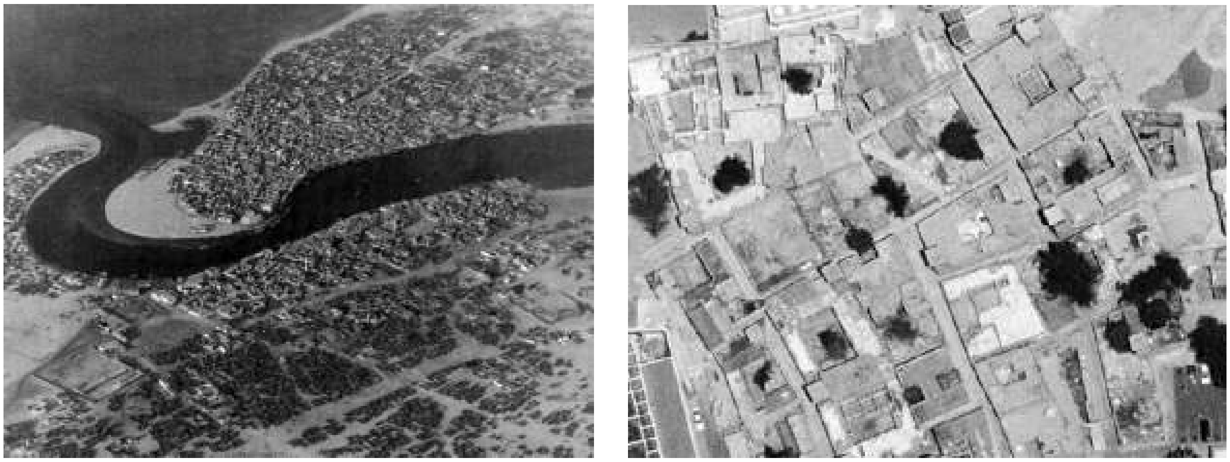


Fig. 3.40: The compact urban fabric of Dubai before oil [175]

The modern process was established in Dubai during the second half of the 20th century, with fast urban development following the discovery of oil. The prosperity of economy has required occidental buildings and western planning ideologies to conform to the new immigrants. The most important things that could happened and worked to change the face of Dubai from random pattern to orthogonality one is the establishment of Dubai Town Planning Scheme, which had an impact on the growth of the city, in particular, providing effective network to link both sides of the creek through constructing Al-Maktoum and Garhoud bridges as well as Al-Shindagha tunnel.

Other factors have impacted over Dubai planning are those: both building materials and technologies has been imported from western countries; moreover, planning organization was based on western codes and dominated by foreign professionals? On the other hand, topography has allowed Dubai to grow along the beach" which even is considered an attractive point", where the internal sprawl toward was always surrounded by desert as shown in Figure 3.41.

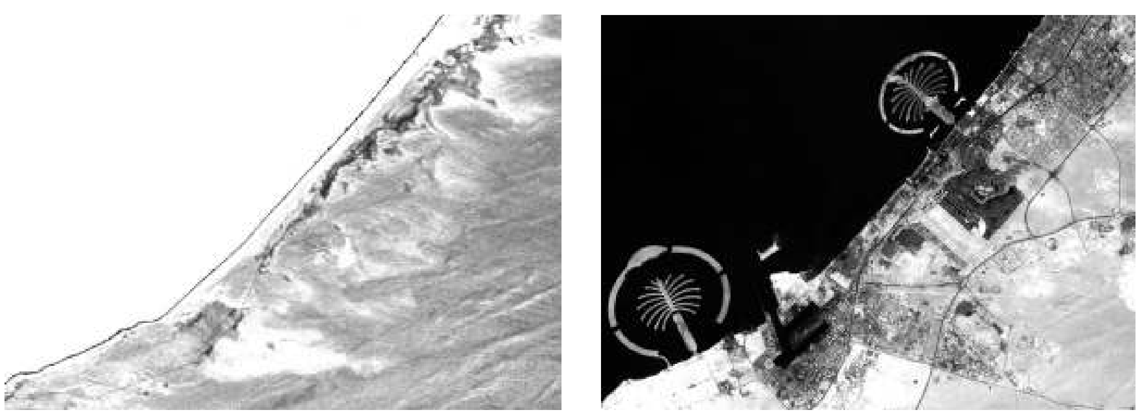


Fig. 3.41: The extension of Dubai between 1973 and 2006 [175]

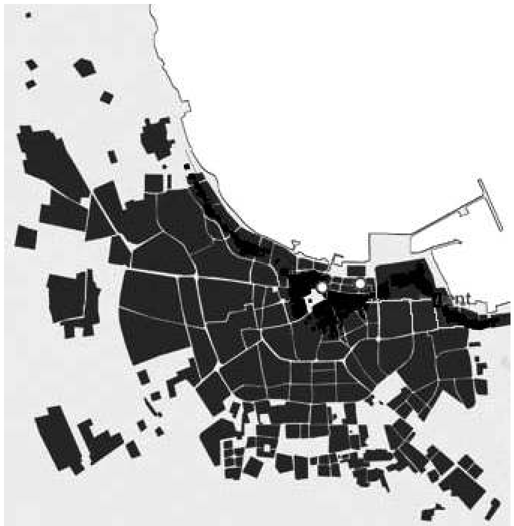
The spatial development pattern of Dubai are characterized by western features, that because during the last 40 years, most of the participants of the urban development process, such as developers, professionals, contractors, and suppliers were foreigners. Moreover, even the local professionals have finished their study in western foreign country, working to influence strongly over architectural style and urban spaces.

Though, looking at Dubai from sky may impress anyone, but anyhow the need to engage the Arab traditional criteria to turn this city to sustainable one, and to change it to be more closer as form to its original population is necessary.

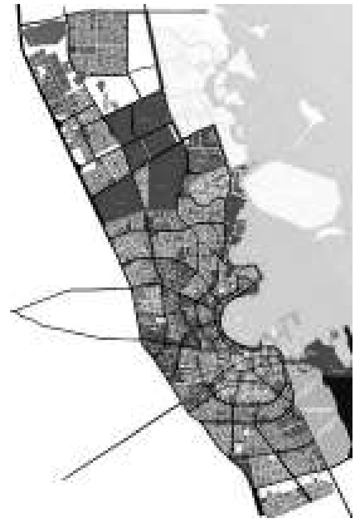
As Dubai, Doha has started seeing its first urbanization since the middle of 20 century which was accompanied with the rapidly increasing of oil production. Until the 60 of last century, Doha "Al Bidaa" had used to be fishing village as shown in fig.11. This village then witnessed a new period of turning after it has become industrialised where technologies allowed the development of regional and global networks [176]. The name of Doha or refers to a big tree standing at the coast or to the radial shape of the shoreline [177]. Despite an adequate urban planning was not used there, the inherited knowledge and traditions have been enough to build this space. Therefore, an organic settlement patterns have evolved based on the principle of cell, where the courtyard house was developed to clusters, forming neighbourhoods that connected to the central spine of the settlement.

By analysing the form that this village had emerged we can see that it started like a line along the semi-circular coastline, and then has grown up, emulating this line forming semi-radial street networks. As being said, the topography and the attractive point which is “coastline” who give Doha this shape to be grown up in the future also like that till reach the maximum sprawl and give view to expand in future longitudinally to be mixed between semi-radial and orthogonal as illustrated in Figure 3.42.

As has been said, Doha had developed into eight salient settlements along the coastline due to the need of access to the gulf [176]. Later groups of Persian immigrants had arrived here to work as craftsmen in boat construction, additionally to East-African slaves that came to work as fishermen or in the pearl industry. These settlements have grown because every family had built their houses one next the other, wall on wall, due to the strong affiliation which stems from the Arab culture and social interaction. The compact urban fabric was also inspired of hot climate and need to shadow alleys. Even though every group had lived separately every neighbourhood had a direct access to the market and harbour as well as to town centre where the Friday mosque was located. Anyhow these street networks were created as a result of the mass building of each family more than conscious planning.



a. Doha between 1947 and 1970



b. concept to develop Doha master plan 2005

Fig. 3.42: Doha development [178]

However, until the discovery of oil Doha's traditional urban form had been saved unto modern buildings began to appear. This traditional urban texture was the result of the correlation between the human and built environment, where the climate and culture had formed this place, creating the natural flow from the external space to inner world of house.

The notable difference in the settlement Doha that most construction concerns were dealt with at lower levels, so mainly development was governed by bottom-up rather than top-down decision-making [179]

The modern movement may start after 1950 when modern infrastructures like street, supply of fresh water, and electricity were started installing. However, the decisive influence over urban form has done due to imported goods like cars and air conditioning, and what concomitant that of vast immigration. As a result of that, wide trails were blazed; traditional buildings with courtyard were demolished, giving the opportunity for modern buildings blocks to be erected. On the other hand, the houses that have been built to absorb the new expatriate labour with Qataris that moved from other part to the capital were distributed spontaneously around the former city boundaries. although the city has grown in all the direction especially toward west where the road to Al Dukhan and south-east toward the airport, the future plan was set to be extended toward northern direction [179].

The first master plan of Doha saw the light after 1970 by the consultant Llewelyn Davis [179]. This plan was basically semi-circles roads separating the land, defining the usage of land regarding each ring. This form has been saved until the oil boom, which has led to swell the urban growth, resulting scattered urban landscape with low densities, forming numbers of suburbs and a large percentage of un-built land due to speculation [180]. As result of that, Qataris and high-income workers have moved to live in houses in the suburbia of Doha, leaving the centre to become the residential area of foreign labour. All afore, led to decrease the investments and subsequently to deterioration in urban qualities in Doha's centre.

3.6.2.2 The future difficulties and strategy to solutions

The difficulties could be summarized in two critical ways: first is to keep the wheel of development on and use the resources to build sustainable buildings and smart neighbourhoods as steps to green cities, second how can keep up with development while maintaining our legacy of urban and architectural style. On the other hand, people that survived in desert for not centuries but millenniums, brought to us great examples of environmental and healthy buildings that stand until these days deserve to be taken in consideration not just to save it and make the renovation, but also to be the inspiration to build our cities that originate from the core of Arab civilization.

The traditional climatic design should be applied on the gulf countries' construction to reduce the consumption of energy in order to reach low-energy design. However, the actual buildings that have constructed in Dubai and Doha are far from to be suitable to the region's climate, solutions that can be applied to reach sustainability are not impossible.

The unresponsive climatic can be summarized in inappropriate site planning, orientation, architectural design, and facades with high level glazing. The application of an interdisciplinary design approach that take in consideration urban design, landscape design, architecture and meteorology may provide a more opportunities to reach low-energy design for such hot and arid climate [181]. The traditional ideas like interior court yard, wind-tower concept, compact urban fabric, using local materials, using the natural ventilation, local architecture style, and less glass skin used or using it like photovoltaic, may be some future low-energy keys.

The inappropriate urban design has led gulf countries to be one of the largest consumers of energy on per capita basis (Figure 3.43). However, the consumption of energy differs according to the building type, still form 70 percent of primary domestic energy, this energy is mostly used in mechanical ventilation and artificial lighting. The main problem is that the majority of buildings were imported from other parts and implanted in this arid climate without taking into account the climatic treatments, resulting urban space unsuitable to the climate and culture.

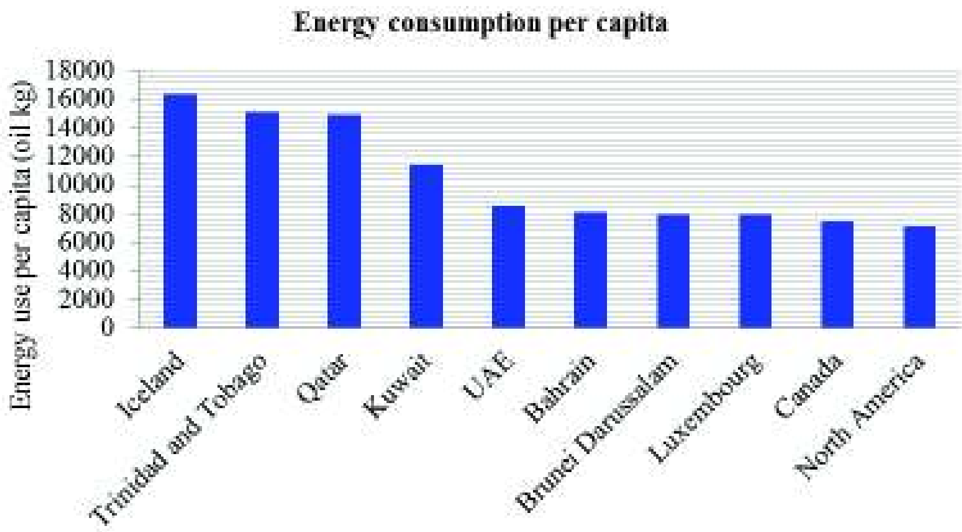


Fig. 3.43: Highest energy users per capita (World Bank)

Recently, because of some cities like Dubai start running out of oil, they have come to realise the important of diversification the economy and searching for alternative resources of energy, concentrating on the concept of zero-energy buildings. Low-energy achievement in building can be reached by minimising the energy needs through correct architectural design like minimize the glazed skin in the facades that faces the direct sun beams, or by using these glasses to cover opaque walls. On the other hand, works to maximize the use of natural ventilation that depends on prevailing breezes.

In the arid climate as other ones is so important the orientation of buildings, which can lead to reduce the cooling loads through reducing the exposing to the solar beams, at the same time minimising the penetration through windows, diminishing the solar absorption through walls and roofs [181].

The orientation is also important to create tracks of air to reduce the high level of humidity between the cooler months. The orientation also should be applied in the internal planning to direct prevailing breezes and ensuring rooms benefit from ventilation.

The use of non-compact urban fabric, resulting high heat loads due to the level of solar radiation and the lack of shading available from other buildings. All afore lead to start searching for solution that can be applied to reach sustainability.

Central courtyard concept can be provided the building with cool natural ventilation, working to reduce the cooling loads. The idea is to open the windows into shaded humid green micro-climate. This can provide cool wind, allowing to the hot one to be vented via convection. Courtyards also helped to reduce the envelope façades that face the direct sun beams, enlarging the shaded areas which help to control the heat transferring. The concept of courtyards can also be applied on the streets by using trees to create shading areas that can also provide cooling benefits to street areas [180].

Undoubtedly, building colour has a deep impact over thermal performance and indoor temperatures. The white surfaces absorb less solar radiation due to the high reflection, where the dark surfaces absorb more because they reflect just 20 percent. However, to avoid glare, we have to pay attention to the use of it, where sometime medium light colours can be used, and colouring the projecting elements such as balconies and walls that located opposite of window by darker ones.

The usage of sustainable insulation can obviously reduce the cooling loads of buildings. Other technic like double layers walls separated by air space can also decrease the passing of air.

With knowledge that such patterns are also environmentally sustainable and have energetic value, another priority may be the restudying them for finding out their key points in sustainable architecture. These kinds of initiatives provide the opportunity to explore the wisdom of the pre-oil period. Giving the way to the question, how the limited environmental resources were used in an efficient way? in order to use them for contemporary buildings. We are searching for sustainability for green eco- friendly ones, our heritage and urban style could be the best solution for us. That people lived in scarcity of resources and have succeeded, I think they had such great experience and we should respect them.

3.7 Key points towards the future

3.7.1 Key points from Renaissance

The emergence of the so-called sequential planning in England, which depends on several consecutive centers, these centers consist of squares and gardens with interest of traffic places. However, the most significant result of the Renaissance is the start thinking to the ideal city. The actual main urban planning theories are the direct result of the Renaissance thinking (e.g., the linear city Soria Y Mata, the garden city Ebenezer Howard) [128].

3.7.2 Key points from Industrial Revolution

The government departments, the business and trade were not interested by the city's population concern, so they allow the development of factories without paying attention to the specific of the site, the function and the nature of the factory.

In the terms of traffic, it was a failure, because:

- It developed an irregular distribution of all the elements of the city;
- The streets are narrow with zigzag, gridiron or radiological paths, and when the cars showed up the streets did not meet the required function;
- The high number of intersections found in every growth pattern (longitudinal traffic, local traffic, and pedestrian, and all types of transportation), and many of the streets with heavy traffic cut the unit of the residential and commercial areas.

Due to the city growth, green areas were lost and city suffered from the lack of entertainment places. The surrounded space of houses was not healthy, and the workplace was not appropriate for its purpose. However, the access between the housing and the workplace was easy and secure, because most of the workers lived around it. A large portion, of about 40%, of the city is occupied by housing in the form of scattered units. Due to the spectacular increase in population, the neighborhoods became overcrowded. Most of the dwellings lacked the necessary requirements of the air and the sun.

The underground city is the most revolutionary concept launched within this era. It relies in a system emerged from the inventions of the mining industry. The tunnel and the road passing below the ground bring freedom in the development of all axes of the city. If the means of transport that were found on the surface of the earth, in the city of coke begun to be replaced on a large scale with underground network facilities. In time these facilities amplified to such an extent that commercial stores and other facilities have been developed. We can say that these underground networks are the first step for sustainable, eco-friendly cities.

3.7.3 Key points from oil age

The shift of modernization of the city planning focused on the need to abandon the traditional surface treatment of the cities, and the need to link buildings together in an organic and harmonious relationship. Moreover, the streets and squares design, are elements from the city components which attempt to reform the functional configuration of the city and to reorganize it, in order to improve the living conditions of the population.

Emerge what it is called a commercial city which has been formed as a results of a sharp development of economy, and when commercial activity started creeping on the business city, and as a reaction of these cities appeared some Urban planning movements as, *Garden cities*, which would combine the best elements of city and country as would avoid the worst elements of city and country. Formed the basis of the earliest suburbs, but failed to separate from city. Self-sufficient community 'sector' of limited zone and population that surrounded by a greenbelt was intended to combine between economic and cultural advantages of both city and country life. In addition, *Beautiful City* that suggest to put a law to curb the bad use of the land which for construction, where formed a restrictions on commercial and industrial buildings, especially after the emergence of skyscrapers and shadows covered the streets no longer allowed to build on an area of 100% of the land to achieve good lighting and ventilation through day inside streets.

In the term of environment, Biodiversity play an important role in the amelioration of the environment due to their tremendous through collect the dust due to their dust trapping ability, Effective carbon sink, Green lungs of the city, supplier of much needed vital oxygen, soil and water conserver, moreover Plants play an important role in both, reducing the environmental pollution load as well as serve as pollution indicator.

A completely renewable base-load electricity generation system is proposed by combining wind energy, compressed air energy storage and biomass gasification. This system can rules out problems linked with wind intermittency and provide a source of electrical energy, functionally equivalent to a large fossil power. Replacing natural gas with synthetic fuel derived from biomass gasification reduce the use of fossil fuels, virtually that eliminates net CO2 emissions from the system. In addition, start using sustainable materials is which have ecological practices and responsibility to humankind and nature. Which its raw material comes solely from wood that is harvested and grown using sustained forestry management practices. When *Wood* uses as construction material, the level of CO_2 gas in the atmosphere when they decompose or burn do not increase, because it releases the same amount of CO_2 into the environment as it had absorbed during its lifetime. Moreover, the factories should all locate near its raw materials, translating into less pollution and consumption of fuel, thanks to reduce transport distances.

It has to be taken in consideration by all greening agencies that every effort should be made for horizontal expansion of green cover inside and around cities. At the same time, efforts for vertical expansion of existing green areas have to be made by way of developing them into multi-storey forest in order to increase efficiency and effectiveness carbon sink and green lungs of the city. Taking into account the high limit that plant can survive. In addition start using clean resources of energy to save the environment and stop draining its resources as a main step toward sustainability.

4. SUSTAINABLE ENGINEERED CONTRIBUTIONS

4.1 Environmental compatibility of the cities

Within the last decades, environment has become the sensitive critical issue for politicians, ecologists, urbanists, architects and engineers. The sustainable urban components and the human behaviour with respect to the surrounding environment became a priority for them in order to stop the deterioration of the environment. On the other hand, the percent of people that live in urban areas raised up to 54 % [183]. All those have urge the urbanists to start thinking of new solutions in turn to save the earth from the cancerous urban sprawl, considering an increased energy demand while the lack of resources grows.

We deal with a dynamic process when a person and/or society aim to change its behavior and build a harmonious relationship with the environment. Environmental compatibility presumes a clean environment, kept away from pollution. Such an approach achieves a balanced psychological life, equally at the level of the individual and society. Moreover, the benefits of dealing and interaction between environment and human have a profound impact over both the human and nature. It is a deeper relationship than just the beauty of appearance; it helps to make the city a better place to live. So, it is an exchange relation and when we reach it, actually we reach a sustainable environment.

The prevailing wind in London, on the south-west direction, has always carried the industrial air pollution, while Thames has carried the water pollution in the rest of London. Therefore, is not surprisingly that the north-east neighbourhoods have always been the home of the poorest [2]. Air and water pollution penetrated London in the XIXth

century due to the industrial revolution. The term *smog* was introduced in the XXth century to describe the mix of smoke from coal fires with London's fog. The motor vehicle fumes endangered the health of London's residents and damaged even the buildings. Moreover, industrialization and unregulated sewage disposal also compromised the condition of London's lifeline. The Thames river was so polluted by the mid of the XIXth century that its smell spread everywhere.

All above aspects have led to take serious procedures, firstly through cleaning the air by banning the coal burning; secondly by laws and projects to improve the water quality of the river. Nowadays there is a large stock of fish and other forms of aquatic life in the Thames river. However, London's air is still polluted by carbon monoxide, nitrogen dioxide, benzene, and other chemicals due to traffic and diminishing industrial activities.

As for new built cities that occurred in this era, like Chandigarh from India which was built starting with the middle of the last century, the architects, under the coordination of Corbusier, have been more aware to the environmental issues. Thus, it came like a reaction to industrialization and agglomeration of heavy cluster of concrete, so that Chandigarh was planned to be a collection of harmonious blend of buildings, trees and other landscape elements. The most fascinating feature of the city's landscaping is the *tree plantation* along the avenues, which put the street-network as the first step towards sustainability. The *tree plantation* reduces the noise, and reduces the air pollution from the automobiles exhaust. Then, open spaces enhance the ventilation, working on passing polluted air out of the city. In addition, green belts around building complexes protect the buildings and create a kind of healthy atmosphere around them. The parklands and gardens cover 29.3 % of its total landmass, while other square kilometers are planted with trees, leading the total green cover to reach 35.7 % of the total geographical area. All these aspects enhance the ecological, environmental and aesthetic richness of the city.

However, the accelerated increase in population (i.e., within 1951-1961 the growing rate of the population was 394.13 %) accompanied by the rapid increase in the number of vehicles, led to the spectacular rise of the pollution levels in Chandigarh. Thus, the annual average dust levels are more than the permissible limit of 140 mg/m^3. The increase in suspended particulate matter and dust level is increasing the possibility of respiratory diseases. In addition, the noise levels on some roads, both avenues and residential lanes are more than the acceptable limit of 55 dB [184].

Nowadays, our biosphere is facing various challenges. The main one is the fossil-fuel, which causes air pollution, acidic precipitation (i.e., acid rains), global warming, large CO_2 emissions and petroleum waste. As we run out of petroleum and natural gas, by the time natural resources have been depleted, some questions arise:

- Which is the actual real situation?
- What should the new energy-system be, so that the damaging of the environment can be stopped?

While the international reports are contradictory with respect to the first question, with regard to the second question there is no doubt that going back to primary energy-options such as coal is not a correct answer. Recent events (e.g., Chernobyl in 1986 and Fukushima in 2011) show that nuclear power is not a solution too. On the other hand, renewable energy sources (e.g., solar, wind, hydro, bio fuel) also affect dramatically the ecosystems. Fusion reactors and hydrogen fuel are still uncertain solutions. It appears evidently that on short and mid-term, a compromise should be made. Consequently, the present research considers the reduction of the energy consumption embedded in the urban development components, focusing on:

- To reduce the oil based materials consumption, looking back to traditional solutions and bring them as future sustainable alternatives;
- Sustainable preservation of old buildings targeting not to consume resources on new buildings;
- To enhance the concept of energy self-sufficient neighbourhoods by the optimization of the buildings distribution adapted to the climate conditions.

4.2 Research on clay pipes

4.2.1 Background

Bob Ward [185] from *Grantham Research Institute on Climate Change and the Environment* noticed ***"The right question is not - was it caused by climate change? But what impact has climate change had on it? It would be unlikely an almost 1 degree increase in global temperature would have no part to play in extreme weather events"***.

Facing global warming and environmental pollution, much research is needed to set up the suitable solutions in order to avoid them. Therefore, taking a look back, of how the world has been developed in the last two centuries, will make us shocked of a sharp shift started since industrial revolution and went through oil discovery era. There is no doubt that oil has worked to impact all the factors that create and develop urban living space. Moreover, its products have entered directly and indirectly in every details of our cities life.

Till now, lot of research tried to find solutions for urban development problems by discovering new ways and materials, regardless if are sustainable or not. In many cases, the main question remains: what is the impact of the new products regarding the environment? Therefore, going back in the history may give us outstanding solutions for problems that we have right now. Cities and buildings that stand since long time till these days, facing all the climate and environmental factors are deserved not just to take a look over their systems, but find right examples of sustainable urban elements and materials to be used for *complex modern cities* of the present. At the same time, our world is running out of oil and thus its materials, and age without oil is not so far to happen. Based on this, analyzing building materials and technologies before and after the age of oil, may give us a great idea how oil has worked to change the face of our cities. Obviously, the discovery of oil made a revolution in various fields, and building materials is one of them. As much as these new materials have made a big change over our cities, they equally had a terrible influence over the climate, because environment and public health it was not taken into account. At the beginning, people were grateful to get rid of the natural materials and to replace them with new, modern ones. In the opinion of the author, traditional materials have a higher sustainability potential. Thus, the present research aims to promote a sustainable natural material in order to replace non-ecological solutions, based on a look back to the pre-oil age. More specific, next the research is done on clay pipes, traditional solution for drainage and sewage since ancient times, replaced nowadays by cement and oil based products (e.g., concrete pipes, polymeric pipes).

Pollution is not just CO_2 emissions and people activities over environment. Polymeric plastic materials, derived from oil, are one of the main factors of environmental pollution, not just because of their origin, but they are strange to nature and need thousands of years to degrade. Considering the bad traces of plastic over environment, and knowing that oil is a limit resources, a look back to the Roman civilization and their sanitation system that used in their outstanding baths to find out that complexes one had made out of clay. Clay is considered a good thermal mass; it is very good in keeping temperatures at a constant level. Buildings built of clay tend to be naturally cool in the summer heat and warm in cold weather. Clay act like stone under heat or cold, where holds it and releases it over a period of time. So we choose the origin materials clay as ecological sustainable materials for constructions trying to replace plastic pipes by clay one [186]. However, vitrified clay pipes to be used in sewer system are already used since two or more decades, but not for water supply systems. Two manufacturing technologies are proposed:

- Treated clay pipes without burning, to be used in sewer system;
- Treated vitrified pipes to be used in sanitation system.

4.2.2 Material selection

Sixteen samples of clay mixtures were manufactured to study their behavior (see Figure 4.1). The choice of the materials was done on paralellipipedic specimens were in size of 40×40×160 mm. Treatments were made with thin films of sunflower oil.

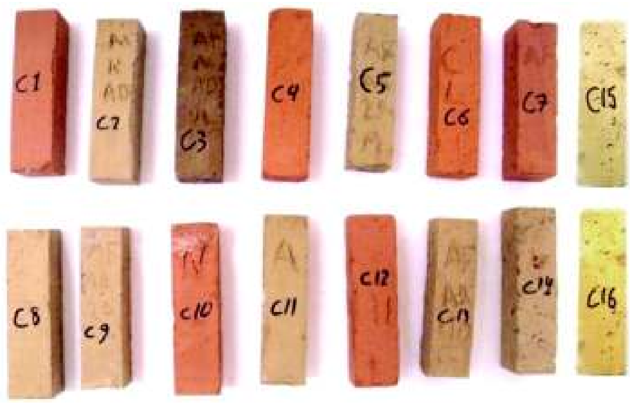


Figure 4.1: Clay specimens

The deciding factor for the quality of a clay product is connected to the quality of the soil being used. The other ingredients introduced into the specimens are various quantities of sand as gravel and straw as disperse reinforcement. One sample replaced sand with sawdust (sample C6), which proved to be unsatisfactory. Some samples also included in the mass of clay aracet (i.e., polyvinyl acetate) and bone glue. All materials are of local origin, as follows: clay from Valea Drăganului and Căpuş, sand from Poieni and straws from Bistriţa. For the burnt samples, special care was given to the ingredients in order to not contain lime (see Figure 4.2), which explodes when burns in high temperature. Figure 4.3 illustrates samples of the clay type and the sand used, and Figure 4.4 shows the straws.

a. sand with lime

b. sand without lime

Figure 4.2: Local sand samples

a. gross claye

b. crushed sieved clay
(clay power)

c.sieved sand
(0-4 mm)

Figure 4.3: Basic ingredients of the specimens

Figure 4.4: Straws

To analyze the behavior of samples before and after burning, one sample of every mixture was burned gradually up to 900 °C following the chart given in Figure 4.5.

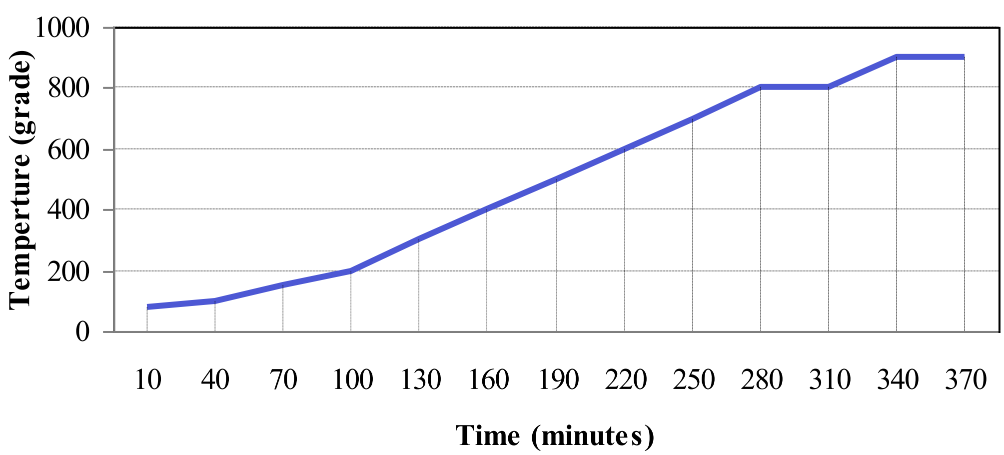


Figure 4.5: Chart of the burning process

All sixteen samples were tested under flexural tension (see Figure 4.6) and compression stresses (see Figure 4.7) at the laboratory of INCERC Cluj-Napoca, to identify the best mixture in order to manufacture the pipes. Figure 4.8 shows the samples after the flexural test. The results are summarized in Table 4.1.

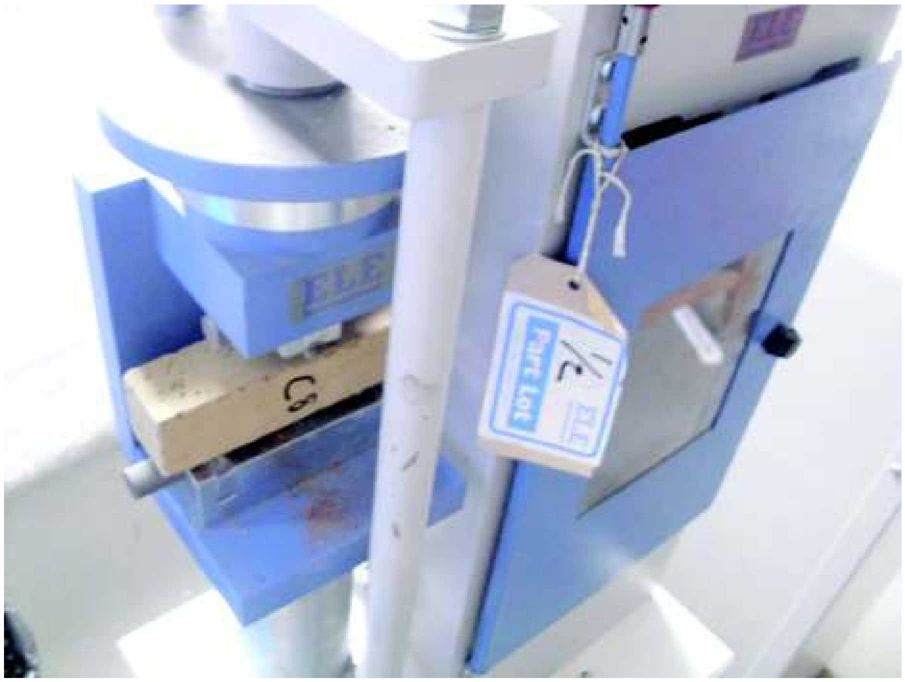


Figure 4.6: Flexural tensile test

Figure 4.7: Compression test

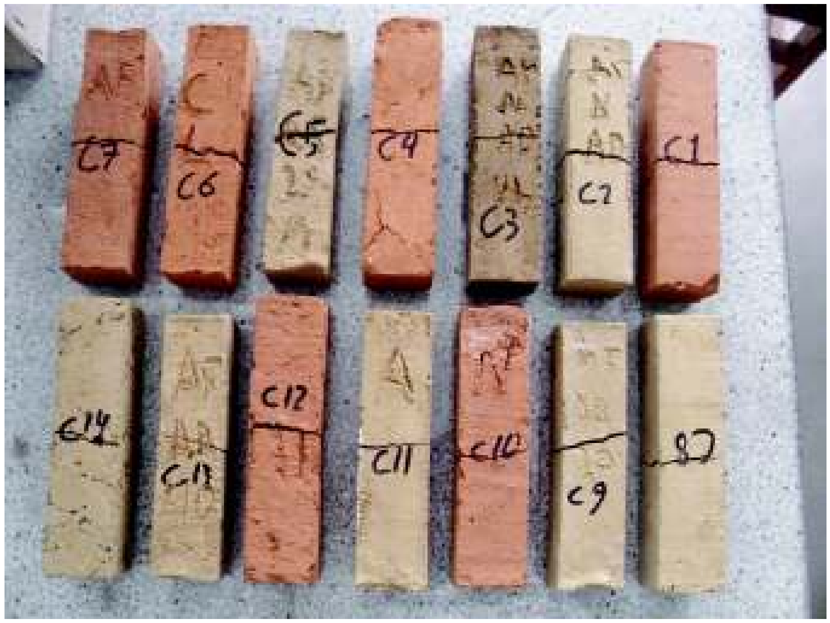


Figure 4.8: Specimens after flexural tensile test

As Table 4.1 shows, the mixture that consists of powder clay and sand (sample C7), burnt up to 900 °C gave the best results. The unburned sample C8 gave very good results in flexural tension. Figures 4.9 and 4.10 emphasize the influence of burning for five mixtures considered.

Tab. 4.1: Results of the preliminary tests on different mixtures

Sample	Composition	Weight g	Tensile strength MPA	Compressive strength MPA
C1	clay+aracet+sand 35 %+burnt	389.03	1.102	7.412-8.034
C2	clay+aracet+sand 35 %	413.16	1.006	3.189-3.325
C3	clay+aracet+sand 35 %+oil	453.5	0.749	1.631-1.645
C4	clay+aracet+sand 35 %+oil+burnt	400.2	0.775	4.929-5.343
C5	powder clay+aracet 20 %+straw+sand 35 %	330.87	0.873	2.050-2.464
C6	clay+bone glue+ sawdust 10 %+burnt	323.23	0.827	4.164-4.728
C7	*powder clay+sand 35 %+burnt*	*385.97*	*1.058*	*9.112-9.434*
C8	*powder clay+sand 35 %*	*415.52*	*1.165*	*3.267-3.382*
C9	powder clay+sand 35 %+bone glue 20 %	398.98	0.962	2.853-3.264
C10	clay+sand 35 %+burnt	385.91	0.566	4.125-4.249
C11	powder clay+water extra 20 %	360.52	0.724	1.917-2.081
C12	clay+burnt	401.89	0.589	4.547-4.902
C13	powder clay+sand+bone glue 40 %	332.99	0.892	2.446-2.660
C14	powder clay+sand+straw	399.58	1.045	2.378-2.423
C15	clay	420.59	1.201	3.054-3.126
C16	clay+sand 35 %	412.52	0.736	2.366-2.653

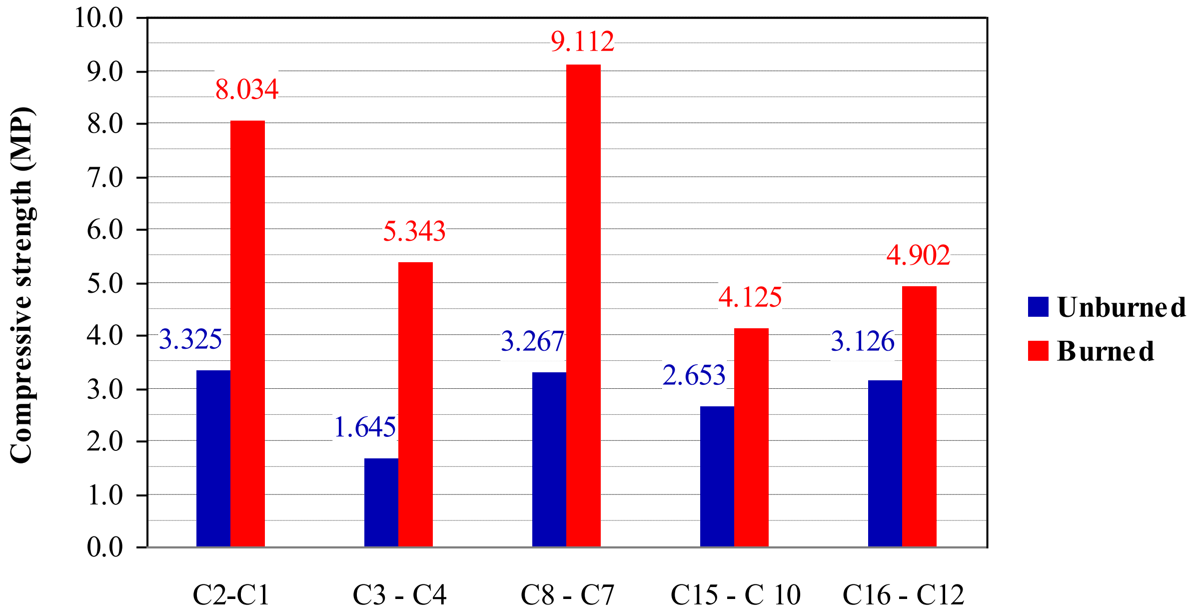


Figure 4.9: Influence of burning over the compressive strength

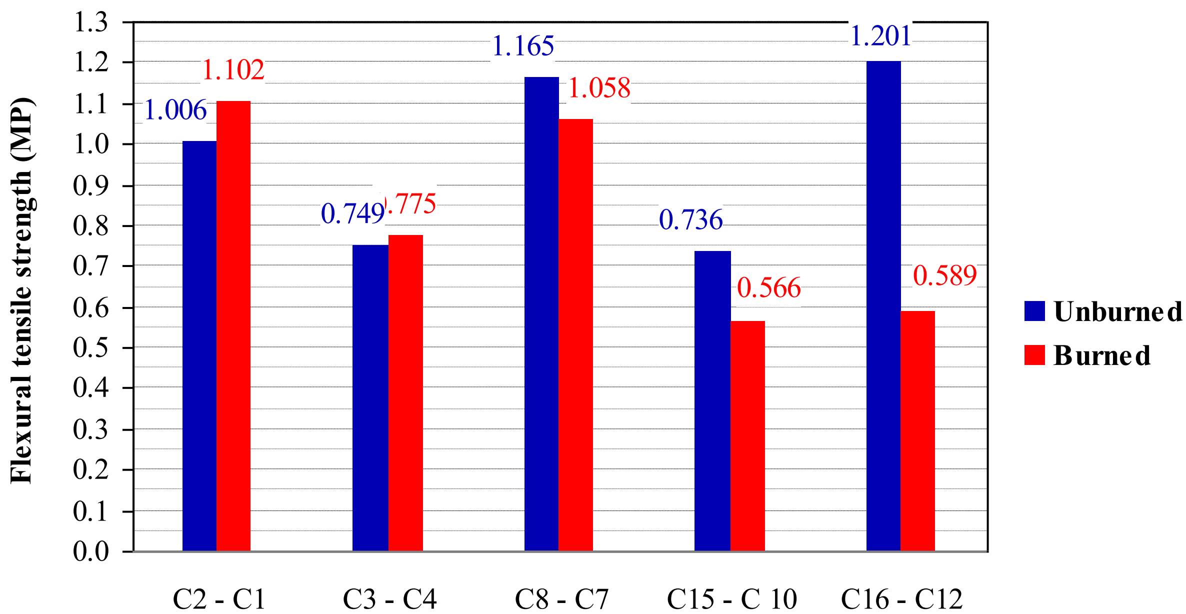


Figure 4.10: Influence of burning over the flexural tensile strength

According to the results burning helps to strengthen the samples in compression, while in tension weaken them. It also appears logic to state that burning makes the mixture less resilient. As the results of samples C1-C4 shows, surprisingly oil treatment has a negative impact upon the mechanical resistances. However, for piping not just compressive and tensile resistances are important, but other features like water pressure, air pressure, permeability, crushing strength, water tightness and water absorption.

The treatment materials (i.e., linseed oil, sunflower oil and pork fat) proved good results for waterproofing. Layers of these materials were brushed over unburned clay dry samples and the decline of the water was observed. The decrease of the initially 50 mm water level is shown in Table 4.2, the linseed oil being the best solution.

Figure 4.11: Waterproof testing of treatment materials

Tab. 4.2: Results of waterpoof tests on treatment materials

Material	**One week level decrease mm**	**Two weeks level decrease mm**
linseed oil	2	4
sunflower oil	4	7
pork fat	3	5

4.2.3 Manufacturing pipe specimens and preliminary tests

Next, based on the results given in Table 4.1, Figures 4.9 and 4.10, for mixtures were selected (C3, C4, C7 and C8) to test them on pipe specimens and then to compare the results with the admissibility criteria given by EN 295 [187]. The pipe specimens were made manually, and it seems reasonable that if a hydraulic manufacturing technology would be used better results would be. Figure 4.12 shows images taken during the calibration of the manufacturing technology. Firstly, the specimens cracked due to shrinkage and mould removal (see Figure 4.13). Finally the best technique found was the vertical extraction of the mould and constant temperature and humidity conditions (23 °C and RH=70 %. Figure 4.14 presents the pipe specimens and Table 4.3 their characteristics.

Figure 4.12: Manufacturing sequences

Figure 4.13: Cracked specimens

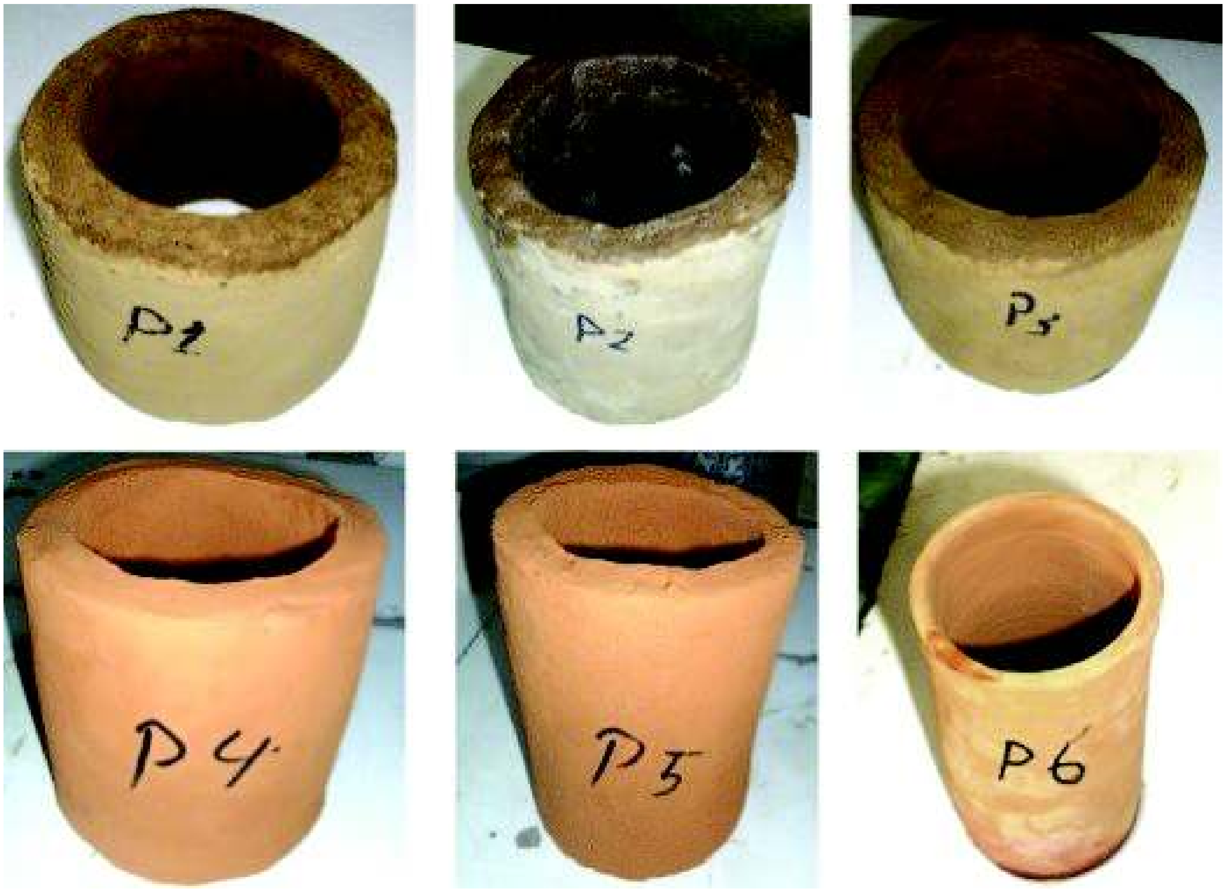


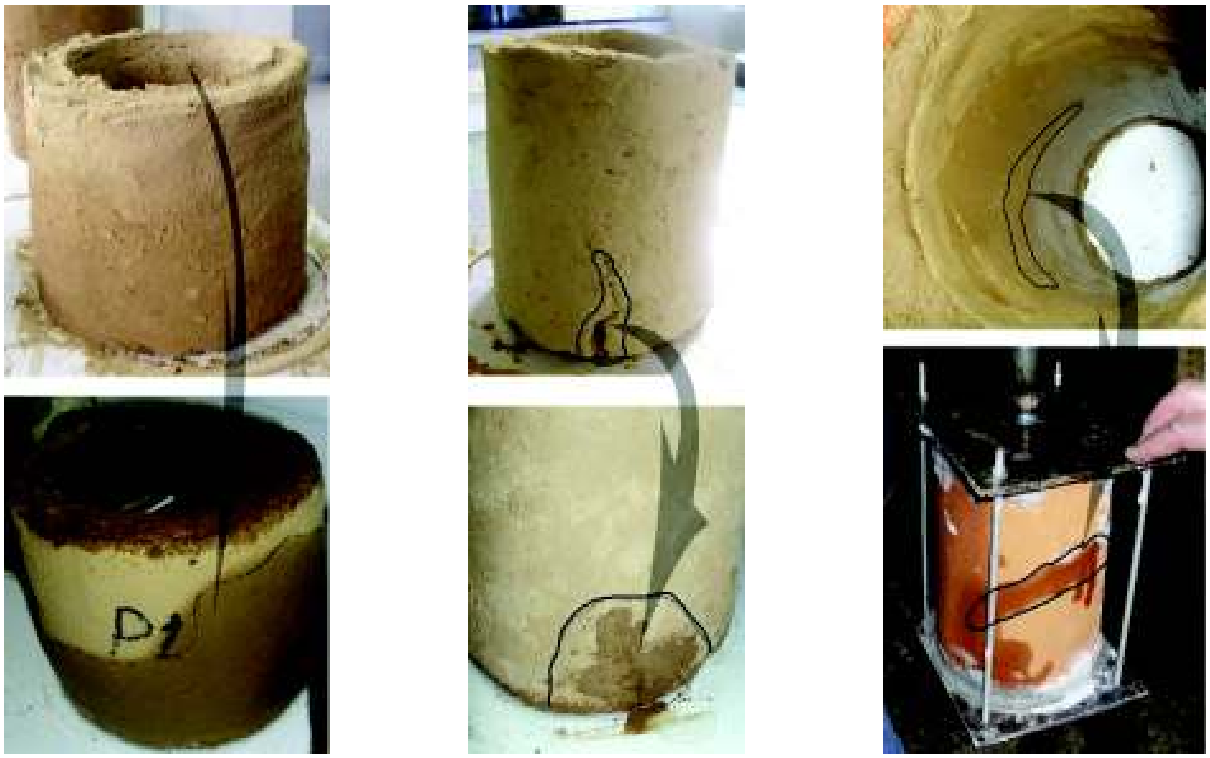
Figure 4.14: Final pipe specimens

Tab. 4.3: Characteristics of the pipe specimens

Specimen	Composition	Exterior diameter mm	Interior diameter mm	Height mm	Treatment
P1	C7	150	115	150	2 layers of linseed oil
P2	C7+sealed cracks	150	115	180	2 layers of pork fat
P3	C3	145	127	150	2 layers of sunflower oil
P4	C8	150	115	150	-
P5	C4+sealed cracks	145	127	200	-
P6a	C8	65	45	100	-
P6b	C8	65	45	100	1 layer of linseed oil

Specimens P2 and P5 (initially cracked), were fixed by adding the same mixture within the cracks. Specimen P6 was made in two variants, oil treated and not treated respectively. Specimens P4, P5 and P6 (both alternatives) were burned up to 900 °C, following the same heating pattern given in Figure 4.5. The treatment was done by cladding the interior surface by layers of natural materials as illustrated in Table 4.2.

Specimens P1, P2 and P3 (i.e., unburned specimens) were preliminary tested by filling them with water and observe how much the treatment material prevents the leakage of water. Specimens P1 and P2 did not hold the water (see Figures 4.15a and 4.15b), due to the porosity of the material and initial cracking respectively. Specimen P3 retained well the water, and was next tested under water pressure. It failed under a pressure of 1 bar, which qualifies such pipes for domestic draining systems.



a.specimen P1 *b.specimen P2* *c.specimen P5*

Figure 4.15: Specimens with unsatisfactory water tightness

Water leakage and water pressure were also tested for the burned specimens. It was noticed that specimen P5 (initially cracked) resisted only up to 0.6 bar (see Figure 4.15c). Next, the standard tests performed according to EN 295 [187] for the specimens P3, P4 and P6 are presented. Moreover, for P6, in both alternatives, even a higher pressure was considered, as for plastic pipes standard, to see if these pipes can replace the plastic ones.

4.2.4 Airtightness of the pipes

According to EN 295-1 clause 5.18 and section 16 of EN 295-3, test setup consists in applying an air gauge pressure of 10 mbar for a period of 6 minutes. The acceptance criteria says that the gauge pressure must not drop below 7.5 mbar. Results are shown in Table 4.4.

Tab. 4.4: Airtightness of pipes

Sample	Test pressure mbar	Permissible Δp mbar	Effective Δp Mbar	Requirement fulfilled?
P3	10	2.5	0.7	yes
P4	10	2.5	2.4	yes
P6a	10	2.5	2.0	yes
P6b	10	2.5	0.5	yes

4.2.5 Water absorption of pipes

According IS 3495 (Part-2)-1992 RA 2011 [188], the specimens were tested by drying in a ventilated oven at a temperature of 105 °C to 115°C, untill they present substantially constant mass. After that specimens were subjected to cooling to the room temperature and obtain its weight. Immerse completely dried specimen in clean water at a temperature of 27+2°C for 24 hours. Take them out and gently dried with a towel and re-weighed. The average water absorption shall not be more than 20 %.

Tab. 4.5: Water absorption results

Sample	Dry weight g	Wet weight g	Water absorption g	Water absorption %	Set values	Requirement fulfilled?
P3	2437	2512	75	3.077%	≤ 20%	yes
P4	1976.94	2266	289.06	14.62%	≤ 20%	yes
P6a	2151.7	2537.3	385.6	17.92%	≤ 20%	yes
P6b	3128	3045.2	82.8	2.71%	≤ 20%	yes

The specimens P3, P6 (b) acheive requirements of water absorption according to set value EN 295-1 [187] which has to be less than 6 %.

4.2.6 Crush strength

For determining the crushing strength of vitrified clay pipes according to EN 295-1 [187], clause 5.9, the pipes were preconditioned according to EN 295-3 [187], clause 7.1.1, method a. That means immersing the pipes in a container filled with water at ambient temperature for a minimum duration of 66 hours. Then it was applied pressure force as shown down in Figure 4.16. The results given in Table 4.6 show that all burned specimens (only these were tested, obviously the unburned specimen cannot fulfill) comply with requirement.

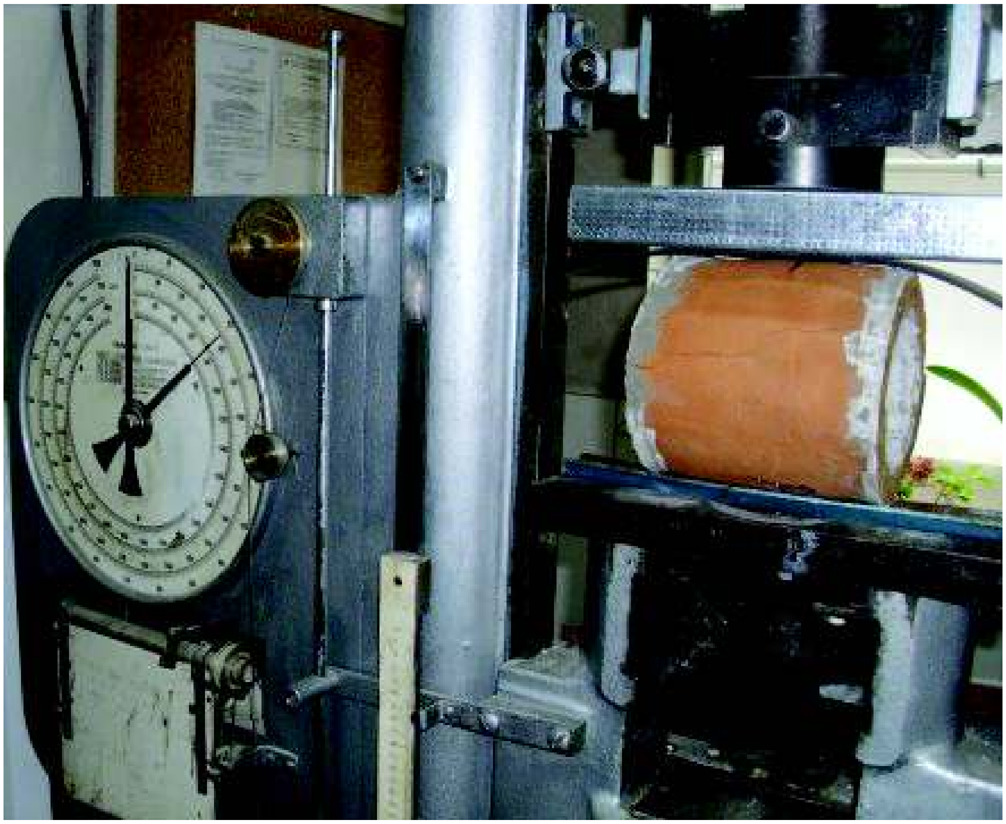


Figure 4.16: Crushing test set up

Tab. 4.6: Crushing strength

Sample	Preconditions hours	Force at failure kN/m	Acceptable force kN/m	Requirement fulfilled?
P4	≥ 66	150	≥ 40	yes
P6a	≥ 66	111	≥ 40	yes
P6b	≥ 66	111	≥ 40	yes

4.2.7 Watertightness and water high pressure

The watertightness test have to follow the standard EN 295-1, clause 5.14 and EN 295-3, clause 12. The pipes have to be filled with water, then apply a pressure of 0.5 bar for the duration of 1 hour precondition time. After another 15 minutes, the water adding should not exceed 0.7 l/m^2 of inner surface of the pipe, as shown in Figure 4.17.a. Moreover, after the watertightness is tested and the maximum water pressure that every pipe can resist is known, a pressure is applied gradually until the point that water starts leaking out of the pipe. The corresponding pressure forces is compared with the addmissible forces of the plastic pipes, and then, depending by the experimental values, their possible use is classified as shown in Table 4.7.

a.pipes under constant pressure of 0.5 bar *b. pipe P4 water leakage at 3.5 bar*

c 

d 

c pipe P3 under pressure of 1.0bar *d. pipe P4 under under 1.2 bar*

Figure 4.17: Specimens with unsatisfactory water tightness

Tab. 4.7: Watertightness and water maximum pressure

Sample	**Visual inspection of leakage pipe surface at 0.5 bar**	**Water addition l/m^2**	**Set values**	**Requirement fulfilled?**	**Maximum pressure bar**	**Use**
P3	No leakage	0.009	≤ 0.027	yes	1.0	drain and sewage
P4	No leakage	0.005	≤ 0.027	yes	3.5	sanitation system
P6a	No leakage	0.004	≤ 0.01	yes	8.0	water supply systems
P6b	No leakage	0.002	≤ 0.01	yes	11.0	water supply systems

4.2.8 Joints

The jointing points between the pipes are of crucial importance. Joints have to be done perfectly and tested to make sure there is no leakage. Moreover, sealing materials have to be made out of natural sustainable materials too. Therefore, looking back into history to see how the sealing materials evolved by years. The first sealant was discovered before 4000 BC, when a resin was used to repair clay pots. It was made out of resin coating taken from the sap of the trees, and twas developed by the Greeks to use in carpentry. The Greeks did not stop here, they also invented special sealants by mixing several components including eggs white, blood, bones, milk, cheese, vegetables and legumes. As for Romans, they used firstly a mixture of tar and beeswax to make sealing glue. Later, they developed a type of adhesive glue that still holds helmets, shields and other battle gear together since 2000 years ago. The German archaeologists [189] found that the glue was made of tar, oil of trees' bark and sap of trees. In the case of modern sealants, the first one was produced in UK and was made out of fish. Then, sealants were developed from natural rubber, bones of animals, fish, starch and milk protein (Casein). So, the natural rubber seems to be the sustainable solution, sealing gaskets interfusing with a natural glue as shown in Figure 4.18.

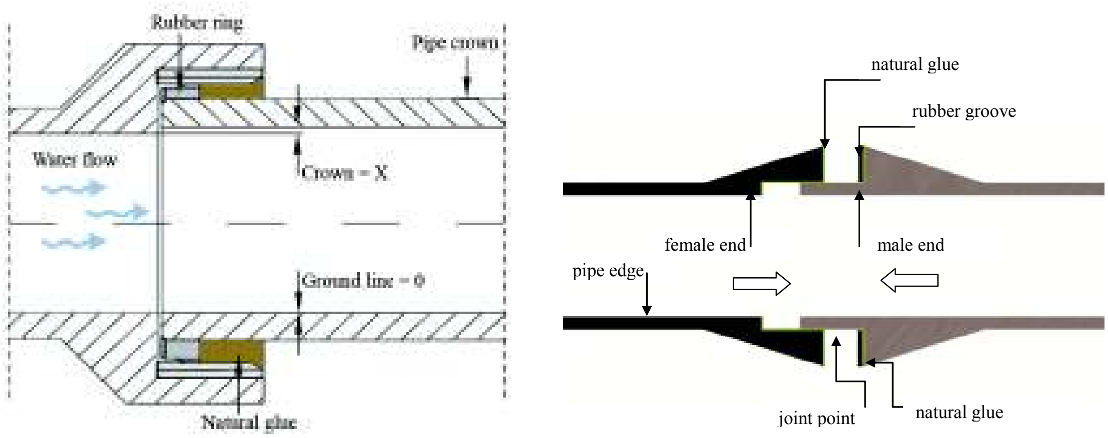


Figure 4.18: Sustainable joints of the clay pipes

4.2.9 Conclusions

First of all, as shown in Table 4.7, clay pipes may be a suitable solution for draining and sewage systems (even the unburned ones), sanitation and water supply systems. Thus, we can replace even oil based plastic pipes and vitrified clay pipes, which consume much more energy during the manufacturing process, as emphasized in Table 4.8.

Tab. 4.8: Burning levels

Temperature °C	What happends
100	any remaining atmospheric water converts to steam
220	when cooling, cristobalite suddenly shrinks.
300-800	burn-off of carbon, sulfur and orhanics.
350-800	chemically combined water driven off
573	quartz inversion occurs
900	sintering begins to occur
945	common bisque temperature
1005-1145	earthenware vitrification range
1165-1210	mid-range vitrification range
1225-1390	high-fire vitrification

Secondly, it should be noticed that if the pipes have cracks, sealing them with clay cannot repair them. In the case of micro- cracks, burning may be able to heal them. That is why the vitrified pipes are less permeable.

The next question regards the durability of the proposed clay pipes. In this respect, supplementary Böhme abrasion tests were performed. Three unburned clay and burnt samples for the mixture C8 (C7), as shown in Figure 4.19. The samples were kept 30 days to be fully dry, and then three of them were burnt until 900 °C.

Figure 4.19: Abrasion samples

The volumes were calculated and the weights were measured before starting the tests. The tests were performed using an abrasion device (see Figure 4.20) and adding the corundum with 100 µm as abrasive material for 16 cycles. The results are summarized in Table 4.9.

Figure 4.20: Abrasion Böhme testing

Tab. 4.9: Abrasion testing results

Sample	Height mm	Area mm^2	Density g/mm^3	Initial mass g	Final mass g	Mass loss	
						g	%
1	51.25	1354.399	0.001734	120.34	92.54	27.80	23.10%
2	51.84	1388.048	0.001745	125.59	90.55	35.04	27.90%
3	51.25	1461.13	0.001748	130.90	101.1	29.80	22.77%
1 burned	51.27	1376.705	0.001569	110.75	98.07	12.68	11.45%
2 burned	52.26	1409.589	0.001531	112.81	97.65	15.16	13.44%
3 burned	51.81	1438.301	0.001536	114.43	97.07	17.36	15.17%

As Aslantas mentions, such mass losses as for unburned clay are typical for concrete specimens with an age of about 7-14 days, while at 28 days typical values range between 10-15 % [190]. Considering the standard service life given in table 4.10, results that a service life of 15-20 years may be assumed for unburned clay pipes, while for the burned pipes the service life expectancy may reach even 70 years.

Tab. 4.10: Service life of pipes

Material	Service life years
vitrified clay	100-113
reinforced concrete	67-90
PVC	25-30
HDPE	25-50
cement	50
iron	50

4.3 Green historical buildings – Ideas for the fortified church Saint Michael from Cisnădioara

4.3.1 General concerns

As shown in subchapter 2.3.4.2, there is no doubt about the impact of oil over the built heritage. The direct impact results in air pollution and acid rain, while the indirect one summarizes in traffic induced vibration. Theses impacts reduce significant the service life of the buildings, accelerated deterioration leading to the prematurely loss of buildings and sculptures presenting historical or cultural values. In the same time, these buildings that lasted for hundreds of years, may give us great lessons of sustainability.

Historical buildings, like the analyzed church, have a direct energy requirement (i.e., electricity, wood, gas or oil for heating), which has an impact on the global energy use and carbon emissions. According to Nichols [191], the carbon management plan sets out a detailed strategy to reduce the carbon emissions by a set of detailed *invest to save* proposal. Upgrading the energy efficiency of the traditional buildings, including the historical ones, has a fundamentally important role to play in meeting the global targets for reducing carbon dioxide emissions. However, it is incorrect to assume that the older a building is, the less energy efficient is [192]. Many historical buildings perform well in the terms of energy efficiency. The thick walls and small windows of many vernacular buildings provide them with a high thermal mass that keeps them warm in winter and cool during summer. The natural ventilation, high ceilings and generous proportions of many historic buildings may also make energy-intensive air conditioning less necessary than in more recent structures. In addition, historical structures often were constructed with traditional, durable materials. When properly maintained, these materials can have a much longer lifespan, venting, air conditioning and lighting. It must be mentioned that even in historical buildings, using efficient technologies can reduce greenhouse gas emissions by reducing energy use [193].

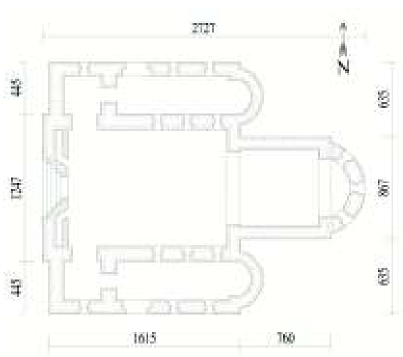
It must always be emphasized that all historical buildings represent a significant past investment of energy and materials. Demolition and replacement means not only losing all these resources embedded in the original buildings, but also the investment of yet more energy for demolition, the creation and delivery of new construction materials, the building process itself, and the disposal of the resulting waste [194].

The implications of the embodied energy and carbon to historical preservation are not well quantified yet. However, we can assume that a global contribution to the energy and carbon footprint balances of 10 % is quite significant. While embodied energy and carbon are only part of the picture, they represent tangible measurements of the value of buildings as an existing resource and how preservation contributes to a sustainable future.

Historical buildings have given us a lot of lessons in the sustainable domains, through the material and the energy efficiency. These learned lessons may be a good step in the way to a sustainable rehabilitation, when we use the new technology. The new elements which will be applied on the buildings should not visually dominate the historical building. Junctions between the historical fabric and any new elements should be carefully designed in order to avoid damage, and there should be a clear and elegant distinction between the new and the old. Respect should be given to the local distinctiveness in material, design and construction detailing. Intervention and new works should not damage the important historical fabric and features, or to promote future decay. When carrying out interventions, the materials, design and detailing of the intervention should be compatible with the historical fabric and should not damage its structural integrity and performance.

4.3.2 Brief description of the church

The fortified church Saint Michael (see Figure 4.21) from Cisnădioara is one of the oldest Romanesque styles in Transylvania, Romania. It is located on the top of a hill called The Fortress Hill. It was built by saxons in the XIIth century, and is characterized by a short basilica with three naves - the central nave surrounded by two side aisles separated by semi-circular arches, square choir, main apse and the side apses. The total length of the church is 25 m, 20 m in width and a maximum height of 16 m.



a. plan

b. south façade

Figure 4.21: The church Saint Michael - Cisnădioara

The central nave is higher than the sides, covered by a wooden ceiling and separated from the two side aisles by a single pair of square pillars supporting the arches.

The choir is covered by a cross vault and the choir apse by semi-dome. Lateral naves end to the east with one apse also covered by a semi-dome.

The altar was removed, but still keeps its fragment of central carved niche that dates from 1425. It depicts the Virgin Mary, which nowadays is exposed at the Brukenthal Museum. In addition, many parts of the church were painted with consecration crosses.

The interior lighting is provided by narrow semi-circular windows and ensures the veneration to the internal atmosphere of the church. The entire church was built of rough stone masonry. The church passed through three stages: The choir had been built first, and then it was proven by link masonry to the eastern part of lateral walls, with calcifying plaster that overlap deeply into the wall. On the choir's walls it can be seen plaster, while on the walls of the three naves can be seen only gneisses and mica. In the third stage, it was built the second floor of the north tower. The oval fortified enclosure was built at the same time with the church. The most interesting part is that the church has not undergone any architectural changes over the ages; what we see today it is the same view dating 800 years ago. The only intervention was done after 1860, when a guard house made of the same rough stone was added. The western portal of the basilica is a unique Romanesque element for the Romanesque architecture in Transylvania. The decor consists of 4 portal frames. From the ionic bases rise four pillars that support cubic capitals. On the sides of the portal, decoration continues with four blind arches. Only the capitals are carved from limestone, the rest is made of sandstone [195].

4.3.3 The impact of pollution

The structure of the church consists of bearing walls made of brutal masonry stone, while portal entrance is made up of sandstone and limestone. Acid precipitations affected the stone by dissolution and alteration. When sulphurous, sulphuric and nitric acids from the polluted air reacted with the calcite in stone, the calcite dissolves. In the exposed areas of building and portal statues, we notice roughened surfaces, removal of material and loss of carved details. The stone surface material may be lost all over or only in spots that are more reactive [196]. However, sheltered areas on limestone and sandstone buildings and monuments show blackened crusts that have spalled at the surface locally, revealing the crumbling stone beneath. This black crust is primarily composed of gypsum. Gypsum is soluble in water; although it can form anywhere on carbonate stone surfaces that are exposed to sulphur dioxide gas (SO_2). Usually is washed away by rain, but remains on the protected surfaces that are not directly exposed. Gypsum is white, but the crystals form networks that trap particles of dirt and pollutants, so the crust looks black as shown in Figure 4.22.

Figure 4.22: The effect of acid rain over churches stone

Acid rain can damage rocks, such as limestone and sandstone that contain large amounts of calcium carbonate. Acids in the rain react with the calcium compounds in the stones to create gypsum, which then flakes off [197]:

$$CaCO_3 + H_2SO_4 \leftrightarrow CaSO_4 + CO_2 + H_2O \tag{4.1}$$

The effects are seen on the portal, where acid rains caused the black crusts blister and spalling of the superficial layer, revealing the crumbling stone [198] [199]. The most important gas which leads to the acidification is sulphur dioxide SO_2. At the global scale, annually 70 tons of SO_2 come from the fossil fuel combustion and industry, 2.8 tons are generated by the wildfires and 7–8 tons are erupted by the volcanoes [200].

4.3.4 Photovoltaic panels and re-use of water

Many historic buildings were designed with passive systems before the invention of electric lighting and powered heating and cooling. As a result, these buildings were designed to take advantage of the natural daylight, ventilation, and solar orientation - the very characteristics that are being considered as *sustainable design* attributes today. Required options that respect the traditional nature of these buildings and reducing our carbon footprint today require *a little intervention to increase the efficiency and decrease* *emissions*. Even if surprisingly, applying photovoltaic panels to improve heating and lighting of historical buildings is a valuable solution. More than 90 % of the historical tile covers are severly damaged and need replacement. Current rehabilitation practices presume their replacement by similar new products. However, todays technology permit the production of photovoltaic cells in various shapes and colors. Personalized cells are already on the market. This technology gives us a wide area to apply a renewable energy in historical building as illustrated in Figure 4.23, without destroying the historical values.

Figure 4.23: Comparison between a common and personalized solar system

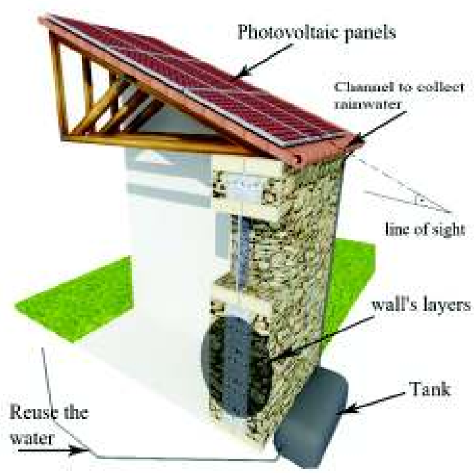


Figure 4.24: Energy efficiency by implementing solar energy and re-use of water

As well as the above technology helps in order to reduce the carbon footprint, the use and re-use of the rain water by collecting it, and perhaps even filtering it, in tanks located underground is also important to supply the church with it for maintenance and cleaning works. The pipes will be hidden and at the same time will work as a barrier to hide the photovoltaic panels, as shown in Figure 4.24.

4.3.5 Environmental balance and conclusions

For countries like Romania, characterized by a temperate climate, the temperature changes from cold in winter to hot in summer. Thus, the high thermal mass walls are the solution for keeping cold air out in winter and warm air out in summer. Stone, brick and adobe are the most effective materials. These materials are also traditional building materials in many parts of the world. Therefore, it is not surprising that old building may be energy efficient. On the other hand, to keep the building in almost constant interior temperature is important not only for the comfort of the users, but also for the preservation of the fabric of the building.

Tab. 4.11: Physical and thermal properties of building and insulation materials

Material	**Density** kg/m^3	**Thermal conductivity W/mK**	**Specific heat J/kgK**
Structural materials			
solid concrete brick	1600-200	1.2-1.4	880
hollow concrete brick	1140	1.6	880
sand brick	1800	1.59	835
hollow adobe bricks	1000-1300	0.35-0.45	1000
hollow clay bricks	1850-2000	0.55-0.65	835
solid clay bricks	1950	1.0	829
pumice bricks	985	0.33	850
limestone	1200	0.6	840
sandstone	2260	0.97	840
sand	1520	0.33	800
gypsum	1200	0.43	1080
concrete	2300	0.93	653
reinforced Concrete	2500	1.74	765
Cladding materials			
marble	2600	2.6	880
granite	2800	3.5	900
finishes mortar	2100	0.75	835
wood	350-750	0.11-0.16	2000
iron	7200-7700	45-60	500
aluminum	2740	221	895
Insulation materials			
foam concrete	450-515	0.21-0.18	1000
light weight concrete	800	0.275	1000
soliton	350-450	0.09-0.12	550
polystyrene	15-30	0.03-0.037	835
extruded polystyrene	25	0.03	835
rock wool	140	0.04	835
glass wool	52	0.038	660

Table 4.11 presents the thermal characteristics of the common used materials. The thermal resistance of the envelope elements is given by:

$$R = R_{is} + \sum_{j=1}^{n} \frac{d_j}{\lambda_j} + R_{es} \tag{4.2}$$

where
R – Thermal resistance [m^2K/W];
$R_{is}=1/\alpha_i$ - Thermal resistance of the interior surface [m^2K/W];
α_i - Heat transfer coefficient of the interior surface (equal with 8);
d_j - Wall layer thickness [m];
λ - Thermal conductivity (see Table 4.1);
$R_{es}=1/\alpha_e$ - Thermal resistance of the exterior surface [m^2K/W];
α_e - Heat transfer coefficient of the exterior surface (equal with 24).

The details of the church's envelope are presented in Figures 4.25. The timber one glass sheet windows and doors were considered with a thermal resistance of 0.17 m^2K/W, and 0.25 m^2K/W respectively. Thermal resistances of the roof tiles cover, stone domes and ground floor are 1.811 m^2K/W, 0.871 m^2K/W and 0.363 m^2K/W. Table 4.12 emphasizes the thermal resistance of the church's wall in comparison with actual solutions. The installed power for lightening is 6.2 kW and heating is ensured by a woodstove.

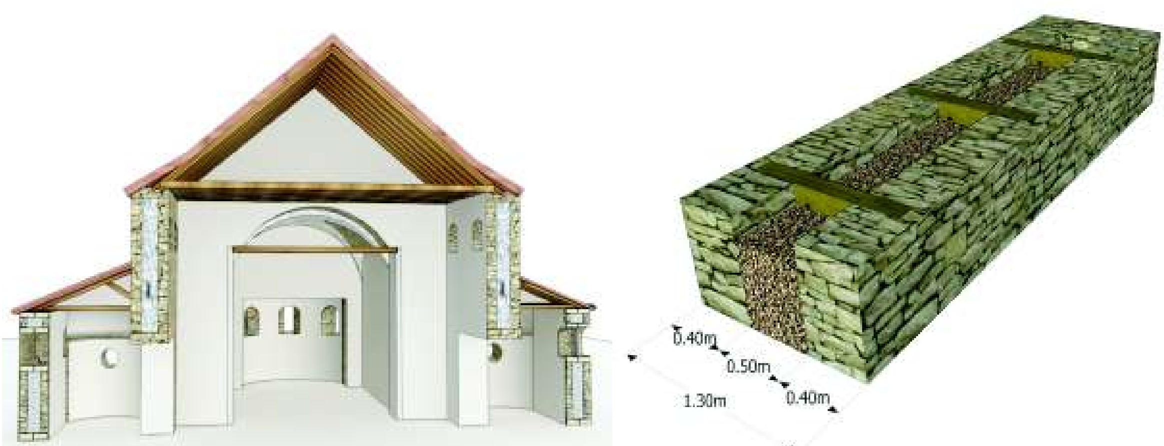


Figure 4.25: Envelope details

Energy balance analyses were performed according to MC 001 parts 1-3 [201]. The results are presented in Table 4.13, and compared with some reference indices.

Tab. 4.12: Thermal resistance of the church's wall and actual solutions

Wall stratification	**Thermal resistance m^2K/W**
limestone 40 cm + earth 50 cm + limestone 40 cm	*3.17*
plaster 2 cm + aerated concrete 35 cm + plaster 2 cm	1.60
plaster 2 cm + aerated concrete 35 cm + plaster 2 cm + pulystyrene 10 cm	3.87
plaster 2 cm + brick 37^5 cm + plaster 2 cm	0.68
plaster 2 cm + brick 37^5 cm + plaster 2 cm + pulystyrene 15 cm	3.68

Tab. 4.13: Environmental balance

Reference	**Specific primary energy consumption kWh/m^2year**		**Index of the equivalent CO_2 emission kg/m^2year**	
	heating	**total**	**heating**	**total**
actual church	155	205	28.03	58.15
rehabilitated church	50	72	9.045	22.30
average church [202]	145-156	199-213	26.23-28.22	58.75-62.55
ordinary house	120-250	200-365	21.7-45.22	69.89-114.49
efficient house	50-100	130-215	9.04-18	57.23-87.36
passive house	<12	<15	<2.17	<3.97

According to U.S Environmental protection Energy: the coefficient of CO_2 emission = 0.1809 kg/ kWh for heating by gas; and 0.60237 kg/ kWh for electricity use. Every 1 m^2 of photovoltaic cells generates 200 W/h of energy. Thus, by installing 280 m^2 of photovoltaic cells (the available area is 280 m^2), the electricity produced is 56 kWh. When the cells work approximately 3 hour per day, will generate 168 kwh, this means at least 133 kwh/m^2 year. In this way, the energy consumption will be reduced from 205 kWh/m^2 to 72 kWh/m^2 preventing 36 kg/m^2year of CO_2 emissions.

Knowledge that, about 25 % of the heat is lost through the roof, in comparison with 35 % through the walls, 15 % through the floor and 25 % windows. But the cost of insulating the roof is usually much lower than the cost of solid wall insulation. However, installing the photovoltaic panels form an insolation layer that increases the thermal conductivity. The initial cost of a costumaized (i.e., with old tiles apearance) photovoltaic cells is about 42,000 Euros, while the annual savings are aproximately 6,100 Euros, leading to an amortization in maximum 7 years.

4.4 Sustainable urban fabric: climate control (case of studies new cities in Middle East)

Starting any project or study, in any country, cannot be done without understanding its climatic and environmental nature, as well as social behavior.

A desert is a barren area of land, where little precipitation occurs and consequently living conditions are hostile for biological and animal life. The lack of vegetation exposes the unprotected surface of the ground to the processes of denudation. About one third of the land surface of the world is arid or semi-arid. This includes many deserts from Africa, Asia, Australia and North America (Figure 4.26). The present research will focus on the African part and Egypt, as a case of study.

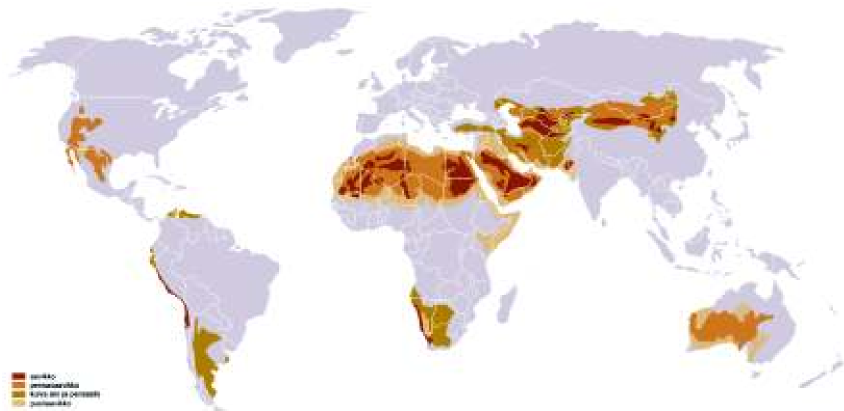


Fig. 4.26: A map showing the extension of the desert in the world

4.4.1 Climatic factor

The desert climate is generally dry. The temperatures are hot or very hot in summer days, and warm or mild in winter days, but warm in summer nights and cool in winter nights.

The prevailing winds in Egypt are the north and west north winds. These winds are dry winds and considered a desirable one, because have as effect the decrease of the temperature as well as the humidity.

A phenomenon of Egypt climate is the hot spring winds that blow across the country. These winds blow from south and east south, reach high velocities and carry great quantities of sand and dust from the deserts. These winds can rise the temperature as much as 20 °C in two hours. The winds blow intermittently and may continue for days, cause illness of people and animals, harm crops, and occasionally damage houses and infrastructure. So, the research proposes a sustainable project and fitted to the available resources (i.e., a social affordable residential complex).

4.4.2 Sun study

The relation between the urban fabric and the solar impacts will analyze and simulated (using the Autodesk computer software Ecotect Analysis 2011) for three cases:

- Cluster of the old city compact fabric (Figure 4.27.a);
- Common modern layout fabric (Figure 4.27.b);
- New innovative proposal, a fabric derived from the combination of the above structures (Figure 4.27.c).

The proposal starts from the idea that the old compact fabric is based on the courtyard and a density that reduces the area exposed to the sun. Through the proposal the courtyard is enlarged to the so called cluster lung, which becomes a green area with shadows controlled by the height of the buildings, vegetation and orientation.

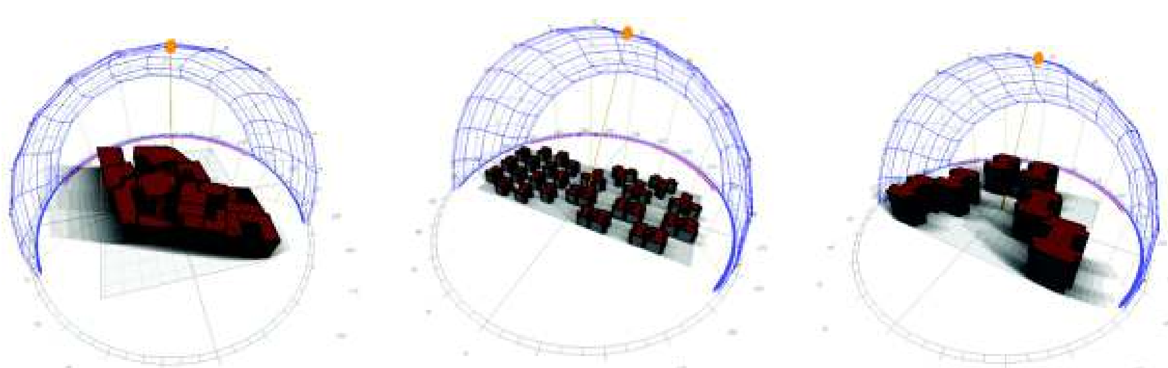
The entrance parameters are for 100 inhabitants:

- compact fabric: population density 0.0216 persons/m^2, covered area 4,620 m^2;
- modern fabric: population density 0.0370 persons/m^2, covered area 2,703 m^2;
- proposal:population density 0.0490 persons/m^2, covered area 2,041 m^2.

4.4.2.1 Shadow studding

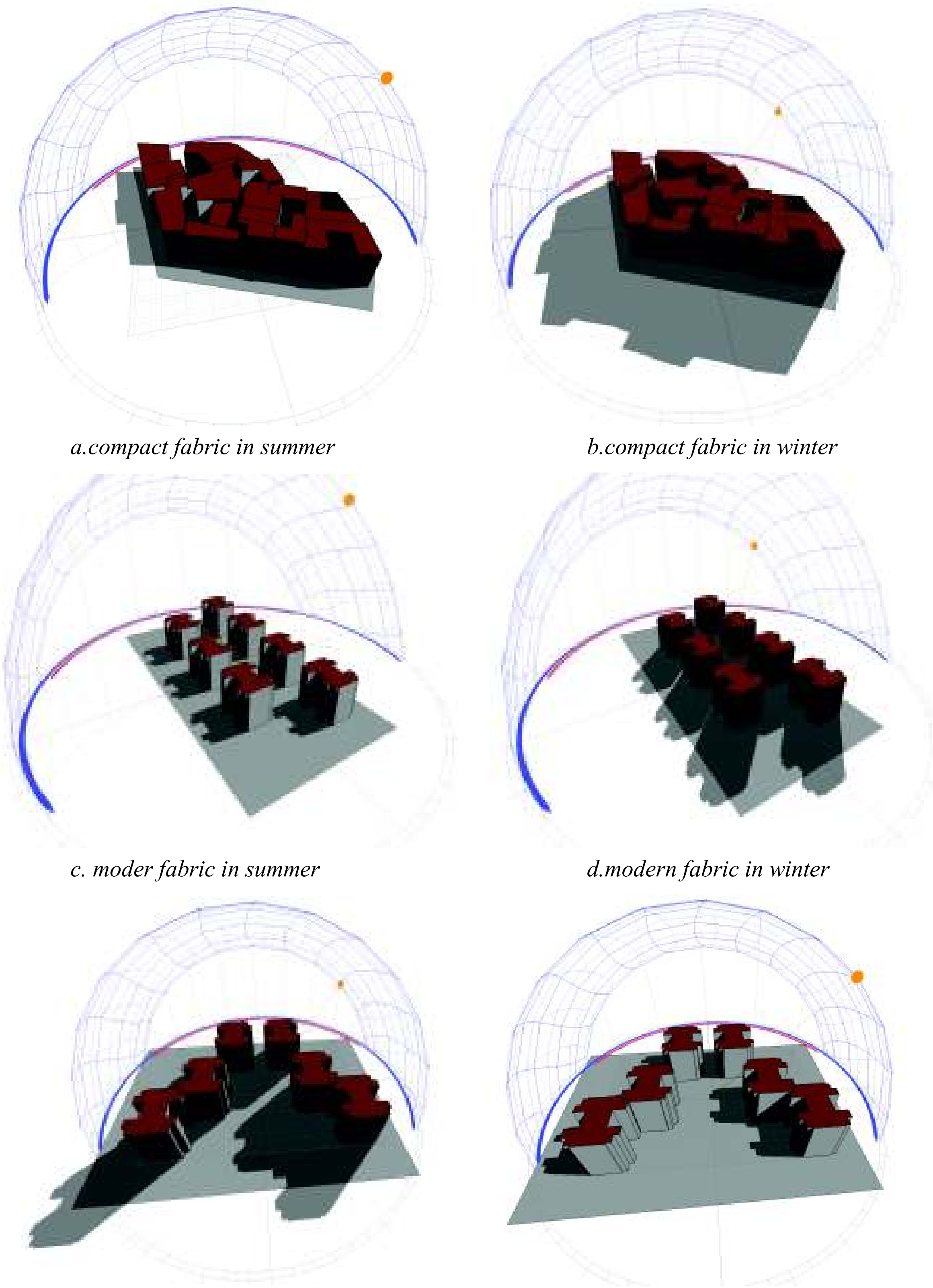
In order to see the impact of the fabric pattern over the shaded areas, 3D models were assembled with the *Revit CAD application* and then test them in Ecotect Analysis 2011 module. The simulation of the shadow was based on the weather of the Middle East as shown in Figure 4.27, all control parameters being in the database of the application.

Computer animated simulations reveal clearly that the most shaded area appears at the old compact fabric. In comparison with the proposed fabric, the modern fabric implies more shadow during winter, which is not desirable. However, the proposal is more balanced (see Figure 4.28 and Table 4.14) and the lung of the cluster is almost completely shaded which cool the internal atmosphere. In addition the planted trees around the clusters increase the shaded areas.



a.compact fabric *b. modern layout fabric* *c proposed fabric*

Figure 4.27: Shading models based on the fabric pattern



a.compact fabric in summer

b.compact fabric in winter

c. moder fabric in summer

d.modern fabric in winter

e. proposed fabric in summer

f. proposed fabric in winter

Figure 4.28: Specific shading patterns for summer and winter

Tab. 4.14: Average monthly shaded areas (in percentage related to the total area)

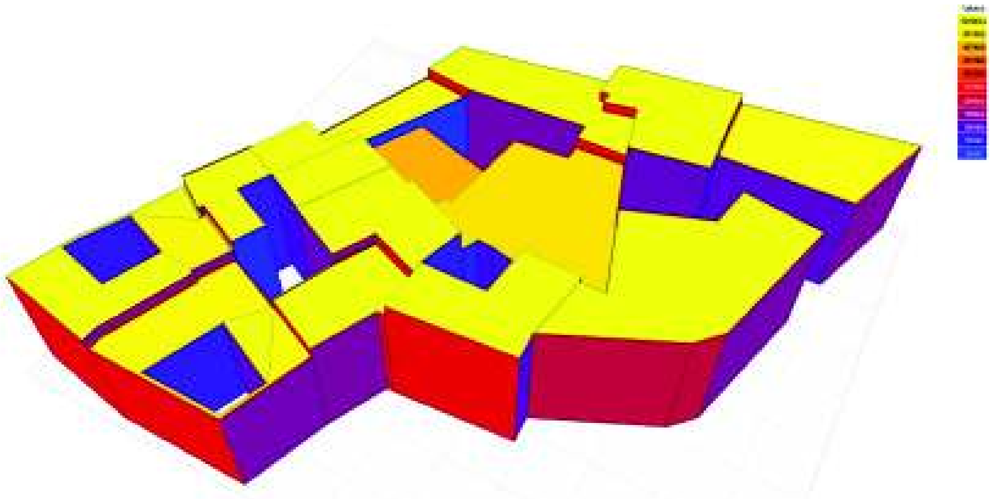
Month	Old fabric	Modern fabric	Proposed fabric
Jan	95 %	65 %	60 %
Feb	94 %	55 %	55 %
Mar	92 %	46 %	50 %
Apr	90 %	38 %	45 %
May	85 %	30 %	38 %
Jun	75 %	24 %	34 %
Jul	70 %	20 %	30 %
Aug	78 %	25 %	35 %
Sep	85 %	32 %	42 %
Oct	90 %	42 %	48 %
Nov	92 %	55 %	55 %
Dec	96 %	65 %	63 %

4.4.2.2 Sun radiation

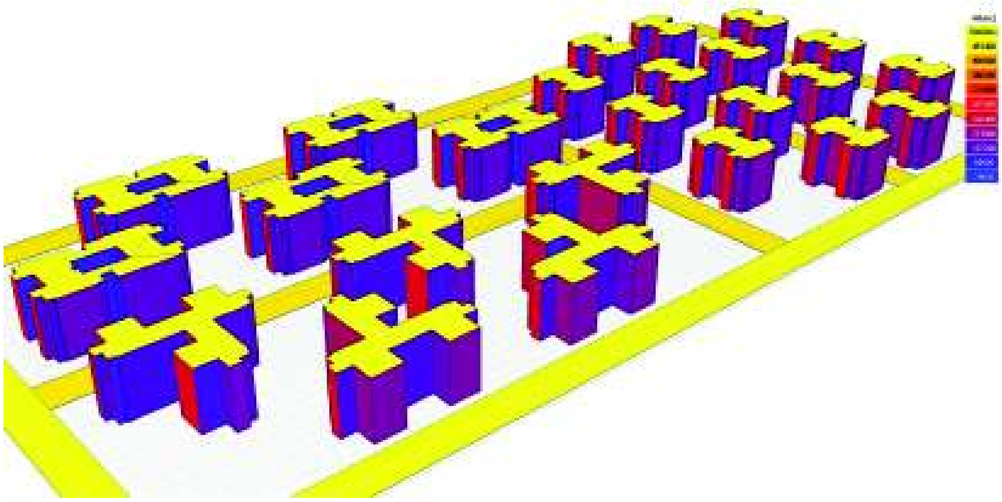
The solar radiation, simulated with the same software, in summer and winter is emphasized in Figures 4.29 and 4.30 at 15:00 o'clock.

The results show that the modern pattern is the most exposed to the direct solar beams, while the compact fabric is the best for summer season. However, the proposed pattern is the most balanced, being good both for summer and winter. Looking at the proposal pattern, it can be noticed that the south facades receive a higher amount of solar beams then the east and west facades. In order to open the windows, adequate solutions have to be adopted for each façade in order avoid the exposure to direct solar beams. Thus, different sunshades were added according to the facades direction, as illustrated in Figure 4.31.

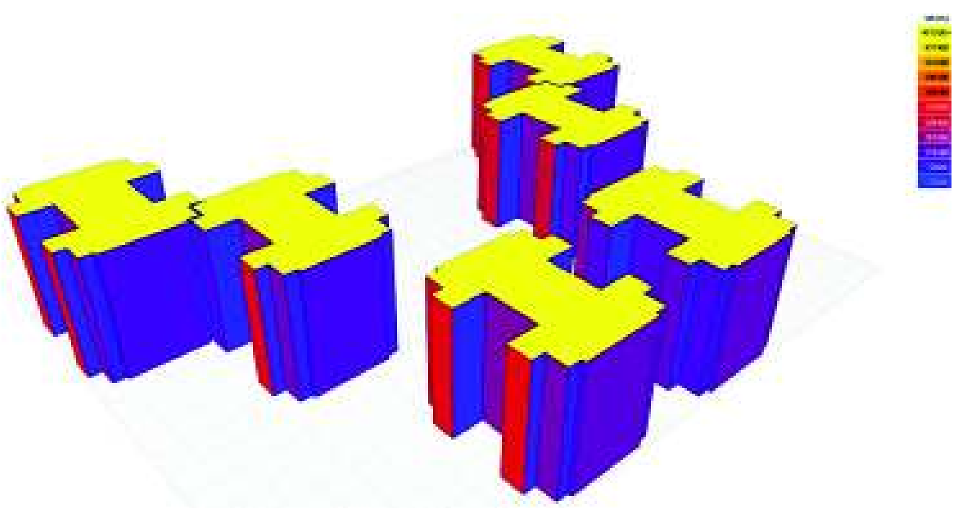
Next, a single building is emphasized to illustrate the difference between the treated façades and the untreated ones (see Figures .4.32 - 4.33). By comparing the results we can clearly infer that the suitable sunshades have diminished the solar beams received and hence to reduce the energy used for the service of the building. Another observation is that the roof is a larger receiver of solar beams then the external walls, increasing spectacular the interior temperature of the upper part of the building. Therefore, these walls and roof should be insulated by using eco-friendly insulation materials and methods. Whereas old pattern of walls used to consist of two layers of stones enclose between them layer of soil, sand and broken brick gave those buildings good thermal and acoustics insulation as shown down in Figure 4.34; for the new buildings the same procedures can be applied by designing multilayer walls, respectively 2 layers of reinforced concrete with a gap between filled with eco-friendly insulation materials (e.g., perlite, glass wool, cellulose waste etc.), as shown in Figures 4.35-4.37.(see Annex A)



a.compact fabric

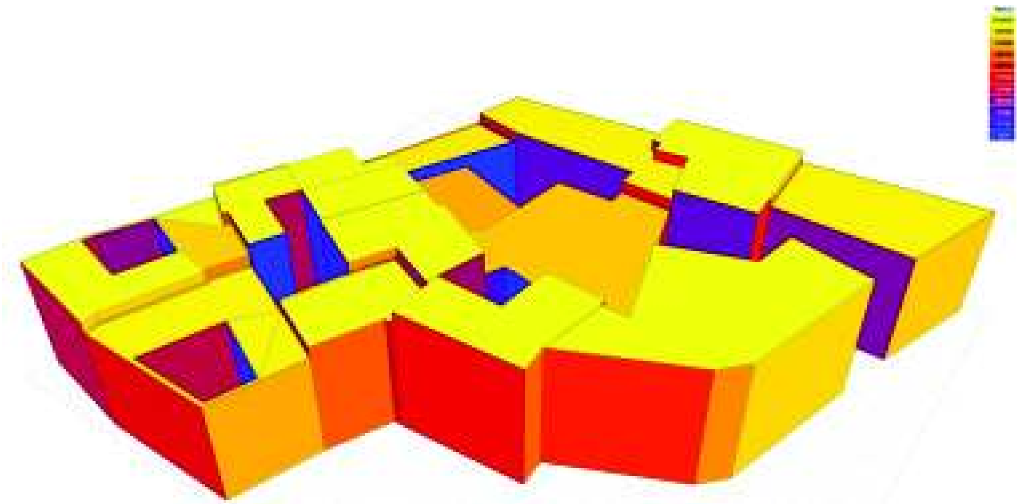


b. modern layout fabric

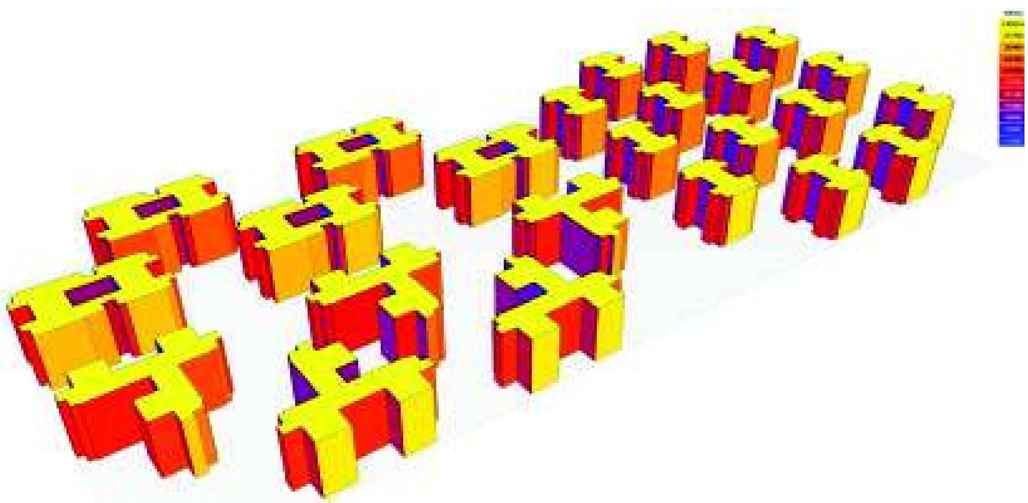


c proposed fabric

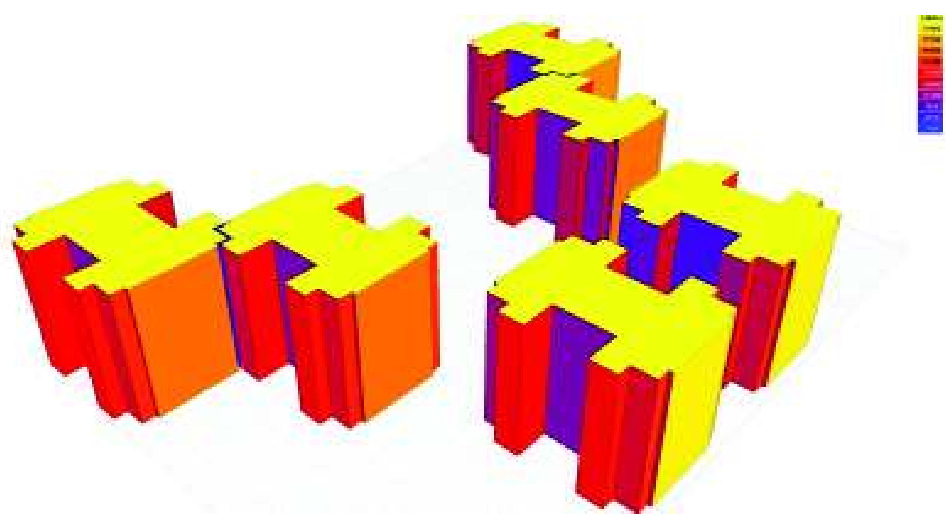
Fig. 4.29: Solar radiation over buildings in july at 3:00 PM



a.compact fabric

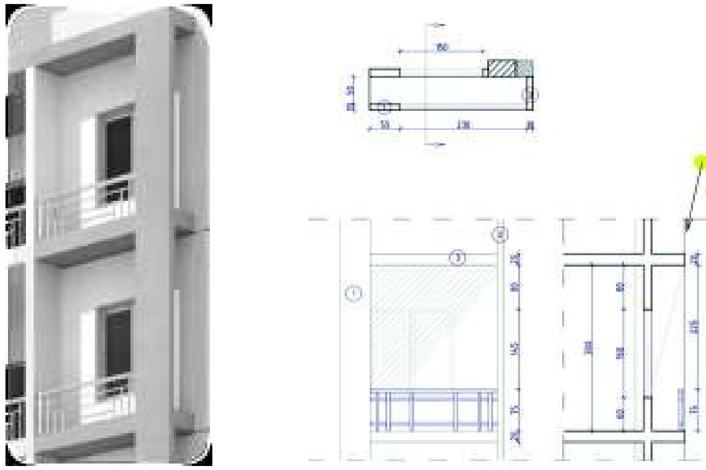


b. modern layout fabric

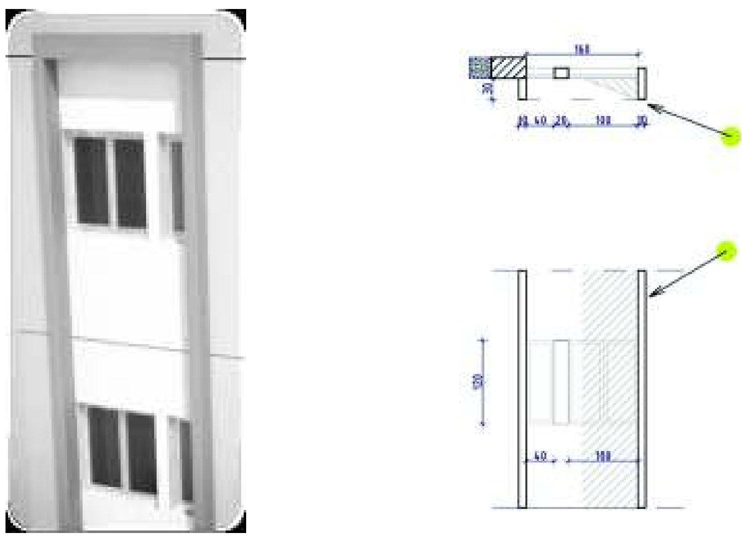


c proposed fabric

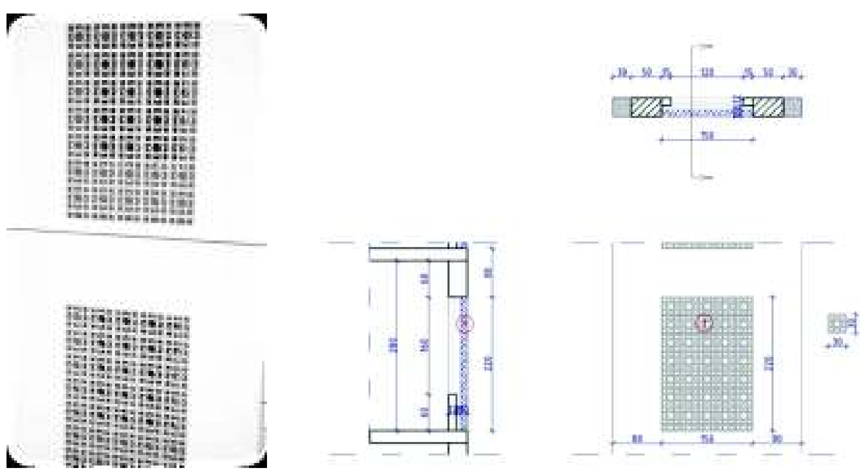
Figure 4.30: Solar radiation over buildings in january at 3:00 PM



a.the sunshade used on the south façade

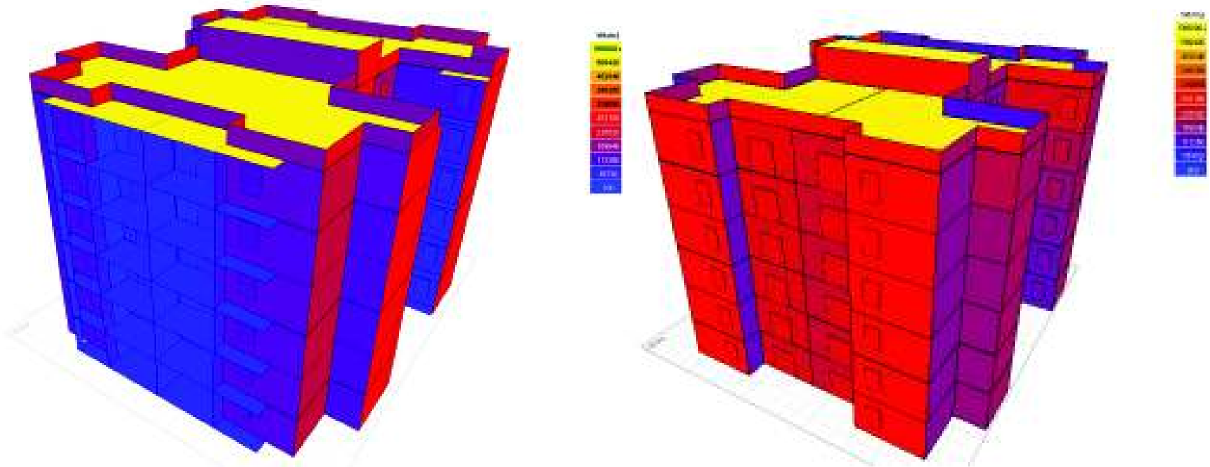


b. the sunshade used on the east and west façades



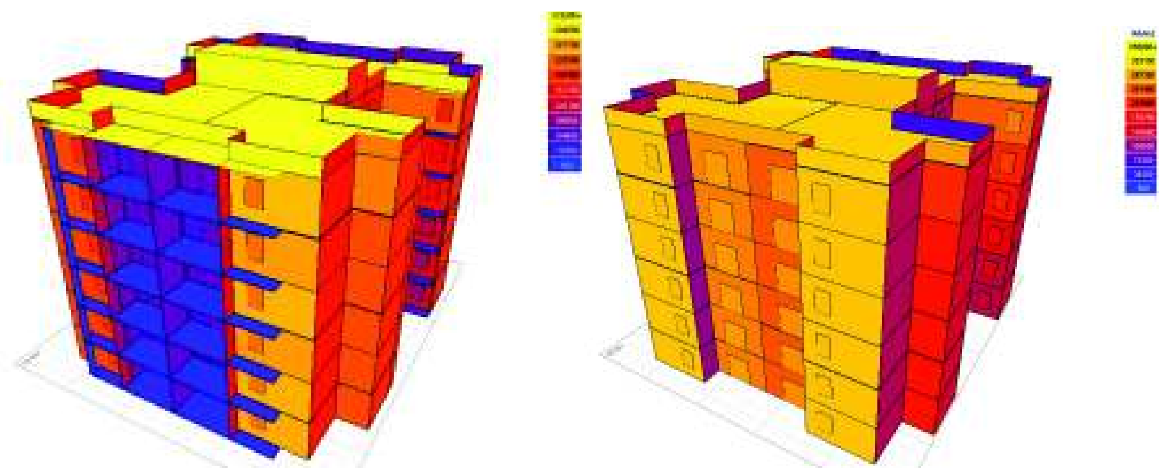
c grid gaps wall to avoid the directed solar beams for the staircase windows

Figure 4.31: Elements to manipulate the sun shades



a. *treated façades* b. *untreated façades*

Figure 4.32: Solar radiation in summer time after adding the sunshades



a. *treated façades* b. *untreated façades*

Figure 4.33: Solar radiation in winter time after adding the sunshades

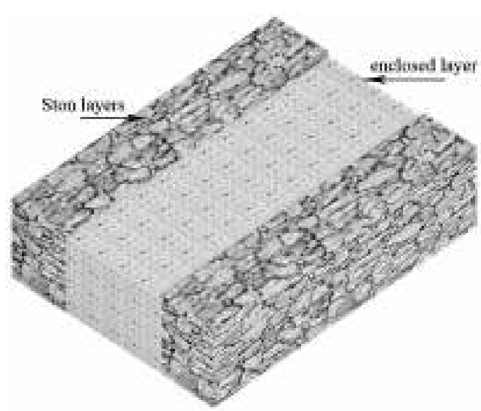
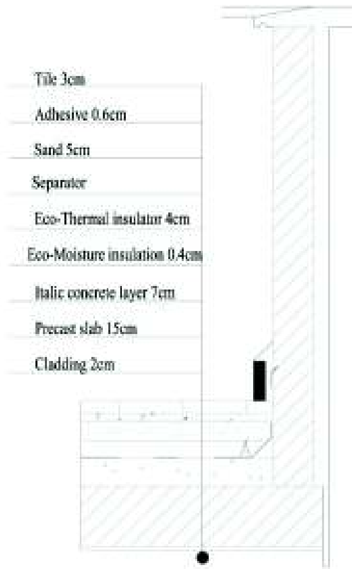
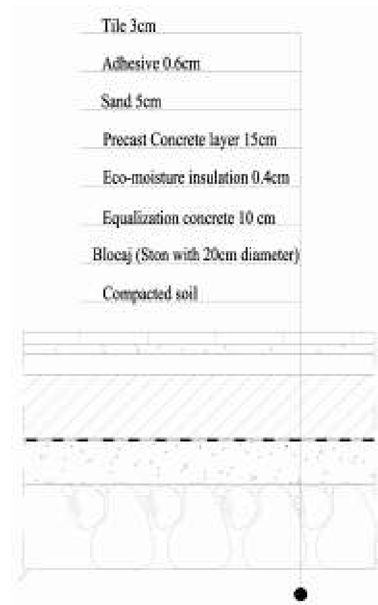


Figure 4.34: Cross-section through the old specific wall

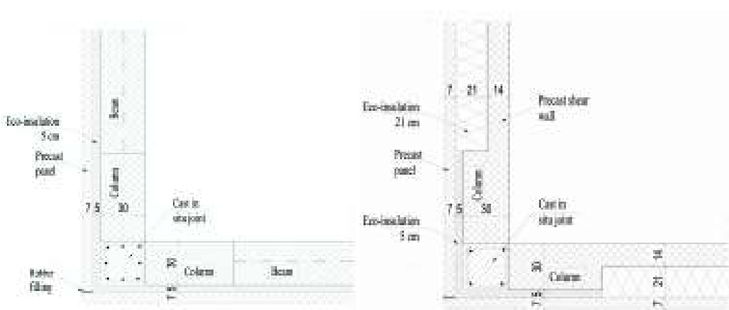


a. roof insulation

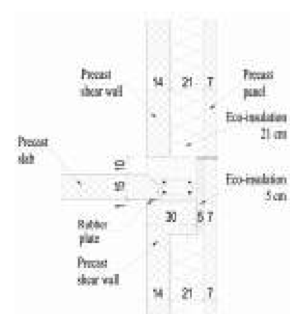


b. ground slab insulation

Figure 4.35: Top slabs and bottom slabs insulation



a. insulation of walls



b. insulation of current slabs

Figure 4.36: Walls and internediate slabs insulation

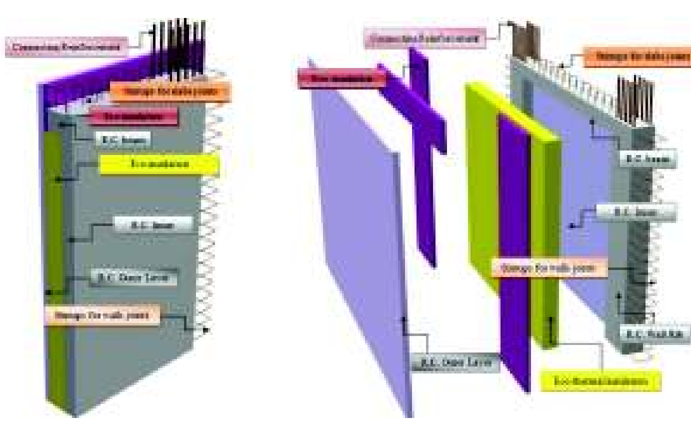
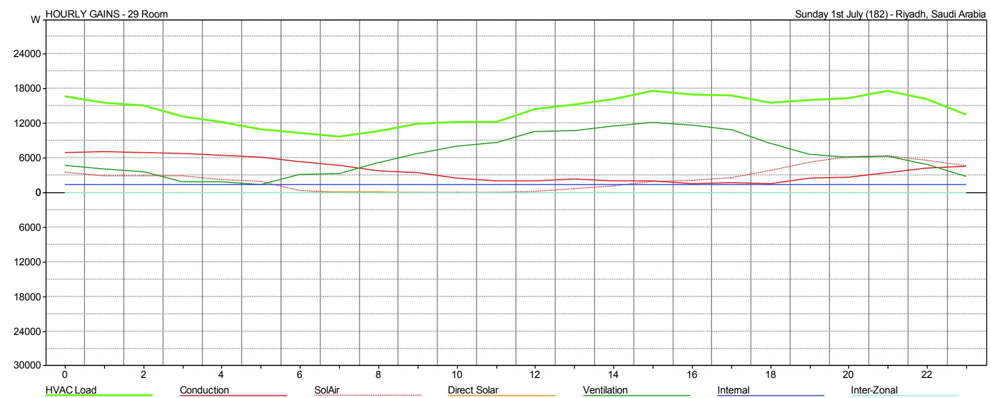


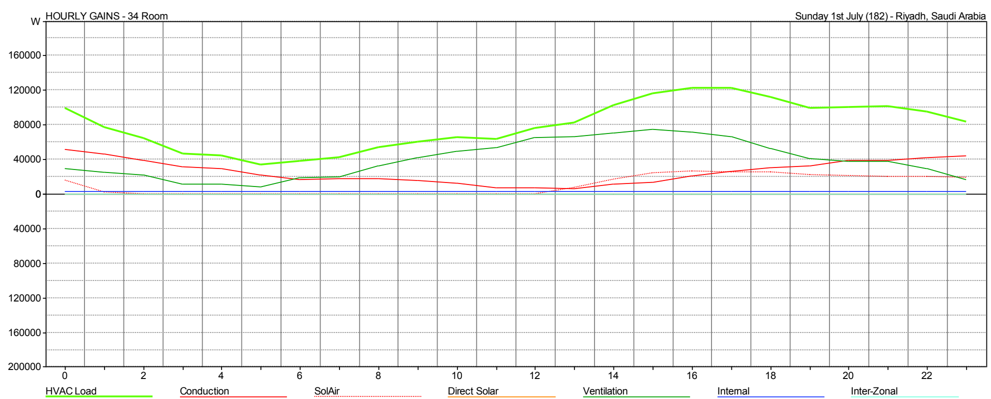
Figure 4.37: 3D model emphasizing the insulation solution of the vertical elements

4.4.3 Thermal analysis

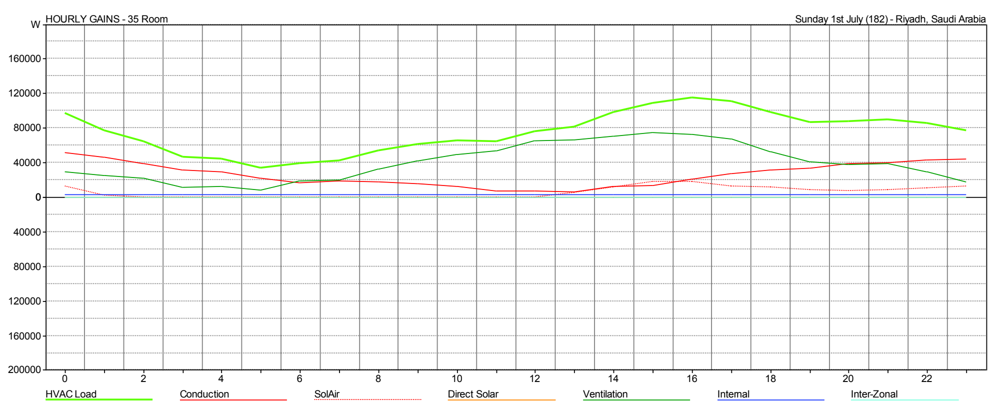
Based on shaded faces and solar radiation, the thermal properties for a chosen typical building of each fabric is next analyzed. All particular and common data regarding the walls, roofs and floors types and layers, the occupancy of space, weather features, and zonal properties has been considered:



a. compact fabric

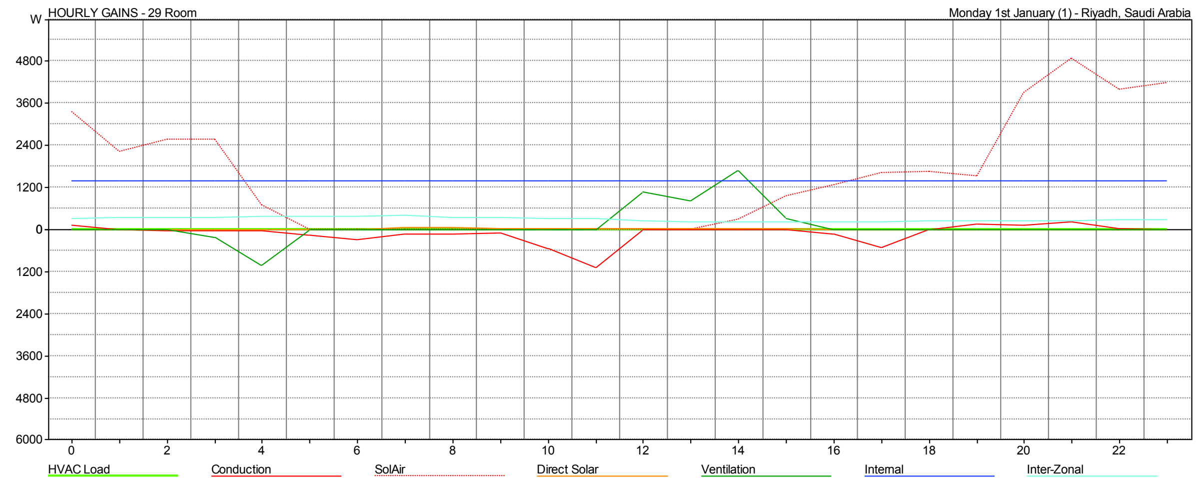


b. modern fabric

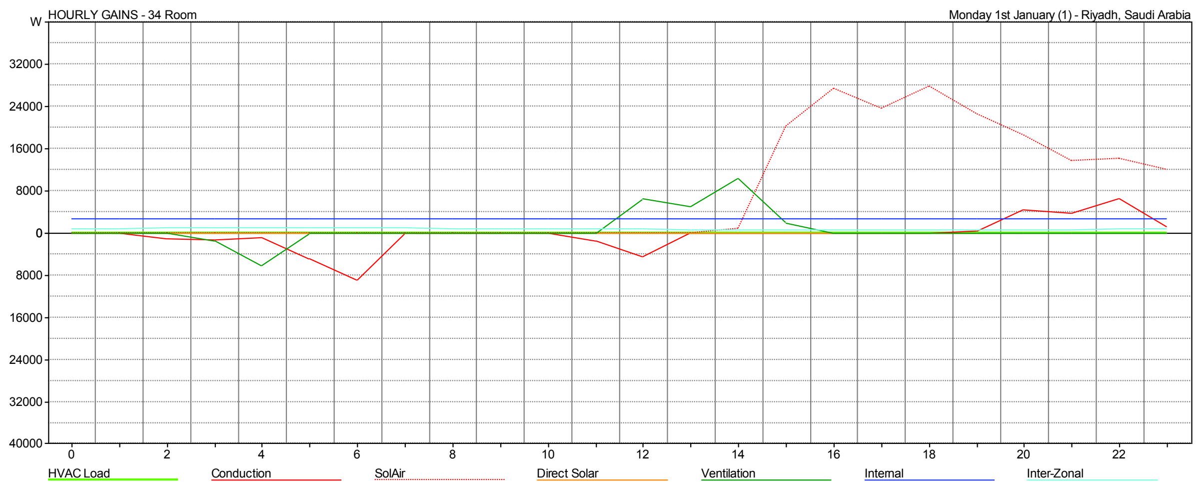


c proposed fabric

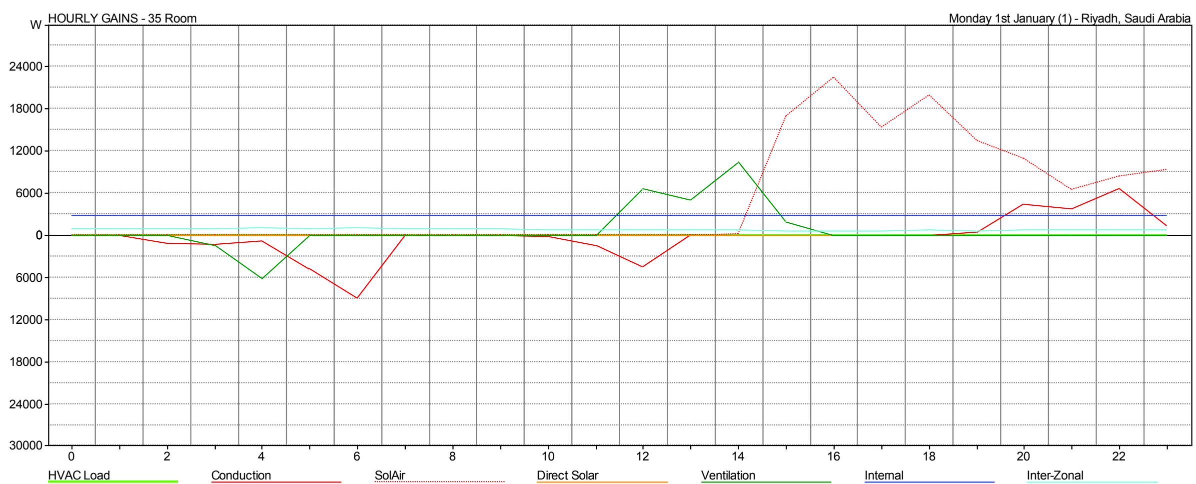
Figure 4.38: Hourly heat loads in summer days of july



a. compact fabric



b. modern fabric



c proposed fabric

Figure 4.39: Hourly heat loads in winter days of january

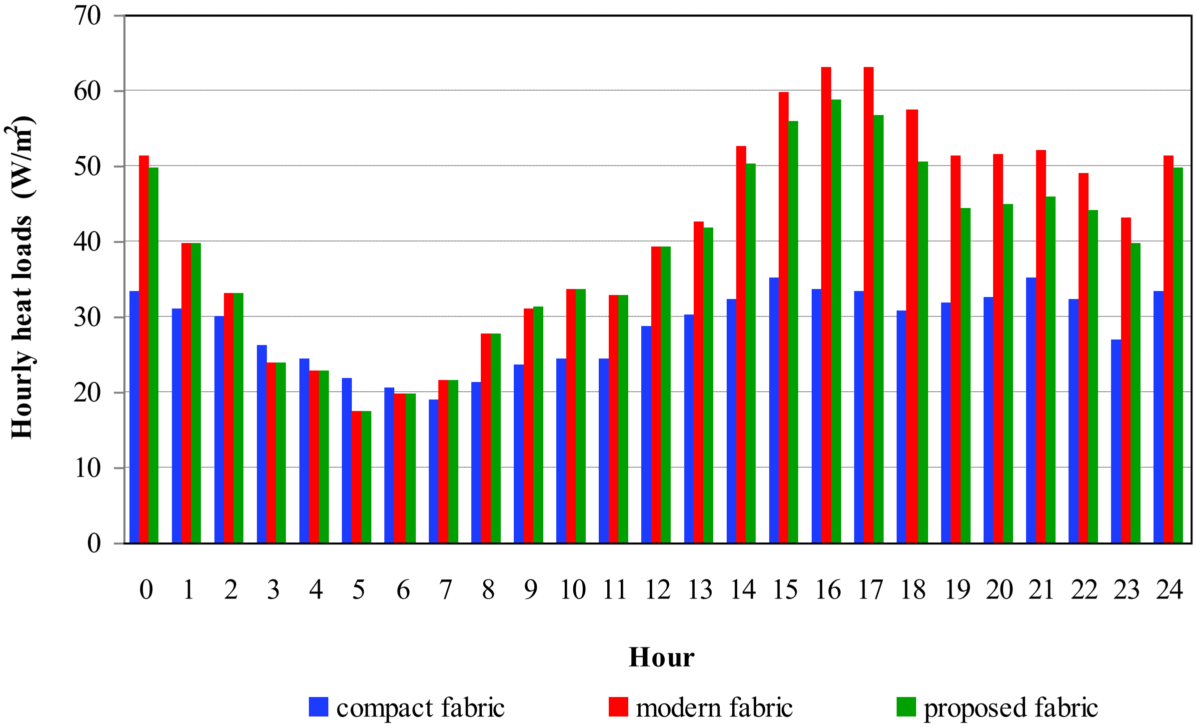


Figure 4.40: Hourly gains in summer day of july

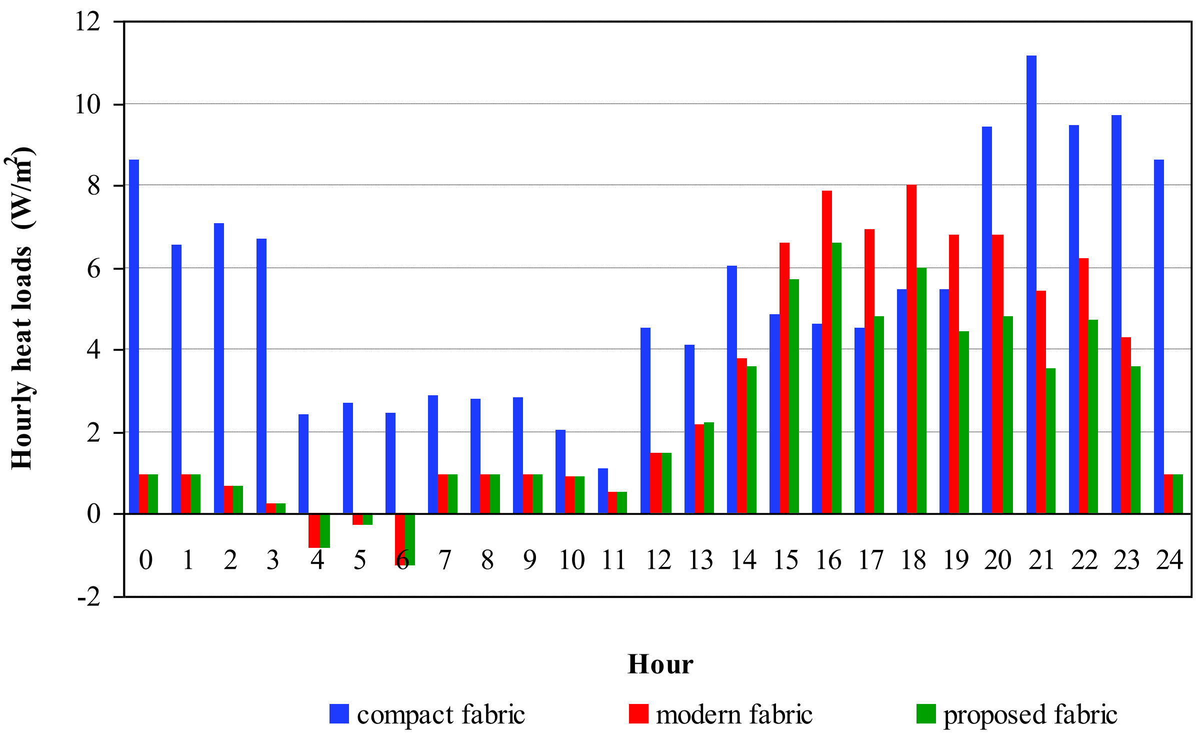


Figure 4.41: Hourly gains and losses in winter day of january

The results prove clearly the importance of the urban fabric for the energy consumption. While the old, compact one has the lowest heat gain, the modern fabric has the highest gain in summer days. Moreover, from summer to winter the difference of the heat gain through the day for the old compact fabric is relatively reduced. Even considering the solar exposure, the proposed pattern presents the most balanced variation. As shown in Figures 4.42 and 4.43 present the cluster layout to save energy by using also trees close to the buildings on the south and west directions to increase the shaded area.

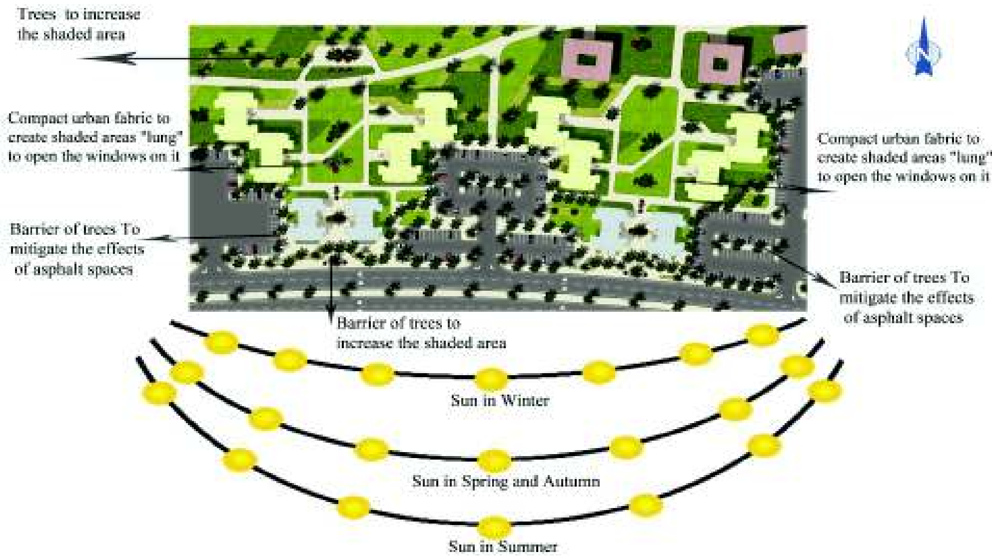


Figure 4.42: Proposed cluster layout and sun analysis

a. section east-west in the cluster illustrating the shade on the façades

b. section north-south in the cluster illustrating the compact urban fabric

Figure 4.43: Supplementary shadowing by trees

4.4.4 Wind study

In Middle East, the desirable wind blows from north and west-north. Sometimes this wind comes dry, and in this case the green areas have to increase its humidity. when it comes from north pole is cold and the same green areas have do diminish its speed. However, every zone has its character of prevailing wind, generally the north, west and west-north are the directions of a desirable wind, where the east and south is the direction of the undesirable ones.

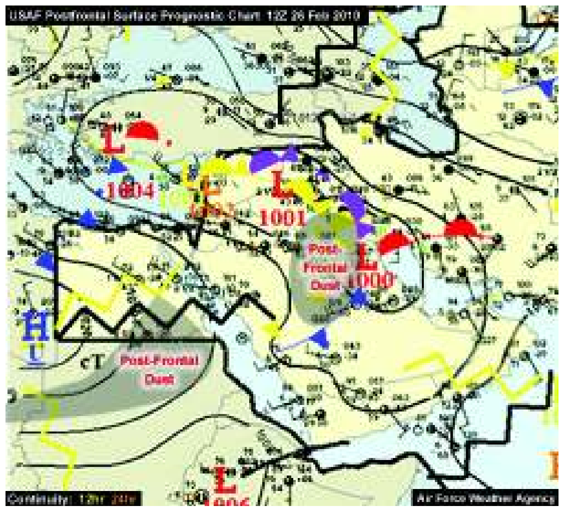


Figure 4.44: Forecast map illustrated the prevailing wind in Middle East

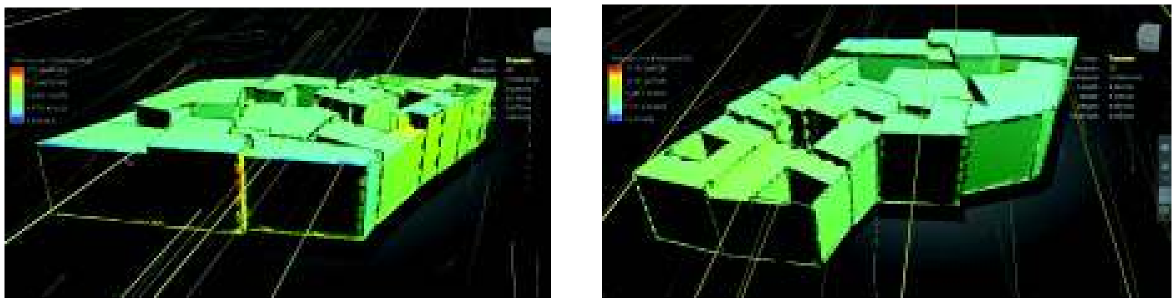
The effect of wind over the urban plan layout has been studied aiming to:

- To protect the buildings;
- Save energy spent in service;
- To ensure the background for sustainable green buildings.

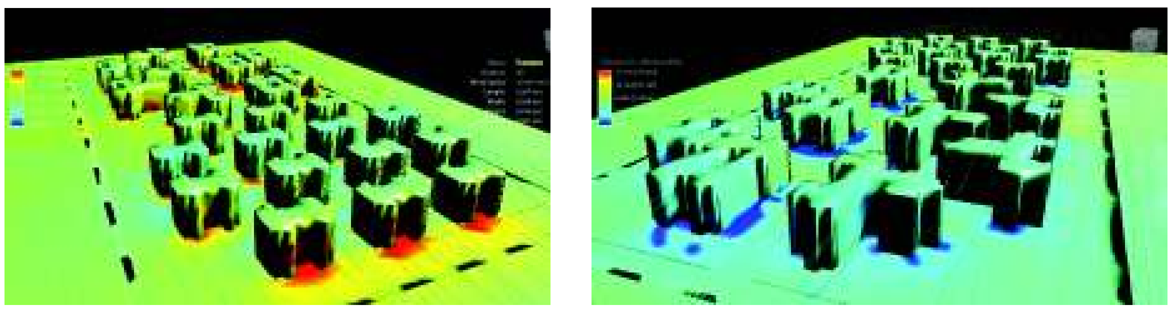
First, a comparison of the buildings distribution in the space was made considering the three analyzed urban fabrics, and the relation between them in order to reach the best urban design against the undesirable wind, and as open hands in front of desirable one. On the other hand, the trees, as environmental elements, were used to direct the desirable wind inside the lung of the cluster and repel and redirect the undesirable ones.

4.4.4.1 Undesirable wind

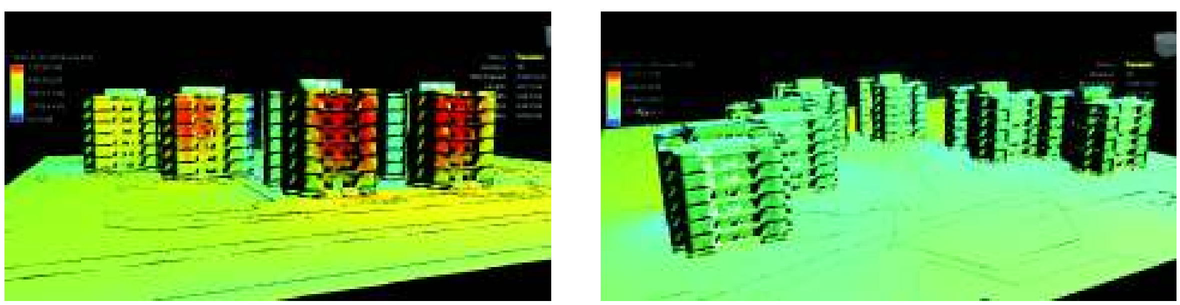
The relation between the urban fabric layout and the wind influence, the computer software *Autodesk flow design* was used. For the three different patterns, the results were compared to find out the best pattern, as shown in Figure 4.45. The velocity and direction of wind were introduced as 10 m/s and south, the undesirable wind.



a. compact fabric



b. modern fabric



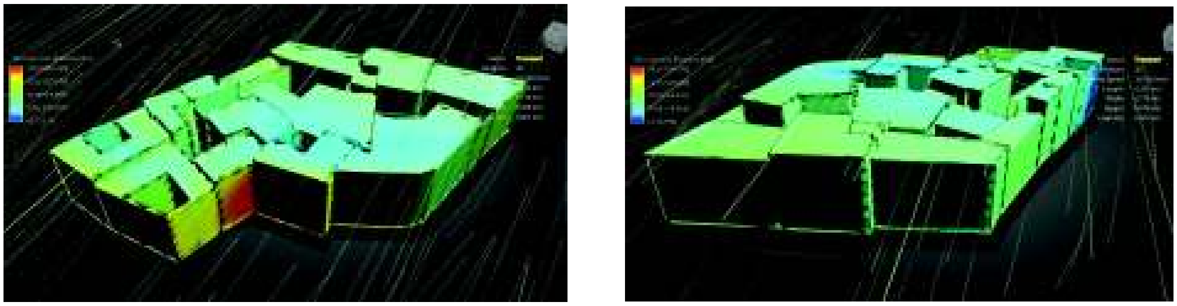
c. proposed fabric

Figure 4.45: Undesirable wind flow simulation over the three different patterns

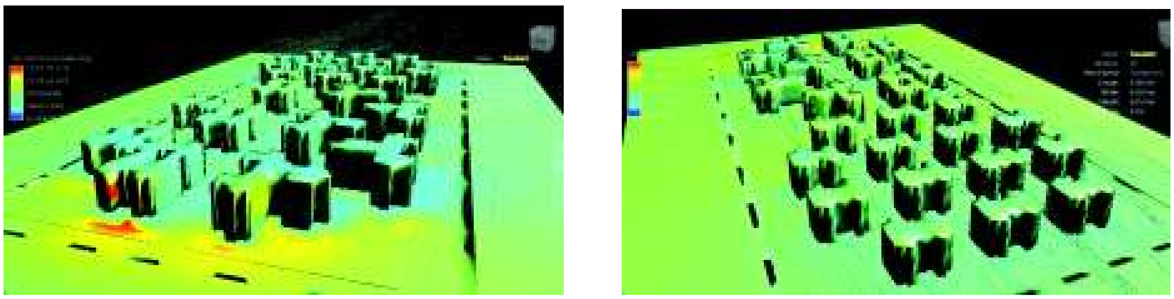
The results show that the first pattern has the smallest area facing the undesirable wind. Moreover, these facades do not have windows, these opening to the internal courtyard. The second pattern, the dispersed modern urban fabric presents the maximum facades area of the buildings facing the direct wind. Also, the corridors increase the wind velocity inside the cluster. As for the proposed pattern, the form of the cluster looks like a funnel, its head facing the undesirable wind, working to keep the wind out of the cluster. Therefore, the minimum facades of the buildings are facing the direct wind and the solution considered was tree barrier.

4.4.4.2 Desirable wind

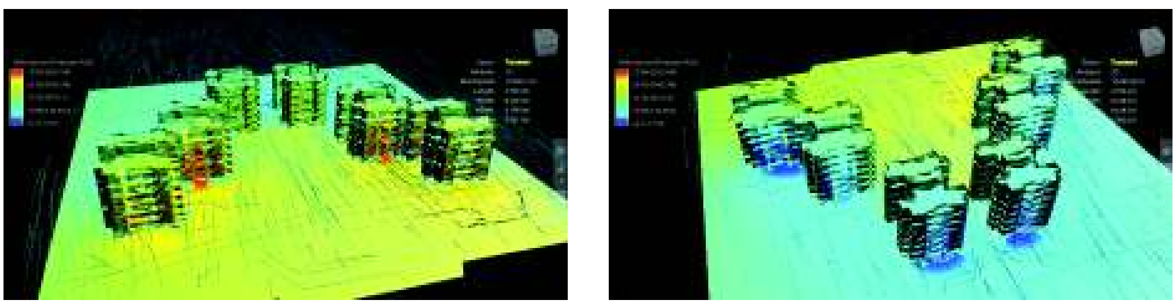
The results of the desirable wind simulations are presented in Figure 4.46, the wind following the north direction.



a. compact fabric



b. modern fabric



c. proposed fabric

Figure 4.46: Desirable wind flow simulation over the three different patterns

As shown in Figure 4.46.a the concept of internal courtyard creates space for cooling the air and diminishing its speed. In addition, the design of every unit in the old compact fabric used to depend on two parts: the south part is higher than the north part in order to make the unite working as a windcatcher. Such a design helps the desirable wind to enter to the upstairs rooms through windows, and downstairs rooms through the internal courtyard. Moreover, this solution of windcatcher gives natural ventilation to the whole rooms, as shown in Figure 4.47.

Figure 4.46.b shows how the minimum facades get good ventilation, the corridors work to increase the speed of the wind and lessen the usage of the natural ventilation. The solution with tree barriers could resolve the problem just for some facades.

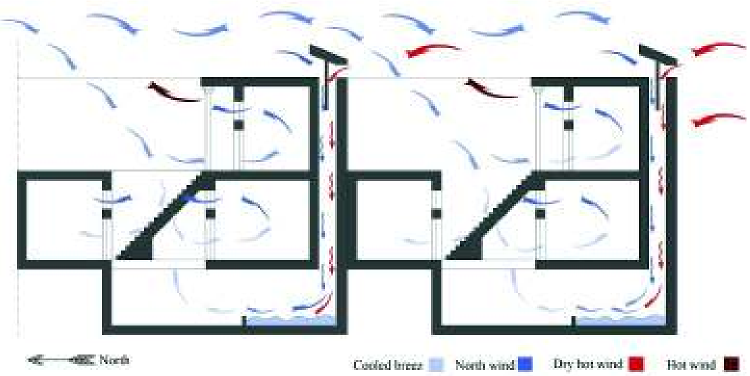


Figure 4.47: Windcatcher and courtyard concepts

By using the compact gradual urban fabric, as illustrated in Figure 4.46c, the cluster works to gather the wind and direct it to the inside of the internal lung. The concept of the internal courtyard has been used in a larger scale, where the lung represents the courtyard. Some small problems arise because sometimes we have to slow down the speed of the wind, or to cool and wet it. Barriers of trees implanted in suitable places can easily resolve these problems, as illustrated in Figure 4.48. Moreover, we can see clearly how by using barriers of trees we can increase from distance the movement of the wind around the buildings and inside the cluster. The tree barriers differ according to the considered direction and the function of it, as illustrated in Figure 4.49.

a. uncompact trees barrier works to reduce the wind velocity and cool it

b. compact tree barrier to repel the undesirable wind

Figure 4.48: Controlling the undesirable wing with tree barriers

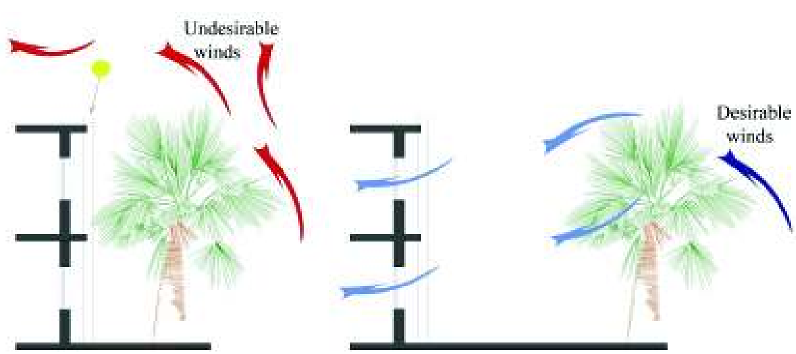
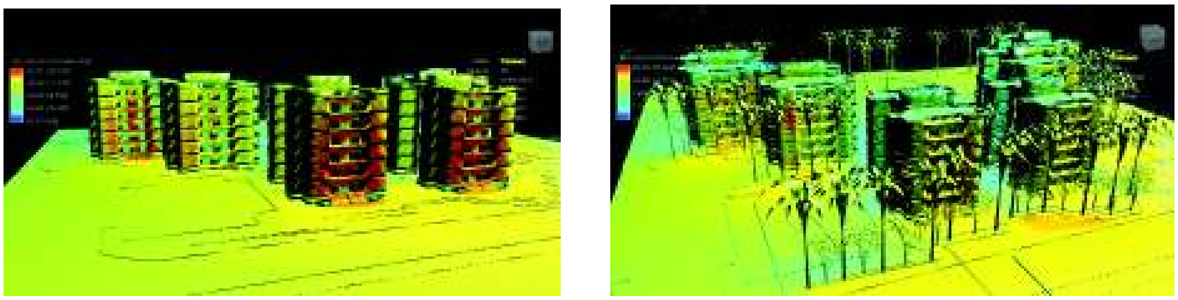
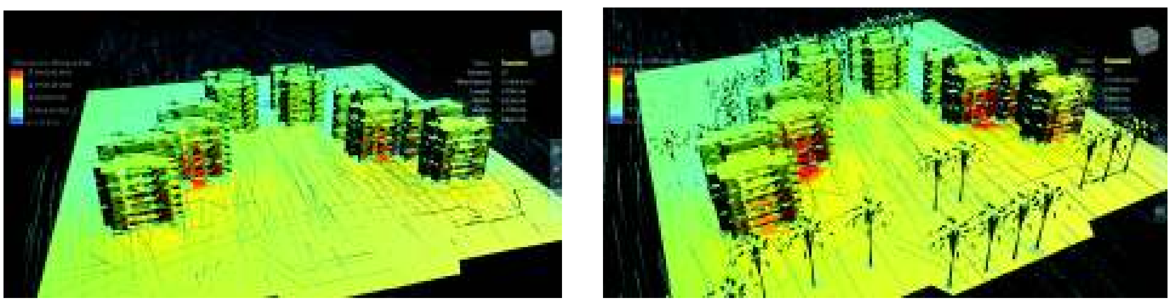


Figure 4.49: The place of trees according to the direction, where the trees work as a barrier or as a filter

The tree barriers have been added to the 3D cluster and then analysed. The results are shown below, in Figure 4.50. A simulation of the wind flow over the buildings, to see how the pressure gradient of the wind affects the interior temperature, which means thermal satisfaction. Based on the results of the simulations, the final cluster layout is as illustrated in Figure 4.51.



a. using the tree barrier to repel the undesirable wind



b. using the tree barrier to create airflow inside the lung

Figure 4.50: Computer simulations of the wind control with tree barriers at the proposed fabric

Figure 4.51: Cluster layout and wind analysis, solutions for save the buildings from the undesirable winds and take advantage of desirable one

4.4.5 Thermal satisfaction

A single representative building has been introduced to the computer software *Autodesk flow design*, in order to get the comparison how the interior climate in the terms of the temperature and humidity is affected by the undesirable wind, without and with a tree barrier (see Figure 4.52).

The 3D of the specific building was analyzed to get the critical affected point by the wind, in order to calculate the interior air flow or *thermal satisfaction*. To control these effects, there are two air velocity limits: indoor air velocity must never be over 0.9 m/s during the summer and below 0.15 m/s in winter. After the introduction of the wind velocity in the computer application, Moreover, to calculate the wind velocity inside the building during the time when windows are opened, we use wind velocity calculated by the application on the external walls, around the windows. Table 4.15 shows the wind velocity inside the rooms depending by the distribution and characteristics of the openings.

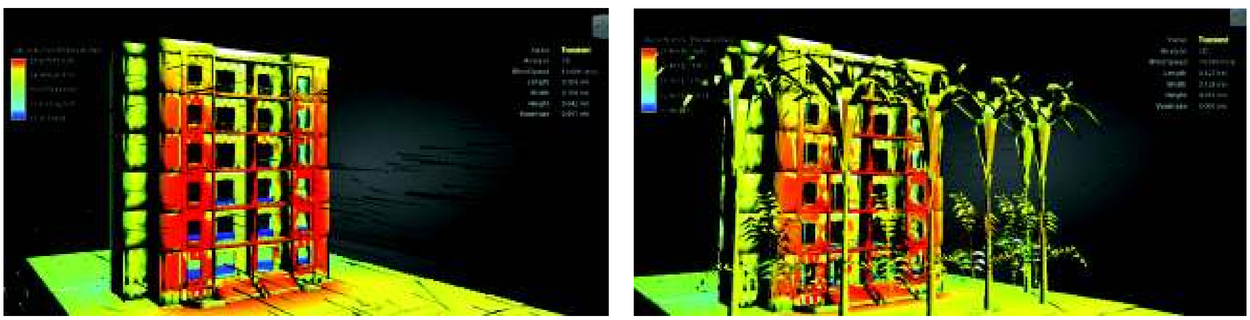


Figure 4.52: How the trees barrier works to repel the wind

Tab. 4.15: The percentage of the internal wind velocity related to the original velocity

Inlet width	**Outlet width**	**Openings facing each other**		**Contiguous openings**	
		normal wind	**diagonal wind**	**normal wind**	**diagonal wind**
1/3	1/3	35 %	42 %	45 %	37 %
1/3	2/3	39 %	40 %	39 %	40 %
2/3	1/3	34 %	43 %	51 %	36 %
2/3	2/3	37 %	51 %	-	-
1/3	3/3	44 %	44 %	51 %	45 %
3/3	1/3	32 %	41 %	50 %	37 %
2/3	3/3	35 %	59 %	-	-
3/3	2/3	36 %	62 %	-	-
3/3	3/3	47 %	65 %	-	-

Note: The ratio 1, 2, 3/3 refers to the windows area reported to the facade area.

After getting the velocity of the wind at the openings, the interior air velocity is calculated using the results from the computer program and, according to the formula [203]:

$$V = \sqrt{\frac{gh\,\Delta T/T_E}{1 + A_2/A_1}} \tag{4.3}$$

with

V – Interior wind velocity [m/s];
g – Gravitationl acceleration [m/s^2];
h – The distance between the window and the air flow exit of a room [m];
ΔT– Temperature gradient [°C];
T_E – Exterior air temperature [°C];
A_1 – Area of the opening where air enters in [m^2];
A_2 – Area of the opining where air goes out [m^2].

From the above formula the interior air temperature results

$$T_I = T_E\left[1 - \frac{V^2\left(1 + A_2/A_1\right)}{gh}\right] \tag{4.4}$$

where

V – Interior wind speed [m/s]
g – Gravitational acceleration [m/s^2]
h – The length between the openings [m]
T_I– Interior air temperature [°C]
T_E –Exterior air temperature [°C]
A_1 – area of opining that air enters in [m^2]
A_2 – area of opining that air goes out [m^2]

In the case study the entry data is: g= 9.81 m/s^2; h = 4 m; A_1= 2 m^2; A_2= 2 m^2. The feeling temperature is related to the interior temperature, air velocity and relative humidity. In order to calculate the real feeling temperature, the inside temperature is adjusted with the air relative humidity. The feeling temperature up to 10 °C gives a cooling sensation, further 20 °C gives a warming feeling, while between there is no different sensation. The heat index (i.e., the feeling temperature) based on relative humidity is developed in the following polynomial series [100]:

$$HI = c_1 + c_2T_i + c_3RH + c_4T_iRH + c_5T_i^2 + c_6RH^2 + c_7T_i^2RH + c_8T_iRH^2 + c_9T_i^2RH^2 \tag{4.5}$$

where
HI – Heat index [°C];
T_i – Interior air temperature [°C];
HR – Relative humidity [%],
And the constants c_1=-42.379, c_2=-2.04901523, c_3=-10.14333127, c_4 =-0.22475541, c_5=-6.83783×10^{-3}; c_6= -5.481717×10^{-2}, c_7=-1.22874×10^{-3}, c_8= 8.5282×10^{-4} and c_9=-1.99×10^{-6}.

The interior temperature and the feeling temperature is given in Annex B in a table format. Figures 4.53 and 4.54 present charts with the interior temperature and the feeling temperature related to the air velocity.

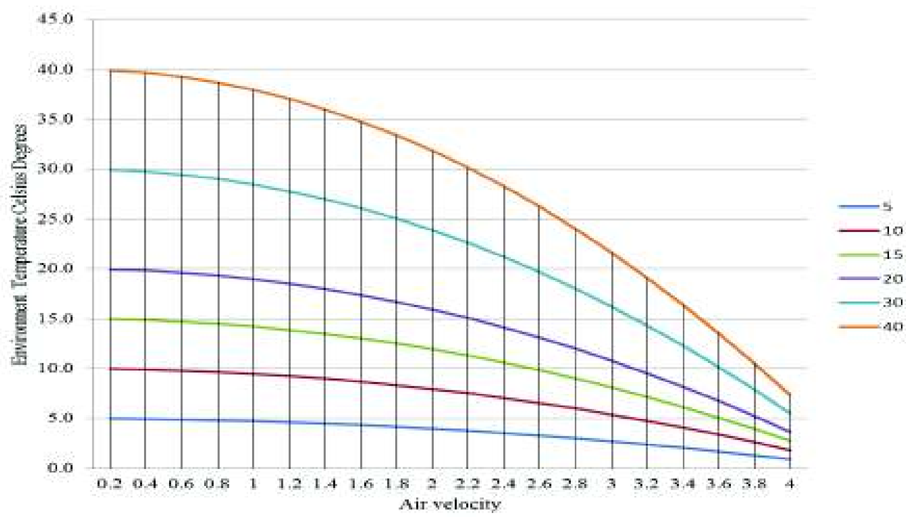


Figure 4.53: Interior temperature related to the air velocity

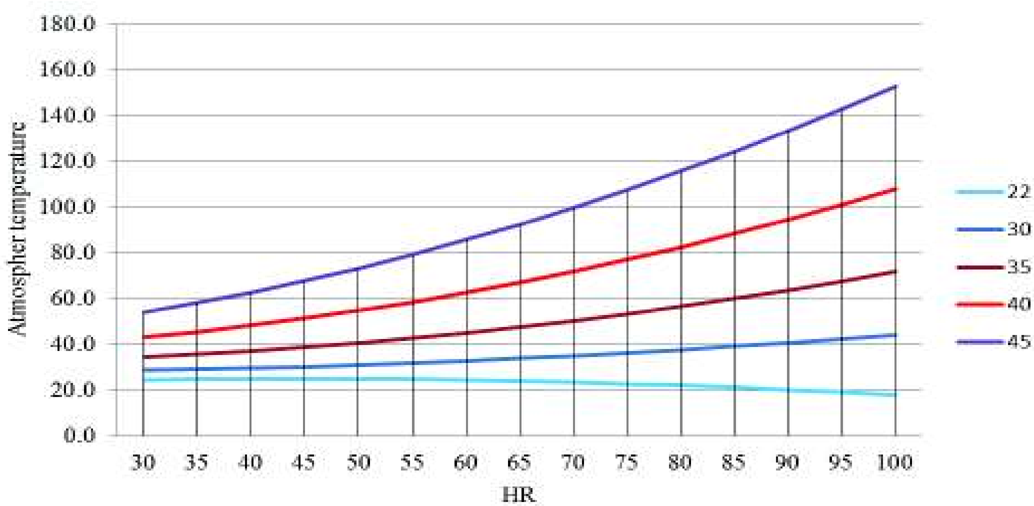


Figure 4.54: Feeling temperature related to the relative humidity

4.4.6 Air change rate

To calculate the volume of air that changed through time, based on the air velocity and the windows area, we follow the following formula [204]:

$$Q = mA_1V_E \quad (4.6)$$

with

Q - Air change rate [m^3/s];

A_1 - inlet openings area [m^2];

V_E – Exterior wind velocity [m/s];

m - Correction factor, given in Table 4.16.

The results are given in Figure 4.55, for A_1=2 m^2; m= 3150.

Tab. 4.16: Correction factor based on the inlet and out let ratio

A_2/A_1	Correction factor	A_2/A_1	Correction factor
1/1	3150	1/5	4400
1/2	4000	4/3	2700
1/3	4250	2/1	2000
1/4	4350	4	1100

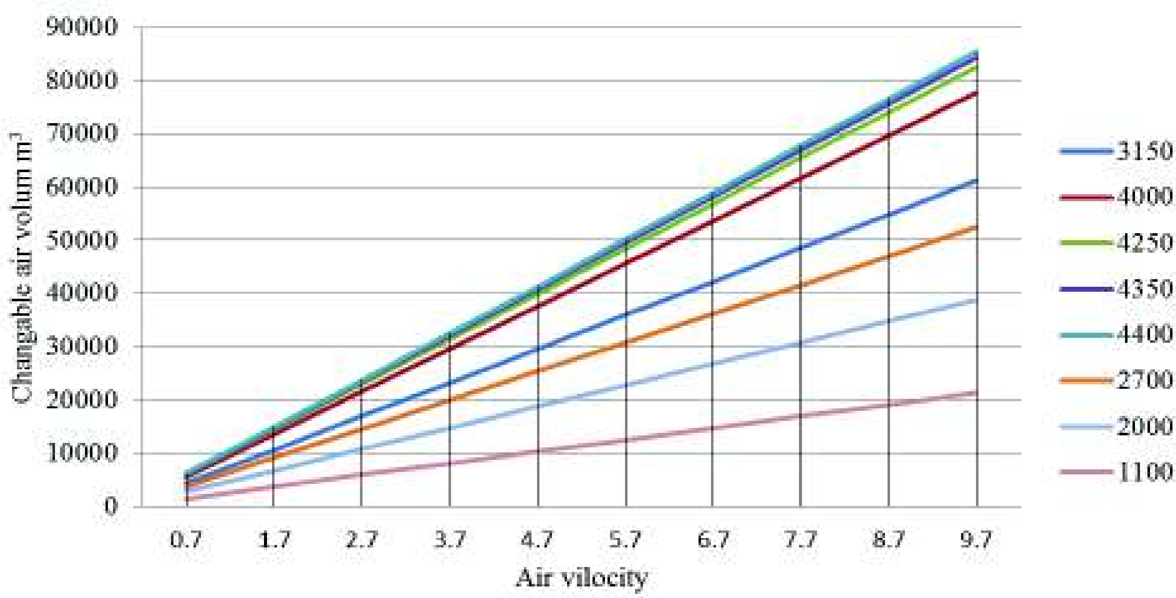


Figure 4.55: The volume of changeable air increases according to the wind velocity

It results clearly how the distribution of the building in the space can reduce the energy use. Moreover, using the environmental elements (e.g., trees) to direct the air to change the interior feeling gives good results, proofing that the proposal is the best for the arid climate.

5. CONCLUSIONS

5.1 Thesis summary

After the ***first***, introductive, ***chapter*** that presents a consistent view over the city development through history and a critical perspective upon the oil based building materials, the thesis continues with ***chapter 2***, dedicated to the urban infrastructure evolution. The chapter is a synthetic critical study emphasizing the profound impact of the oil and its products over the development of urban infrastructure. Unlike the traditional research that is interested in the invention of new materials and technologies for the future urban planning, the possibilities of reusing the local materials and technologies are presented from a sustainability point of view.

Chapter 3 continues with an original approach upon the significant urban achievements, a review of the conceptual urban development since the medieval age in the European and Middle East civilizations. The oil implications are scientifically argued and its impact on the economy, social, politics, and environment are reviewed. Finally, a scientific analysis regarding the interaction between the oil and the city is performed, with the objective identification of the key points of the urban development in both civilizations.

Chapter 4 is the central part of thesis and treats main steps performed during the research project. If previous chapter are dominated by a substantial theory and rationality, chapter 4 brings the original contribution of the author to a higher level. First, an important return in time is proposed to bring a gain to the sustainable development of the urban infrastructure, replacement of the oil plastic products embedded in the urban and rural infrastructure. The author proves that plastic pipes can be successfully replaced by traditional clay pipes, without implementing the costly effective vitrification technologies. The author proposes a simple manufacturing technology, with economical pipes complying with the standardized tests. The next innovative contribution refers to interventions based on the state of the art technology (e.g., customized photovoltaic solar panels, as a renewable energy source) upon the historical buildings. Computer simulations are finally embedded in an original optimizing parametric procedure for the future design of the cluster urban fabrics.

Chapter 5 presents the conclusion of PhD thesis, and emphasize the contribution of the author to the research topic.

5.2 Original contributions and objectives analysis

As a general conclusion, the thesis brings an original step forward in urban development, representing a holistic approach focused both on historical certainties and mysteries, and future demands respectively.

The work integrates the achievement of the specific proposed objectives (see subchapter 1.6) by ***original and innovative contribution***s, as follows:

- **Objective 1:** The objective is reached through the original study with the objective definition and identification of the oil applications in urban development, and their consequences upon the present and future progress of human society;
- **Objective 2:** The is fulfilled by the critical innovative study from chapter 3; identifies the interaction paths between the urban planning historical stages, with an accent on the European and Middle East experience'
- **Objective 3 :** The author proposes in chapter 4 a solution to replace the oil based plastic pipes with ceramic clay pipes, based on an innovative simple manufacturing technique, and complying with the requirements of the standard tests;
- **Objective 4:** The author proposes an innovative solution to the sustainable rehabilitation of the historical buildings, maintaining the cultural values, in the same time capitalizing the building and generating an environmental friendly service;
- **Objective 5:** The author developed a parametric optimization methodology in urban planning of the cluster fabrics for a sustainable development, using green concepts.

5.3 Future work and developments

Further developments of the research carried out on the engineering aproach of the urban development could be done to investigate replace how to plastic pipes of electricity by paperboard. Another direction is to find natural sustainable materials to be able to replace the polystyrene insulation. Moreover, the concept of zero-carbon immersion from concrete it will be a good idea, but developing the concrete materials to absorb the CO_2 from environment it will the best.

Future oil free cities are the main long term target. There is no doubt that our cities are far to be the best place to live, and oil implications in this respect are proved. Since the world is running out of oil, and the world without oil is not so far to be, solutions should be found to keep the cities in service, saving their resources and bringing them back to an organic integration with nature .

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ANNEX A THERMAL RESISTANCE

Thermal properties of walls as shown subchapter 4.4 (see also figure 4.36, 4.37)

Tab.A.1. Physical and thermal properties of insulation materials

Material	**Density kg/m³**	**Thermal conductivity W/mK**
cellulose waste	48	0.05
	35	0.039
	29	0.042
perlite (sodium silicate)	200	0.064
	250	0.076
	300	0.082
glass wool	24	0.03
	32	0.032
	48	0.034

Thermal resistant for walls with using cellulose waste for the studied case:

- d1 = 12cm   λ1= 1.7 [m*K/W]   reinforcement concrete
- d2 = 23cm   λ1= 0.039 [m*K/W]   cellulose waste
- d3 = 7cm   λ1= 0.275 [m*K/W]   light concrete

$$R = 0.125 + \frac{d1}{\lambda 1} + \frac{d2}{\lambda 2} + \frac{d3}{\lambda 3} + 0.042 = 6.387[\mathrm{m2.K/W}]$$ ………………..A.1

- d1 = 30cm   λ1= 1.7 [m*K/W]   reinforcement concrete
- d2 = 5cm   λ1= 0.039 [m*K/W]   cellulose waste
- d3 = 7cm   λ1= 0.275 [m*K/W]   light concrete

$$R = 0.125 + \frac{d1}{\lambda 1} + \frac{d2}{\lambda 2} + \frac{d3}{\lambda 3} + 0.042 = 1.877[\mathrm{m2.K/W}]$$ …………………A.2

Thermal resistant with using perlite (sodium silicate) waste for the studied case:

- d1 = 12cm λ1= 1.7 [m*K/W] reinforcement concrete
- d2 = 23cm λ1= 0.064 [m*K/W] cellulose waste
- d3 = 7cm λ1= 0.275 [m*K/W] light concrete

$$R = 0.125 + \frac{d1}{\lambda 1} + \frac{d2}{\lambda 2} + \frac{d3}{\lambda 3} + 0.042 = 4.081[\mathrm{m2.K/W}]$$ ………………..A.3

- d1 = 30cm λ1= 1.7 [m*K/W] reinforcement concrete
- d2 = 5cm λ1= 0.064 [m*K/W] cellulose waste
- d3 = 7cm λ1= 0.275 [m*K/W] light concrete

$$R = 0.125 + \frac{d1}{\lambda 1} + \frac{d2}{\lambda 2} + \frac{d3}{\lambda 3} + 0.042 = 1.378[\mathrm{m2.K/W}]$$ …………………A.4

Thermal resistant with using glass wall waste for the studied case:

- d1 = 12cm λ1= 1.7 [m*K/W] reinforcement concrete
- d2 = 23cm λ1= 0.042 [m*K/W] cellulose waste
- d3 = 7cm λ1= 0.275 [m*K/W] light concrete

$$R = 0.125 + \frac{d1}{\lambda 1} + \frac{d2}{\lambda 2} + \frac{d3}{\lambda 3} + 0.042 = 5.967[\mathrm{m2.K/W}]$$ ………………..A.5

- d1 = 30cm λ1= 1.7 [m*K/W] reinforcement concrete
- d2 = 5cm λ1= 0.042 [m*K/W] cellulose waste
- d3 = 7cm λ1= 0.275 [m*K/W] light concrete

$$R = 0.125 + \frac{d1}{\lambda 1} + \frac{d2}{\lambda 2} + \frac{d3}{\lambda 3} + 0.042 = 1.788[\mathrm{m2.K/W}]$$ …………………A.6

ANNEX B THERMAL RESISTANCE

Tab. B.1 Interior Temperature based on exterior air velocity and according to the Tab.4.15

Environment Temperature Celsius Degrees	Interior Temperature																			
	Air Velocity [m/s]																			
	0.2	***0.4***	***0.6***	***0.8***	***1***	***1.2***	***1.4***	***1.6***	***1.8***	***2***	***2.2***	***2.4***	***2.6***	***2.8***	***3***	***3.2***	***3.4***	***3.6***	***3.8***	***4***
5	5.0	5.0	4.9	4.8	4.7	4.6	4.5	4.3	4.2	4.0	3.8	3.5	3.3	3.0	2.7	2.4	2.1	1.7	1.3	0.9
6	6.0	6.0	5.9	5.8	5.7	5.6	5.4	5.2	5.0	4.8	4.5	4.2	3.9	3.6	3.2	2.9	2.5	2.0	1.6	1.1
7	7.0	6.9	6.9	6.8	6.6	6.5	6.3	6.1	5.8	5.6	5.3	4.9	4.6	4.2	3.8	3.3	2.9	2.4	1.8	1.3
8	8.0	7.9	7.9	7.7	7.6	7.4	7.2	7.0	6.7	6.4	6.0	5.7	5.2	4.8	4.3	3.8	3.3	2.7	2.1	1.5
9	9.0	8.9	8.8	8.7	8.5	8.3	8.1	7.8	7.5	7.2	6.8	6.4	5.9	5.4	4.9	4.3	3.7	3.1	2.4	1.7
10	10.0	9.9	9.8	9.7	9.5	9.3	9.0	8.7	8.3	8.0	7.5	7.1	6.6	6.0	5.4	4.8	4.1	3.4	2.6	1.8
11	11.0	10.9	10.8	10.6	10.4	10.2	9.9	9.6	9.2	8.8	8.3	7.8	7.2	6.6	6.0	5.3	4.5	3.7	2.9	2.0
12	12.0	11.9	11.8	11.6	11.4	11.1	10.8	10.4	10.0	9.6	9.0	8.5	7.9	7.2	6.5	5.7	4.9	4.1	3.2	2.2
13	13.0	12.9	12.8	12.6	12.3	12.0	11.7	11.3	10.9	10.3	9.8	9.2	8.5	7.8	7.0	6.2	5.3	4.4	3.4	2.4
14	14.0	13.9	13.7	13.5	13.3	13.0	12.6	12.2	11.7	11.1	10.5	9.9	9.2	8.4	7.6	6.7	5.8	4.8	3.7	2.6
15	15.0	14.9	14.7	14.5	14.2	13.9	13.5	13.0	12.5	11.9	11.3	10.6	9.8	9.0	8.1	7.2	6.2	5.1	4.0	2.8
16	16.0	15.9	15.7	15.5	15.2	14.8	14.4	13.9	13.4	12.7	12.1	11.3	10.5	9.6	8.7	7.6	6.6	5.4	4.2	3.0
17	17.0	16.9	16.7	16.4	16.1	15.8	15.3	14.8	14.2	13.5	12.8	12.0	11.1	10.2	9.2	8.1	7.0	5.8	4.5	3.1
18	18.0	17.9	17.7	17.4	17.1	16.7	16.2	15.7	15.0	14.3	13.6	12.7	11.8	10.8	9.7	8.6	7.4	6.1	4.8	3.3
19	19.0	18.8	18.7	18.4	18.0	17.6	17.1	16.5	15.9	15.1	14.3	13.4	12.5	11.4	10.3	9.1	7.8	6.4	5.0	3.5
20	20.0	19.8	19.6	19.3	19.0	18.5	18.0	17.4	16.7	15.9	15.1	14.1	13.1	12.0	10.8	9.6	8.2	6.8	5.3	3.7
21	21.0	20.8	20.6	20.3	19.9	19.5	18.9	18.3	17.5	16.7	15.8	14.8	13.8	12.6	11.4	10.0	8.6	7.1	5.5	3.9
22	22.0	21.8	21.6	21.3	20.9	20.4	19.8	19.1	18.4	17.5	16.6	15.5	14.4	13.2	11.9	10.5	9.0	7.5	5.8	4.1
23	23.0	22.8	22.6	22.2	21.8	21.3	20.7	20.0	19.2	18.3	17.3	16.2	15.1	13.8	12.4	11.0	9.4	7.8	6.1	4.2
24	24.0	23.8	23.6	23.2	22.8	22.2	21.6	20.9	20.0	19.1	18.1	17.0	15.7	14.4	13.0	11.5	9.9	8.1	6.3	4.4
25	24.9	24.8	24.5	24.2	23.7	23.2	22.5	21.7	20.9	19.9	18.8	17.7	16.4	15.0	13.5	12.0	10.3	8.5	6.6	4.6
26	25.9	25.8	25.5	25.2	24.7	24.1	23.4	22.6	21.7	20.7	19.6	18.4	17.0	15.6	14.1	12.4	10.7	8.8	6.9	4.8
27	26.9	26.8	26.5	26.1	25.6	25.0	24.3	23.5	22.5	21.5	20.3	19.1	17.7	16.2	14.6	12.9	11.1	9.2	7.1	5.0
28	27.9	27.8	27.5	27.1	26.6	25.9	25.2	24.3	23.4	22.3	21.1	19.8	18.4	16.8	15.2	13.4	11.5	9.5	7.4	5.2
29	28.9	28.8	28.5	28.1	27.5	26.9	26.1	25.2	24.2	23.1	21.8	20.5	19.0	17.4	15.7	13.9	11.9	9.8	7.7	5.4
30	29.9	29.8	29.4	29.0	28.5	27.8	27.0	26.1	25.0	23.9	22.6	21.2	19.7	18.0	16.2	14.3	12.3	10.2	7.9	5.5
31	30.9	30.7	30.4	30.0	29.4	28.7	27.9	27.0	25.9	24.7	23.4	21.9	20.3	18.6	16.8	14.8	12.7	10.5	8.2	5.7
32	31.9	31.7	31.4	31.0	30.4	29.7	28.8	27.8	26.7	25.5	24.1	22.6	21.0	19.2	17.3	15.3	13.1	10.9	8.4	5.9
33	32.9	32.7	32.4	31.9	31.3	30.6	29.7	28.7	27.6	26.3	24.9	23.3	21.6	19.8	17.9	15.8	13.6	11.2	8.7	6.1
34	33.9	33.7	33.4	32.9	32.3	31.5	30.6	29.6	28.4	27.1	25.6	24.0	22.3	20.4	18.4	16.3	14.0	11.5	9.0	6.3
35	34.9	34.7	34.4	33.9	33.2	32.4	31.5	30.4	29.2	27.9	26.4	24.7	22.9	21.0	18.9	16.7	14.4	11.9	9.2	6.5
36	35.9	35.7	35.3	34.8	34.2	33.4	32.4	31.3	30.1	28.7	27.1	25.4	23.6	21.6	19.5	17.2	14.8	12.2	9.5	6.6
37	36.9	36.7	36.3	35.8	35.1	34.3	33.3	32.2	30.9	29.5	27.9	26.1	24.3	22.2	20.0	17.7	15.2	12.6	9.8	6.8
38	37.9	37.7	37.3	36.8	36.1	35.2	34.2	33.0	31.7	30.3	28.6	26.8	24.9	22.8	20.6	18.2	15.6	12.9	10.0	7.0
39	38.9	38.7	38.3	37.7	37.0	36.1	35.1	33.9	32.6	31.0	29.4	27.6	25.6	23.4	21.1	18.6	16.0	13.2	10.3	7.2
40	39.9	39.7	39.3	38.7	38.0	37.1	36.0	34.8	33.4	31.8	30.1	28.3	26.2	24.0	21.7	19.1	16.4	13.6	10.6	7.4
41	40.9	40.7	40.2	39.7	38.9	38.0	36.9	35.7	34.2	32.6	30.9	29.0	26.9	24.6	22.2	19.6	16.8	13.9	10.8	7.6
42	41.9	41.7	41.2	40.6	39.9	38.9	37.8	36.5	35.1	33.4	31.6	29.7	27.5	25.2	22.7	20.1	17.3	14.3	11.1	7.7
43	42.9	42.6	42.2	41.6	40.8	39.8	38.7	37.4	35.9	34.2	32.4	30.4	28.2	25.8	23.3	20.6	17.7	14.6	11.4	7.9
44	43.9	43.6	43.2	42.6	41.8	40.8	39.6	38.3	36.7	35.0	33.1	31.1	28.8	26.4	23.8	21.0	18.1	14.9	11.6	8.1
45	44.9	44.6	44.2	43.5	42.7	41.7	40.5	39.1	37.6	35.8	33.9	31.8	29.5	27.0	24.4	21.5	18.5	15.3	11.9	8.3

Tab B.2. Interior temperature based on air velocity

		Heat Index														
		Relative humidity %														
		30	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
Environment Temperature Celsius Degrees	***22***	24.6	24.8	25.0	25.0	24.9	24.8	24.5	24.1	23.5	22.9	22.2	21.4	20.4	19.3	18.2
	23	24.7	24.9	25.1	25.1	25.1	25.0	24.8	24.5	24.1	23.7	23.1	22.5	21.8	21.1	20.2
	24	25.0	25.2	25.3	25.4	25.4	25.4	25.3	25.1	24.9	24.7	24.4	24.0	23.6	23.1	22.6
	25	25.4	25.5	25.7	25.8	25.9	26.0	26.0	26.0	26.0	25.9	25.9	25.8	25.7	25.5	25.3
	26	25.8	26.0	26.2	26.4	26.6	26.7	26.9	27.1	27.3	27.5	27.7	27.9	28.0	28.2	28.4
	27	26.4	26.6	26.9	27.1	27.4	27.7	28.1	28.5	28.9	29.3	29.7	30.2	30.7	31.3	31.8
	28	27.1	27.4	27.7	28.0	28.4	28.9	29.4	30.0	30.7	31.4	32.1	32.9	33.7	34.7	35.6
	29	27.9	28.2	28.6	29.1	29.7	30.3	31.0	31.8	32.7	33.7	34.7	35.9	37.1	38.4	39.7
	30	28.8	29.2	29.7	30.3	31.0	31.9	32.8	33.9	35.0	36.3	37.7	39.1	40.7	42.4	44.2
	31	29.7	30.3	30.9	31.7	32.6	33.7	34.8	36.2	37.6	39.2	40.9	42.7	44.7	46.8	49.0
	32	30.8	31.5	32.3	33.2	34.4	35.6	37.1	38.7	40.4	42.3	44.4	46.6	49.0	51.5	54.2
	33	32.0	32.8	33.8	34.9	36.3	37.8	39.5	41.4	43.5	45.7	48.1	50.8	53.5	56.5	59.7
	34	33.3	34.3	35.4	36.8	38.4	40.2	42.2	44.4	46.8	49.4	52.2	55.2	58.4	61.9	65.5
	35	34.7	35.8	37.2	38.8	40.7	42.7	45.0	47.6	50.3	53.3	56.5	60.0	63.7	67.6	71.7
	36	36.2	37.5	39.1	41.0	43.1	45.5	48.1	51.0	54.2	57.5	61.2	65.1	69.2	73.6	78.2
	37	37.8	39.3	41.2	43.4	45.8	48.5	51.4	54.7	58.2	62.0	66.1	70.4	75.1	80.0	85.1
	38	39.4	41.3	43.4	45.9	48.6	51.6	55.0	58.6	62.5	66.7	71.3	76.1	81.2	86.6	92.4
	39	41.2	43.3	45.8	48.5	51.6	55.0	58.7	62.7	67.1	71.8	76.8	82.1	87.7	93.7	99.9
	40	43.1	45.5	48.3	51.3	54.8	58.5	62.6	67.1	71.9	77.0	82.5	88.3	94.5	101.0	107.9
	41	45.1	47.8	50.9	54.3	58.1	62.3	66.8	71.7	77.0	82.6	88.6	94.9	101.6	108.7	116.1
	42	47.2	50.3	53.7	57.5	61.7	66.2	71.2	76.5	82.3	88.4	94.9	101.8	109.0	116.7	124.8
	43	49.4	52.8	56.6	60.8	65.4	70.4	75.8	81.6	87.8	94.5	101.5	108.9	116.8	125.1	133.7
	44	51.7	55.5	59.6	64.2	69.3	74.7	80.6	86.9	93.6	100.8	108.4	116.4	124.9	133.7	143.0
	45	54.1	58.3	62.8	67.9	73.3	79.2	85.6	92.4	99.7	107.4	115.6	124.2	133.2	142.7	152.7

Following formula calculates the outdoor feeling temperature based on air velocity

$$°F = 35.74 + 0.6215T - °F35.75(V^{0.16}) + 0.4275T(V^{0.16}) \quad (B.1)$$

Where:

°F – wind chill; feeling temperature

T– air temperature; [Celsius degree];

V–wind speed [m/s]

Tab. B.3. Outdoor feeling temperature based on air velocity

Wind Chill													
	Wind Speed [km/hour]												
Environment Temperature Celsius Degrees	***5***	***10***	***15***	***20***	***25***	***30***	***35***	***40***	***45***	***50***	***60***	***70***	***80***
-15	-18.4	-21.0	-22.7	-24.0	-25.0	-25.8	-26.6	-27.2	-27.8	-28.4	-29.3	-30.2	-30.9
-13	-16.1	-18.6	-20.2	-21.4	-22.4	-23.2	-23.9	-24.6	-25.1	-25.7	-26.6	-27.4	-28.1
-11	-13.9	-16.3	-17.8	-18.9	-19.9	-20.6	-21.3	-21.9	-22.5	-23.0	-23.8	-24.6	-25.3
-9	-11.6	-13.9	-15.4	-16.4	-17.3	-18.1	-18.7	-19.3	-19.8	-20.2	-21.1	-21.8	-22.4
-7	-9.4	-11.5	-12.9	-13.9	-14.8	-15.5	-16.1	-16.6	-17.1	-17.5	-18.3	-19.0	-19.6
-5	-7.1	-9.2	-10.5	-11.4	-12.2	-12.9	-13.4	-14.0	-14.4	-14.8	-15.6	-16.2	-16.8
-3	-4.9	-6.8	-8.0	-8.9	-9.7	-10.3	-10.8	-11.3	-11.7	-12.1	-12.8	-13.4	-14.0
-1	-2.6	-4.4	-5.6	-6.4	-7.1	-7.7	-8.2	-8.6	-9.0	-9.4	-10.1	-10.6	-11.1
0	-1.5	-3.2	-4.3	-5.2	-5.8	-6.4	-6.9	-7.3	-7.7	-8.1	-8.7	-9.2	-9.7
1	-0.4	-2.0	-3.1	-3.9	-4.6	-5.1	-5.6	-6.0	-6.4	-6.7	-7.3	-7.8	-8.3
3	1.9	0.3	-0.7	-1.4	-2.0	-2.5	-2.9	-3.3	-3.7	-4.0	-4.6	-5.1	-5.5
5	4.1	2.7	1.8	1.1	0.6	0.1	-0.3	-0.7	-1.0	-1.3	-1.8	-2.3	-2.7
7	6.4	5.1	4.2	3.6	3.1	2.7	2.3	2.0	1.7	1.4	0.9	0.5	0.2
9	8.6	7.4	6.7	6.1	5.7	5.3	4.9	4.6	4.4	4.1	3.7	3.3	3.0
11	10.9	9.8	9.1	8.6	8.2	7.9	7.6	7.3	7.1	6.8	6.4	6.1	5.8
13	13.1	12.2	11.6	11.1	10.8	10.5	10.2	9.9	9.7	9.5	9.2	8.9	8.6
15	15.4	14.5	14.0	13.6	13.3	13.0	12.8	12.6	12.4	12.2	11.9	11.7	11.5
17	17.6	16.9	16.5	16.1	15.9	15.6	15.4	15.3	15.1	15.0	14.7	14.5	14.3
19	19.9	19.3	18.9	18.6	18.4	18.2	18.1	17.9	17.8	17.7	17.5	17.3	17.1
21	22.1	21.7	21.4	21.1	21.0	20.8	20.7	20.6	20.5	20.4	20.2	20.1	19.9
23	24.4	24.0	23.8	23.7	23.5	23.4	23.3	23.2	23.1	23.1	23.0	22.8	22.8
25	26.6	26.4	26.3	26.2	26.1	26.0	25.9	25.9	25.8	25.8	25.7	25.6	25.6
27	28.9	28.8	28.7	28.7	28.6	28.6	28.6	28.5	28.5	28.5	28.5	28.4	28.4
29	31.1	31.1	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2	31.2
31	33.4	33.5	33.6	33.7	33.7	33.8	33.8	33.9	33.9	33.9	34.0	34.0	34.0
33	35.6	35.9	36.1	36.2	36.3	36.4	36.4	36.5	36.6	36.6	36.7	36.8	36.9
35	37.9	38.3	38.5	38.7	38.8	39.0	39.1	39.2	39.2	39.3	39.5	39.6	39.7
37	40.1	40.6	41.0	41.2	41.4	41.5	41.7	41.8	41.9	42.0	42.2	42.4	42.5
39	42.4	43.0	43.4	43.7	43.9	44.1	44.3	44.5	44.6	44.7	45.0	45.2	45.3
40	43.5	44.2	44.6	45.0	45.2	45.4	45.6	45.8	46.0	46.1	46.3	46.6	46.8

Tab.B.4 Interior changeable air volume based on air velocity and open area

Changeable air											
		Air Velocity [m/s]									
		0.7	***1.7***	***2.7***	***3.7***	***4.7***	***5.7***	***6.7***	***7.7***	***8.7***	***9.7***
Changeable air volume	***3150***	4410.0	10710.0	17010.0	23310.0	29610.0	35910.0	42210.0	48510.0	54810.0	61110.0
	4000	5600.0	13600.0	21600.0	29600.0	37600.0	45600.0	53600.0	61600.0	69600.0	77600.0
	4250	5950.0	14450.0	22950.0	31450.0	39950.0	48450.0	56950.0	65450.0	73950.0	82450.0
	4350	6090.0	14790.0	23490.0	32190.0	40890.0	49590.0	58290.0	66990.0	75690.0	84390.0
	4400	6160.0	14960.0	23760.0	32560.0	41360.0	50160.0	58960.0	67760.0	76560.0	85360.0
	2700	3780.0	9180.0	14580.0	19980.0	25380.0	30780.0	36180.0	41580.0	46980.0	52380.0
	2000	2800.0	6800.0	10800.0	14800.0	18800.0	22800.0	26800.0	30800.0	34800.0	38800.0
	1100	1540.0	3740.0	5940.0	8140.0	10340.0	12540.0	14740.0	16940.0	19140.0	21340.0