IEREK PRESS
Academic Research Community

http://www.press.ierek.com

Resourceedings
Proceedings of Science and Technology

CrossMark

ISSN (Print: 2537-0731, online: 2537-074X)

International Journal on:

Proceedings of Science and Technology

DOI: 10.21625/resourceedings.v1i2.319

A Review to Innovative Ventilation Techniques Used in Historical Hospitals in Middle East and Europe

S. Maraqa[1], G. Dweik[1], G. Van Moeseke[2], A. de Herde[3]

[1]*Palestine Polytechnic University, West Bank, Palestine*

[2]*Architecture et climat, LOCI, Universite catholique de Louvain, Belgium*

[3]*MATRIciel, Place de l'universite 25, LLN, Belgium*

Abstract

Historically, natural ventilation has been an important factor to achieve thermal comfort and reduce energy consumption in healthcare buildings. Since the recent century, there has been an increasing change and scientific advancement that led to the reliance of mechanical ventilation systems in commercial buildings and especially in hospitals and healthcare settings. However, the fully mechanical system approaches have changed gradually after global warming and the lack of energy sources. In this context, this study investigated systematically, passive ventilation techniques used in medieval near eastern hospitals "Bimaristans" and historical hospitals in Europe. The study traced the roots of natural ventilation in a sample of historical healthcare buildings. It also investigated ventilation techniques used in historical hospitals in Middle East and Europe.

This study is looking forward to discover the architectural design parameters' effects of historical hospitals on ventilation, to make a better environment for patients' health by learning from past lessons in traditional architecture, and how could we adapt these techniques in our nowadays healthcare buildings. This step will allow further research on the adaption and integration of passive techniques inherited from the past in our contemporary hospital design.

Keywords

Natural ventilation; Passive cooling; Bimaristans; Climate adaptation; Historical buildings; Innovative ventilation techniques

1. Introduction

Ventilation and air quality are very important factors to assess any built environment and its influences in human health and performance in architectural spaces. Indoor air quality, good ventilation, and natural lighting are so essential to healthy environment especially hospitals. The researcher is interested in investigating natural ventilation techniques used in historical hospitals. Adequate natural ventilation preferred by occupants to maximize occupant comfort and provide adequate and healthy indoor environment with better performance. Natural ventilation also is important in energy efficient buildings and sustainable design and was important design aspect to our predecessors. These ideas hearken back to the late eighteenth century, when the concept of providing fresh air and access to the 'healing powers of nature' were first employed by hospital architects in improving their buildings (Hannen, 2007).

The main aim of this study is to investigate natural ventilation techniques in traditional and historical hospitals, and how to utilize from this renewable and clean source by learning from past techniques in our heritage. This will provide a new perspective to architects and designers in this field about natural ventilation role in hospital design from historical point of view. This will contribute in improving hospital design environment to archive healthy comfortable spaces and energy efficient buildings by learning lessons from our heritage in healthcare buildings.

In the old Islamic cities, hospitals called "Bimaristan" which were organized as a group of various buildings including health care centers, clinics, medical schools, library, chemistry, prayer area and often a section for the treatment of mentally retarded patients and to cure neural diseases. Bimaristans were designed in order to provide the most adequate environmental condition. To achieve balance in physical and spiritual needs, the selection of a site for the hospital was a crucial parameter, and different natural elements were used in its design (Belakehal et al., 2004).

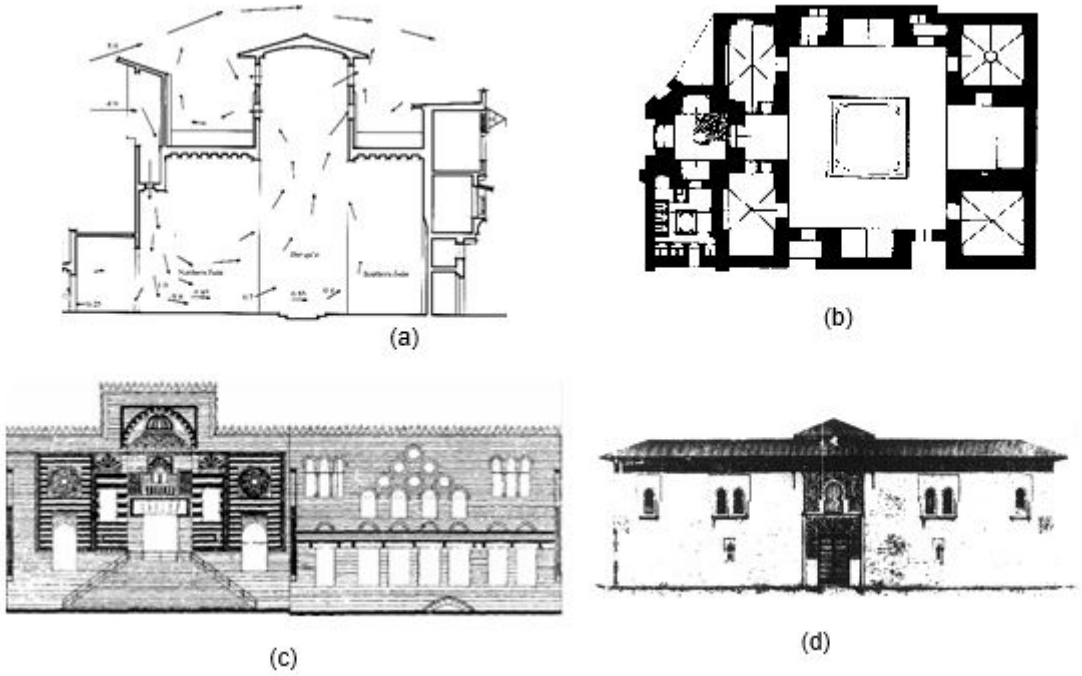


Figure 1. (a) Malqaf sec. (Fathy et al., 1986) (b) Nuri Bimaristan, Dams. (Herzfeld, 1942)
(c) Al-Muayad bimaristan (Kaf Al-Ghazal,2007) (d) Granada (García Granadoset al., 1989)

In Europe the medieval concept of Christian care evolved during the sixteenth and seventeenth centuries into a secular one, but it was in the eighteenth century that the modern hospital began to appear, serving only medical needs and staffed with physicians and surgeons. Since the nineteenth century, architecture and health as specialized area, has slowly evolved, rising to a place of recognized professional stature and relevancy. Its autonomy exists within the profession of architecture and, namely, medicine, public health, and the allied health sciences (Verderber, 2010). By the mid-nineteenth century, most of Europe and the United States had established a variety of public and private hospital systems. In continental Europe the new hospitals generally were built and run from public funds. The National Health Service, the principle provider of health care in the United Kingdom, was founded in 1948.

In the medieval era in Europe, with the fall of Rome in the fourth century and the decline of secular city-states, the Catholic Church emerged to fill the void in healthcare across Europe from the third to the late fourteenth century. In this era, Christian religious orders provided care through networks of monastic hospitals based on cross-ward plans and the separation of sacred from secular facilities, which gradually disappeared in the western health institutions to be replaced by new ideologies of architecture and health as a specialized area of research and practice (Verderber, 2010).

The three major methods of heating buildings, based on hot air, hot water and steam, were all developed in the

late 18th and early 19th century, largely in Great Britain. At the same time, forced ventilation, based on the drawing power of heat or in the use of the mechanical means like the fan, was also established. Many problems had to be overcome. Medical doubts of ventilation, the rivalry between architects and engineers, and difficulties in reconciling design with equipment, and by the last quarter of 19th century standardized the technology and made it readily available to the architects, engineers and general public. Use of new technology made possible many new architectural developments. Prison, theatre, greenhouse, and hospital were largely dependent on central heating and forced ventilation. Perhaps the most profound change was in the conception of the building itself. Buildings could be seen literally in terms of living organisms or machines (Bruegmann, 1978).

Nomenclature
ANV Advanced Natural Ventilation
SNV Simple Natural Ventilation
IAQ Simple Natural Ventilation

2. Residential Buildings in Palestine as a Beginning

Most of the new Palestinian architects did not understand and appreciate the suitability of the old traditional houses, especially those who had studied in the western countries. They returned with the idea of the (closed house), which was developed in the west. But this new type of house plan has not answered the principle demands of Hebron's society, such as religious and considerations, nor has it satisfactorily met climatic conditions or proved compatible with local materials. So, the importance of the old buildings, besides their sturdiness and their resistance is that the majority of them have been available for living in until now. They also illustrate the way in which, in the past the Palestinian people solved the basic challenges of religious and social demands, climatic and economic factors, which the new architecture up to date has ignored. For example, many modern houses are detached, which the maximum area exposed to direct sunlight, and with large climatically unprotected windows. Traditional houses are mainly found in the old city of Hebron and in the old quarters, such as Haret Al Sawakneh and Haret Al Aqqabeh. They are mainly grouped around a focal point such as a community mosque, a market place, or both (Dweik & Shaheen, 2017).

Al Hoosh in Aal Aljubeh House in the old city of Hebron means the yard and it is used here in the sense of collective houses or units of houses overlooking the common yard. The families might be extended ones as the families as the families inhabited Al Ja'bah yard. This type of houses was constructed for one family that might be extended family and it includes some relatives. This style of buildings emerged because of the nature of the prevailing family structure. The family system relied on big extended family, which consists of parents and children and their families. This combination had an observable impact on the design of the housing unit, where Hoosh (yard) system appeared and deemed to be the basic unit of the urban structure. Families of the same origin got together in specific quarters. This was reflected on the overall composition of the city where such composition appeared as clusters of knit fabric resulting from the random contact and overlap of these yards. Those buildings were features by their simple design and spontaneity of architectural configuration paying no attention for decoration and the construction of facades. Security issues, infighting besides the economic factors facilitated the emergence of the pattern of buildings.

This pattern is featured by its simple shape and internal distribution. The horizontal projection is often coming in a rectangle or square shape. The internal distribution depends on the existence of an inner roofed courtyard (Iwan) where spaces are distributed symmetrically on its both sides. In most cases, spaces are distributed in one floor and sometimes in two floors. As for facades, they are very simple with no decorations or other works.

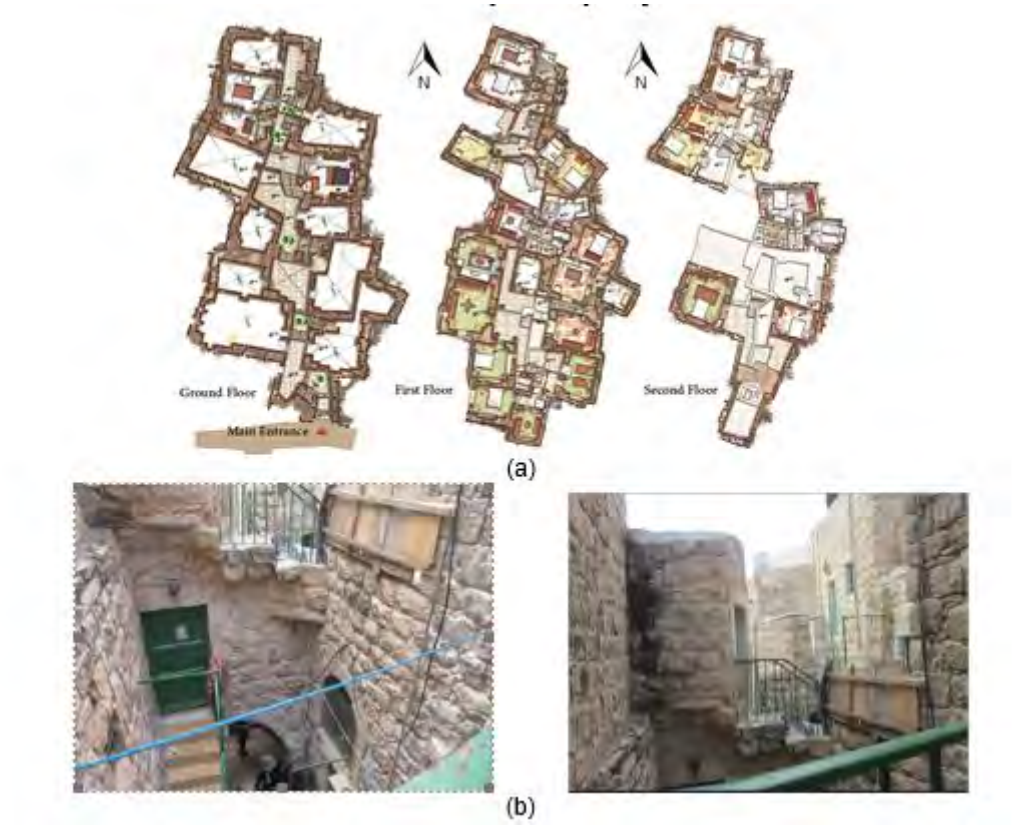


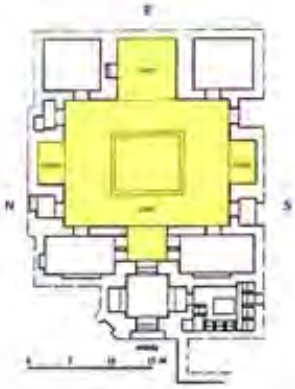
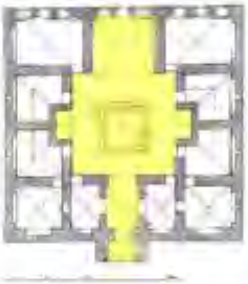
Figure 2. (a) Collective Houses overlooking the Common Yard (b) Yard shots

3. Bimaristans in the Middle East

As hospitals developed during the Islamic civilization, specific characteristics were attained. Bimaristans were secular. They served all people regardless of their race, religion, citizenship, or gender (Nagamia, 2003). The "Waqf" documents stated nobody was ever to be turned away (Rahman, 2004). The ultimate goal of all physicians and hospital staff was to work together to help the well-being of their patients (Rahman, 2004). There was no time limit a patient could spend as an inpatient (Miller, 2006); the Waqf documents stated the hospital was required to keep all patients until they were fully recovered (Nagamia, 2003). Men and women were admitted to separate but equally equipped wards (Nagamia, 2003; Rahman, 2004). The separate wards were further divided into mental disease, contagious disease, non-contagious disease, surgery, medicine, and eye disease (Rahman, 2004; Miller, 2006). Patients were attended to by same sex nurses and staff (Miller, 2006). Each hospital contained a lecture hall, kitchen, pharmacy, library, mosque and occasionally a chapel for Christian patients (Miller, 2006; Shanks & Al-Kalai, 1984). Recreational materials and musicians were often employed to comfort and cheer patients up (Miller, 2006). Concerning the technical choice of the site, they used to choose the best location with regard to the health conditions. They preferred to build Bimaristans over hills or by rivers. They also used to select the site of the best fresh air by putting several pieces of meat in the proposed sites and chose less spoiled meat site expecting to be the best fresh air one (Usaibi'ah). The hospital was not just a place to treat patients, it also served as a medical school to educate and train students (Rahman, 2004; Shanks & Al-Kalai, 1984). Basic science preparation was learned through private tutors, self-study and lectures. Islamic hospitals were the first to keep written records of patients and their medical treatment (Rahman, 2004). Students were responsible in keeping these patient records, which were later edited by doctors and referenced in future treatments (Miller, 2006). During this era, physician licensure became mandatory in the Abbasid Caliphate (Miller, 2006). In 931 AD, Caliph Al-Muqtadir ordered his muhtasib Sinan ibn Thabit to examine and prevent doctors from practicing until they passed an examination (Miller, 2006; Shanks & Al-Kalai, 1984). From this time on, licensing exams were required and only qualified physicians were allowed to practice medicine (Miller, 2006; Shanks & Al-Kalai, 1984). The following figure

presents some interesting Bimaristans in Egypt and Syria at that Era:

Hospital Information	Image	Plan
Hospital Name	Al-Mansouri Hospital	
Built in: 1248 A.D. in Cairo (Egypt) **Function:** Medical School **Capacity:** 400 beds **specialized wards:** general medicine, surgery, fractures, fever, eye diseases		
Design Courtyard-Iwan complex coupled with wind escape technique.	  	

Hospital Information	Image	Plan
Hospital Name		
Built in: 1154 A.D. in Damas (Syria) **Function:** Medical School Now: Museum **Used** till beginning of 20th century **Design:** Typical Courtyard-Iwan		
Hospital Information	**Image**	**Plan**
Hospital Name	Bimaristan al-Qaymari	
Built in: 1248 A.D. in Damas. (Syria) **Function:** Health center **Design** Typical Courtyard-Iwan **Replica to** Al-Nuri Bimaristan		

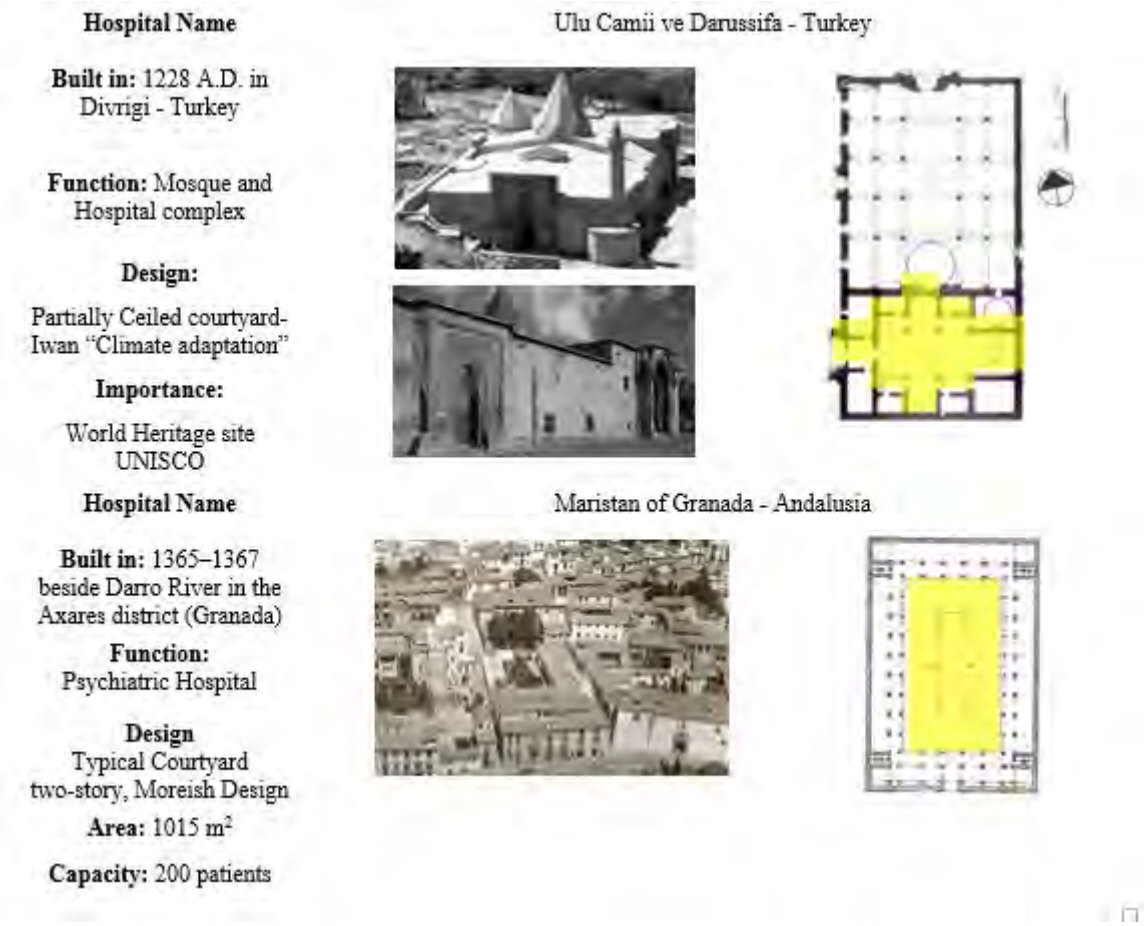


Figure 3. Bimaristan example in Syria, Egypt and Spain

It's noticed that Arabic passion for mathematics, physics, and chemistry advanced these studies, and increasingly integrated them with practical, clinical experience into medicine across the Islamic world. Islamic Bimaristans as medical institutions proliferated and spread widely in the ninth and tenth centuries, notably in Damascus, Cairo, and reached Granada in the fourteenth century (Galton, 1997; Elgood, 2010). From the previous examples we can notice that courtyard is a main element in Bimaristan design. Also, Chimney effect is used in high Iwans, domes or stairs. It was observed that ventilation was an important aspect in their design strategy. They took natural ventilation and thermal comfort in consideration from urban "choosing site and orientation" down to building scale technical details like Iwans, courtyards etc.

4. Roots of Healthcare Buildings in Europe

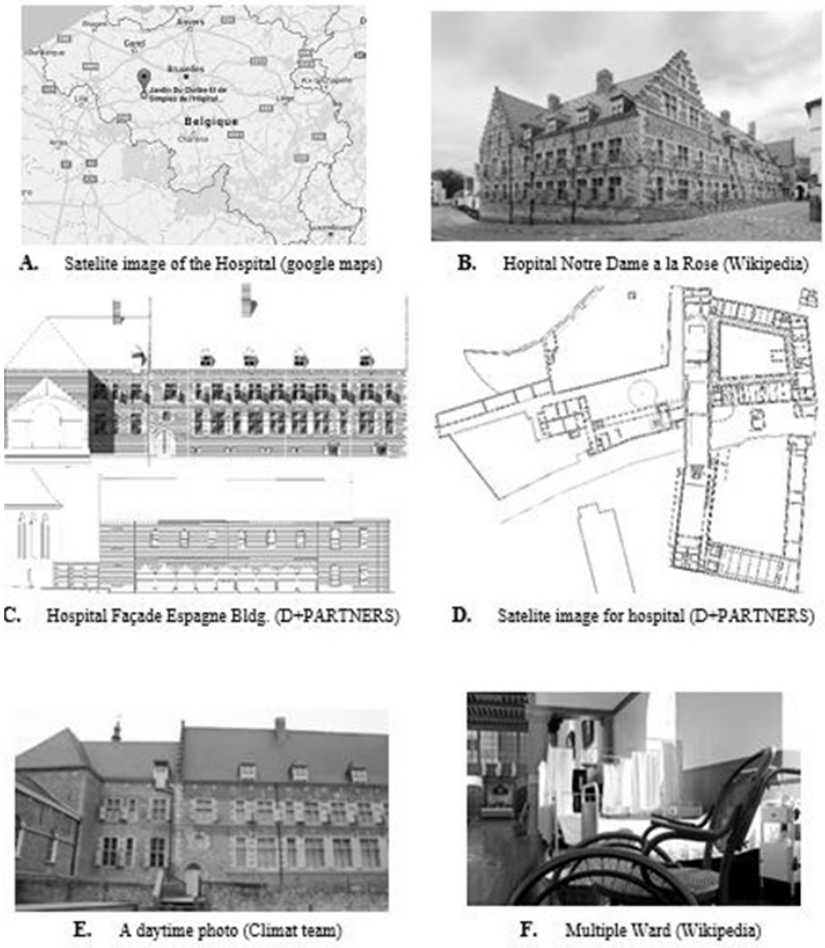
In the 18th century, under the influence of the Age of Enlightenment, the modern hospital began to appear in Europe, serving only medical needs and staffed with trained physicians and surgeons. The goal was to use modern methods to cure patients. Within the hospitals, acute cases were increasingly treated alone, and separate departments were set up for different categories of patient. The voluntary hospital movement began in the early 18th century, with hospitals being founded in London by the 1710s and 20s, including Westminster Hospital (1719) promoted by the private bank C. Hoare & Co and Guy's Hospital (1724) funded from the bequest of the wealthy merchant, Thomas Guy. Other hospitals sprang up in London and other British cities over the century. St. Bartholomew's in London was rebuilt in 1730, and the London Hospital opened in 1752. These hospitals represented a turning point in the function of the institution (Reinarz, 2007).

In the same sequence, the three major methods of heating buildings, based on hot air, hot water and steam, were all developed in the late 18^{th} and early 19^{th} century as well, largely in Great Britain. At the same time, forced ventila-

tion, based on the drawing power of heat or in the use of the mechanical means like the fan, was also established. Many problems had to be overcome. Medical doubts of ventilation, the rivalry between architects and engineers, and difficulties in reconciling design with equipment, and by the last quarter of 19^{th} century standardized the technology and made it readily available to the architects, engineers and general public. Use of new technology made possible many new architectural developments. Prison, theater, greenhouse, and hospital were largely dependent on central heating and forced ventilation. Perhaps the most profound change was in the conception of the building itself. Buildings could be seen literally in terms of living organisms or machines.

5. Hôpital Notre Dame a la rose—Belgium

The hospital in the middle Ages must have been L-shaped, situated in Lessines - Belgium along the Dendre River and comprising the present-day East wing and a part of the South wing. Building work began in 1243 till 1260. Today's building, which forms a harmonious quadrilateral around the cloister and its small garden, do not go back to the middle Ages. They were actually converted and extended between the 16th and the 18th century by priors, which followed one another at the head of the hospital. The main facade, finished in 1664, underwent the baroque influence. The chapel and the sick ward were rebuilt at the beginning of the 18th century. The farm, which used to feed the nuns and the sick, kept going until the beginning of the nineteen nineties. The mill, driven by the waters of the Dendre, meant that the hospital was self-sufficient.

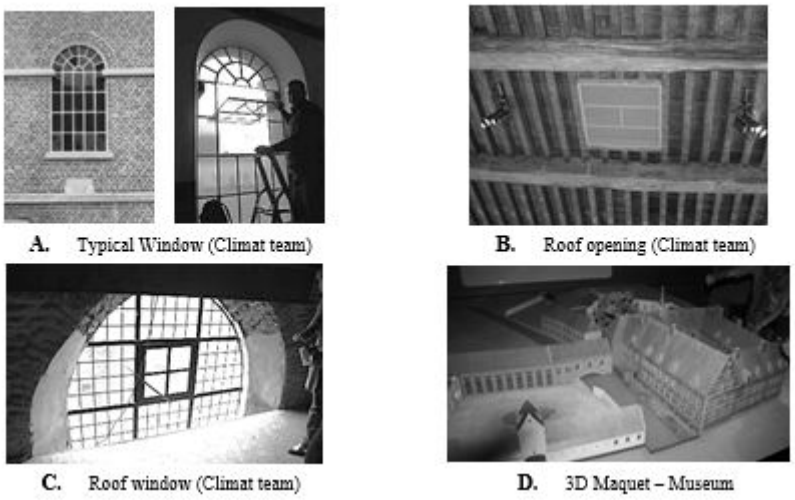


A. Satelite image of the Hospital (google maps)
B. Hopital Notre Dame a la Rose (Wikipedia)
C. Hospital Façade Espagne Bldg. (D+PARTNERS)
D. Satelite image for hospital (D+PARTNERS)
E. A daytime photo (Climat team)
F. Multiple Ward (Wikipedia)

Figure 4. Illustrations for Hospital Notre Dame a la Rose

It was noticed that small openings under and over the windows expected to be used for buoyancy ventilation. In addition, there is an opening in the wooden ceiling in the middle of the ward space, connected to the roof; the specialist in the hospital mentioned that it was used for ventilation due to thermal effect. The following pictures

clarify ventilation techniques used in the hospital.



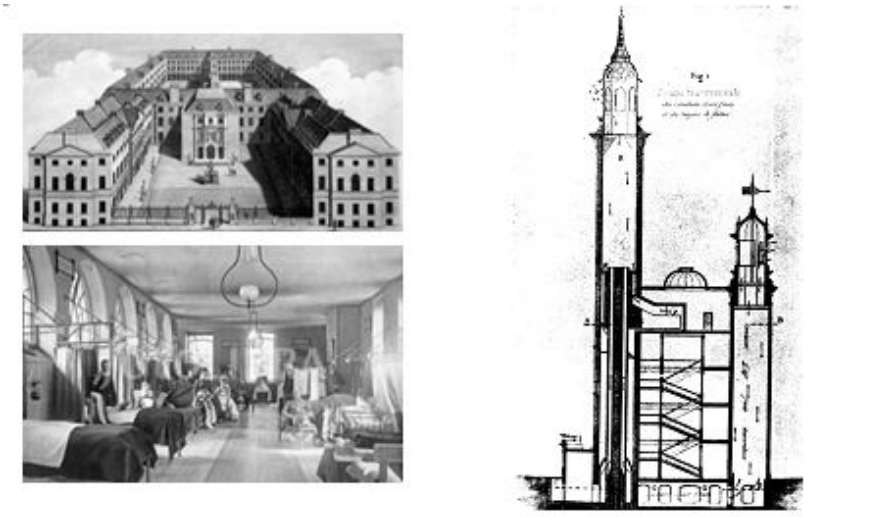
A. Typical Window (Climat team) **B.** Roof opening (Climat team)

C. Roof window (Climat team) **D.** 3D Maquet – Museum

Figure 5. Openings details -Hopital Notre Dame a la Rose.

6. Guy's Hospital — London, UK

By the middle of the 19^{th} century a glance over the skyline of London would have left little doubt that new age of technology had arrived. Above a horizon blackened by the smoke of hundreds of factories. Guy's Hospital opened in 1726 with 100 beds and a staff of 51. It was for the incurably ill and the hopelessly insane. It soon, however, developed into a general hospital. Employees included a butler and a man responsible for killing bed bugs. When John Howard, the great prison reformer, visited the hospital in 1780 bugs were still a notable problem. Nevertheless, he praised the iron bedsteads, ventilation, sanitation and new cold, hot and vapor baths. At Guy's hospital, the intake and exhaust shafts of the new ward block constructed in the 1850s rose well above the building's roof forming great towers to either side.



A. Perspective and Inpatient ward photo, Guy's hospital - London **B.** Guy's hospital, new ward block, 1850s, section of heating & ventilation system, John Sylvester

Figure 6. Illustrations for Guy's hospital – London, UK.

7. Wakefield Asylum — Wakefield, UK

The Wakefield asylum was the earliest public asylum to introduce the use of work in the building and grounds at a significant level as a form of therapy, reflecting the increasing interest in moral therapy in public asylums, as such it was influential on other public asylums. It's considered as first medical superintendent.

In addition, Wakefield asylum is an interesting example in terms of ventilation design. Subordination of a building's design to requirements imposed by heating and ventilation equipment can be found at Watson and Pritchett's Wakefield Asylum, constructed 1816-1818. A furnace based on Strutt's designs was placed at the bottom of circular stairwells centrally located in each of two sets of radiated wings. The warmed air rose into the well and escaped into the wards through a series of increasingly large transform windows. This system was coordinated with the need for surveillance, since the stairway and transoms were also used to provide uninterrupted views into the various wards.

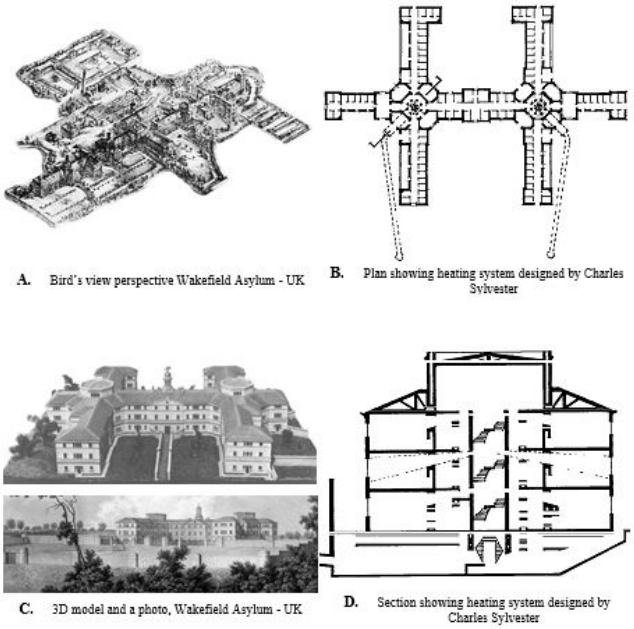


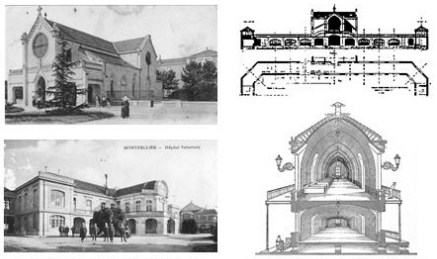
Figure 7. Illustrations for Wakefield Asylum, UK.

8. Tollet System — Paris, France

In 1874, in his first research on sanitary architecture, Tollet imagined double exterior walls, whose space between the two layers of bricks makes it possible to wash or flame inside the walls to clean them. This procedure does not find any real application but the engineer suggests that the internal dubbing of the patient rooms be renewed every twenty years for health reasons. From 1889, following unpublished studies on the sanitary properties of building materials, Tollet gave preference to millstone. Inside the sick rooms, the air introduced from the outside flows imperceptibly to orifices located at their upper part. All interior corners are rounded; the walls are covered with smooth, hard materials, accessible to washing, to buckling, and later to the disinfection. Tollet perfectly perfected the means of ventilating and heating the wards of the sick, and introducing there sanitary devices practiced abroad: dirty linen hoppers, incineration of sweepings. Organization of places of ease, etc. For about ten years, from 1872 to 1879, Toiles devoted all his efforts to promoting his system within the army for the construction of the barracks, and in the civilian world by participating in international exhibitions and hygiene congresses.

As for the hospital - Bichat, built between 1881 and 1882, it was to be the first of a series of twelve hospitals built around Paris, the duration of which should not exceed fifty years. The sickroom plan corresponds to a precise sanitary program: the isolated patients are carried into the forecourt of the buildings, the rooms are set up over

covered courtyards and the base is left free of any occupation. In this way, Tollet approaches the room of the sick, floating like one in the air desired by Leroy a century earlier. The Saint Jacques Hospital, built in 1884, is still in operation on the rue des Volontaires in Paris. As for the civil and military hospital of Montpellier, it is the most important of Tollet's construction sites, devoted to it for eleven years. Well before its completion, it is considered in France and abroad as a model of hospital architecture



A. Perspective photo, MONTPELLIER. Hôpital suburbain La chapelle

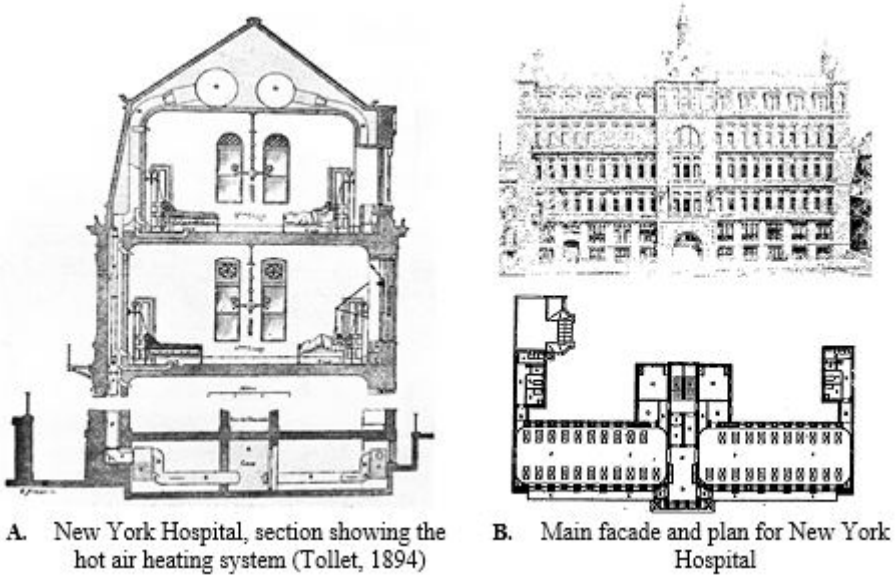
B. Façade, plan and typical section, Hôpital suburbain La chapelle

Figure 8. Illustrations for Hôpital suburbain Lachapelle – MONTPELLIER

9. New York Hospital — NY, USA

New York Hospital or Old New York Hospital or City Hospital was founded in 1771 with a charter from King George III, and is the second oldest hospital in New York City, and the third oldest in the United States. It was originally located on Broadway between Anthony Street (now Duane Street) and Catherine Street (now Worth Street) (Jackson, Keller & Flood, 2010).

In 1875, George B. Post had demonstrated to give much more logical solutions to the problem posed by the architects of the Belfast hospital at New York hospital extension. The proposed central heating and mechanical ventilation allowed the wards to be stacked vertically, solving all the problems tackled at Belfast hospital, but without sacrificing the windows (Bruegmann, 1978).



A. New York Hospital, section showing the hot air heating system (Tollet, 1894)

B. Main facade and plan for New York Hospital

Figure 9. Illustrations for New York Hospital - USA

10. Johns Hopkins Hospital – Baltimore, USA

However unlikely it may seem that useful learnings are available from pre-antibiotic era of hospital design; it is usually illuminating to unravel historical precautions to reduce the incidence of airborne cross infection through architectural form. An important movement in history was the invention of the original John Hopkins Hospital (JHH) in Baltimore (Short, 2017). The acceptance of germ theory, namely, the acceptance of disinfection as the principle means to control the spread of diseases, gained a foothold at this time. In early 1870s John Shaw Billings, probably America's preeminent authority in public health and its symbiotic relationship with hospital architecture, concluded that fresh air and hygiene must be of highest priority in hospital architecture. In 1875, Billings produced a report on military hygiene as well as a model plan for Johns

Hopkins hospital, to be built a few years later in Baltimore. The John Hopkins prototype would emphasize the continual replacement of toxic indoor air with fresh air combined with the disinfection of all hospital spaces, equipment, and patient wounds. This was done to rid the interior spaces of disease germs, microzymes, micrococci, biplasm, and germinal matter he referred to as key contribution to hospitalism (Calkins & Cassella, 2007).

Recent measurements in redundant late 19^{th} century Nightingale wards in the north of England confirm their efficiency in improving sufficient, reliable and well-distributed ventilation (Gilkeson et al., 2013). Figure below show that the final scheme for the JHH the air paths became indirect. Air is introduced in occupied ward through ducts within the external wall, either directly in warm and mid-season conditions, or perhaps via a 'diverter' through a steam coil supplied with steam at (70°C). A combination of both was possible, the 'diverter' can be employed as a mixing valve controlled by a lever within the inlet grillage just above skirting level in the ward between pairs of beds, the principle means of control accessible to nurses, patients and orderlies (Billings, 1893). Air is exhausted Billings explained, in winter and mid-season through domed mesh-covered openings in the floor and is drawn down into these exhausts because they are connected with iron pipes sweeping into a spine duct connecting to a 75 feet height chimney, 4 feet 2" in diameter, generating a powerful stack driven flows, assisted by a heating element and its base. Out of the heating season a series of 2ft by 2ft shutters at the apex of the concave ceiling connect the ward volume to a tapering duct growing in girth as it progresses towards a high level connection to the same stack. It's not clear from Billing's descriptions whether the hatches were remotely operable, as they were heavy, and built of solid timber and galvanized sheet metal. One ward was equipped with a fan supplying the basement level duct. It helped considerably in summer. The final design devotes 55.8% of its cross section to voids required by the ventilation strategy, not including the stack. Only 44.2% is actually occupied, suggesting an investment broadly equivalent to half the construction cost to eliminate transmission of a disease.

11. Royal Victoria Hospital – Belfast, UK

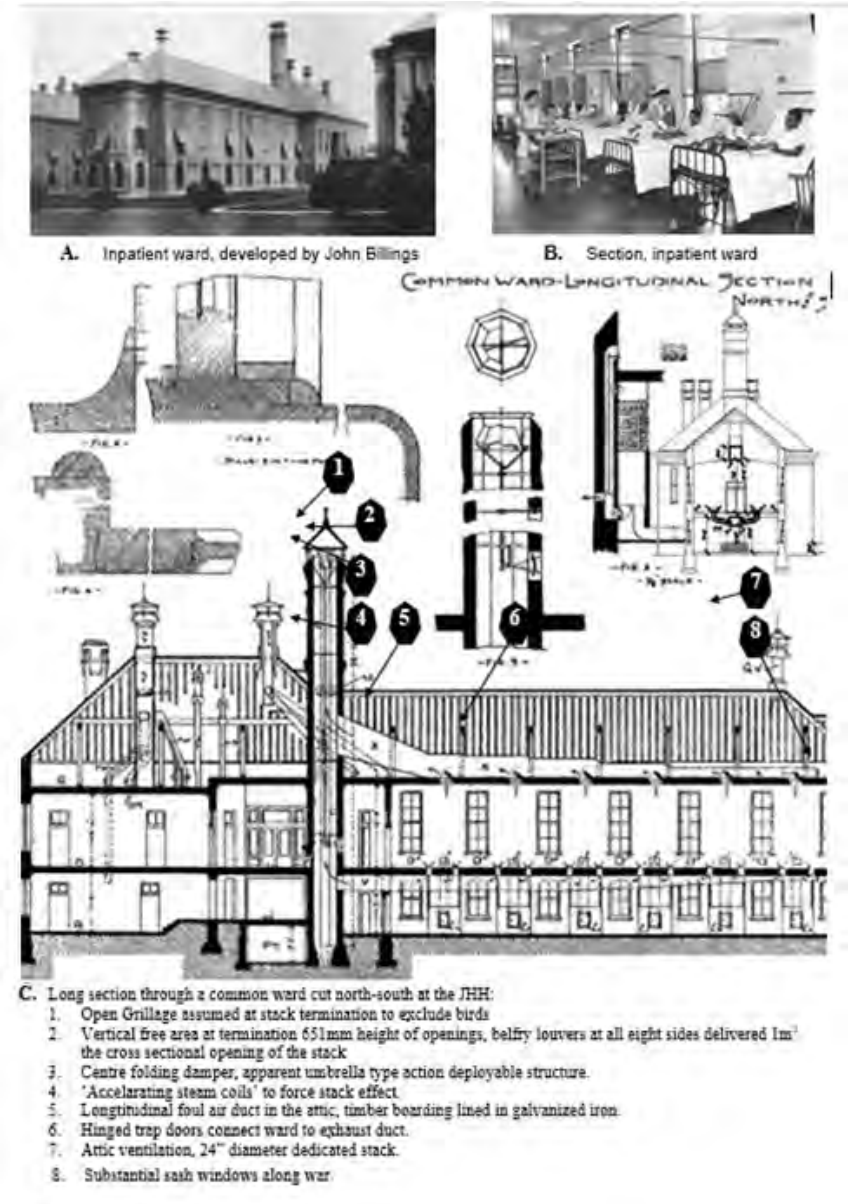
The kit of new mechanical devices for environmental management that existed by 1900 posed two different sets of radical problems opportunities in architecture. One set has to do with changes in buildings that were enforced by the employment of new devices especially finding a room to accommodate the plan, and necessary structural changes such as improved insulation to extract reasonably economic performance from them. The other set had to do with changes in building facilitated by the new devices, especially the freedoms accruing from not having to adapt the structure to husband. The very largeness of large buildings created new environmental problems, not only from the vaster bulks of structural material involved or from the greater volumes of air enclosed, but also by upsetting exterior metrological conditions by banking up wind-pressures or overshadowing large areas of ground. Large mechanical devices were used to deal with the internal consequences of these disturbances of customary scale.

One outstanding example maybe cited from the first years of the previous century, motivated by an external climate containing a local excess of pollutants, architectural form and almost complete conscious control on the internal environmental conditions are inextricably entangled. The less progressive in architectural style, but more advanced environmentally is the Royal Victoria Hospital in Belfast, Northern Ireland. At face-value, the credit for this

design goes straightforwardly to the Birmingham architectural firm of Henman and Cooper, with Henry lea as their engineering consultant. Within the work of Henman and Cooper in their design for the Birmingham General Hospital in 1893, they have applied William Key's Plenum system of ventilation to a hospital organized on the traditional pavilion plan.

The system was not a good solution because the entire hygienic motivation of the use of separate pavilions had been to promote good natural ventilation between windows and other openings on the opposite sides of relatively tall narrow buildings, and the large amount of external surface relative to the floor area would lead to a relatively uneconomic waste of heat. To get full advantage from the plenum system, a much more compact plan would be required; with as much as possible of the accommodation packed into a single structural volume in order to avoid heat wastage from underground ducts between separated buildings.

These ideas were fully achieved in the Royal Victoria Hospital where the maximum compactness of plan is combined with the minimum length of duct. This system, intended first to provide warmed and cleaned air to all the medical and surgical areas of the hospital, brought with it an additional benefit. Because the outside air was dirty in winter and also the biggest difference between external and internal temperature. In any case, the importance of



C. Long section through a common ward cut north-south at the JHH:
1. Open Grillage assumed at stack termination to exclude birds
2. Vertical free area at termination 651mm height of openings, belfry louvers at all eight sides delivered 1m² the cross sectional opening of the stack
3. Centre folding damper, apparent umbrella type action deployable structure.
4. 'Accelarating steam coils' to force stack effect.
5. Longtitudinal foul air duct in the attic, timber boarding lined in galvanized iron.
6. Hinged trap doors connect ward to exhaust duct.
7. Attic ventilation, 24" diameter dedicated stack.
8. Substantial sash windows along war.

Figure 10. John Hopkins Hospital– Baltimore

this hospital in the history of architecture lies in its total adaptation in section and plan to the environmental system employed. What makes it more interesting historically is that more than one environmental system is employed, the architecture changing to suit, for the great part of the accommodation to the 'right' of the great corridor and duct was not served by the conditioning system, which was reserved for areas occupied by the sick.

The areas occupied by the fit had conventional heating by gas fires and conventional ventilation by means of opening windows. What is immediately striking about these areas of conventional environmental control is that they do also revert to conventional architectural form in plan and section; they are relatively tall 'five full stories' and thin, so that the windows on the either side of the block.

The external massing of the various parts of the hospital thus give direct 'expression' to two different kinds of environmental management, a low, top-lit format corresponding to mechanical systems, and a tall, side-lit format to natural systems.

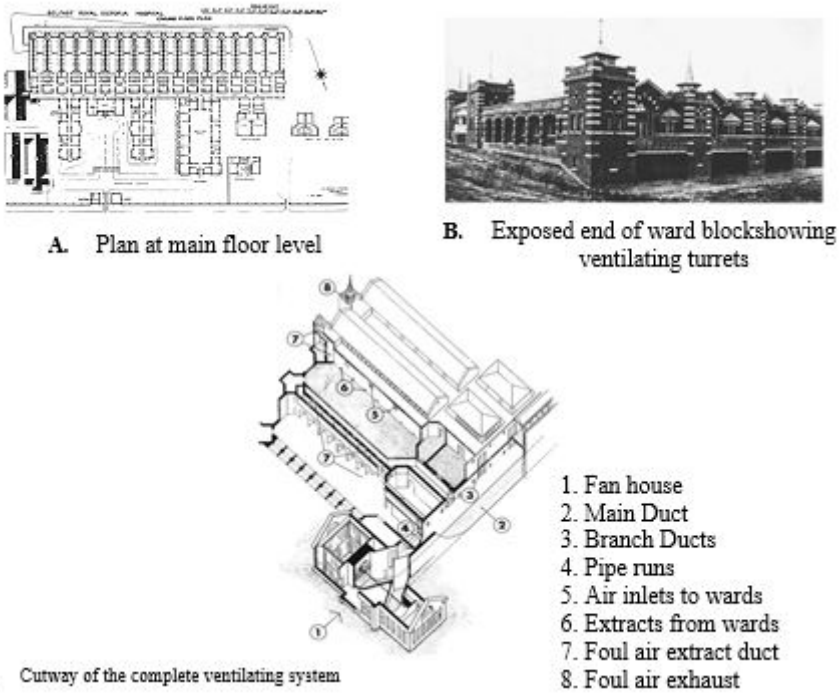


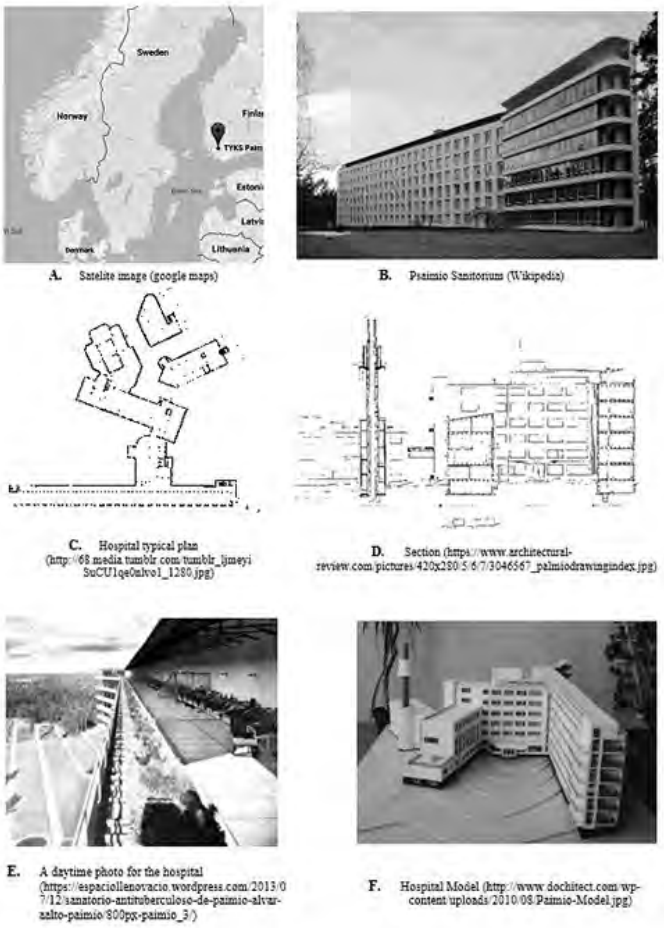
Figure 11. Illustrations forRoyal Victoria Hospital

12. Paimio Sanatorium – Paimio, Finland

Paimio hospital (1927 – 1929) by the Finnish architect Alvar Alto was seen as innovative for its site planning and sustainable architectural design. This tuberculosis sunitorium was conceived as a medical instrument itself. Before the discovery of definitive antibiotic for TB in 1944, the curative power of dry, fresh air and sunlight were emphasized to combat this disease. The hospital includes sunning balconies where patients could spend hours even in winter months. The hospital's footprint was composed of a series of pavilions connected to a main administration building. These patients' rooms and respite terraces were housed in a linear, single-loaded wing six levels in height with a roof terrace. The hospital was designed to foster a communal atmosphere for both staff and patients, who generally remained at the facility for many months. Aalto wrote what amounted to a manifesto in his submittal to the design competition held to award the commission for this hospital. He oversaw virtually every aspect of its design and construction. (Wiener, 2010).

Built with the collaboration of forty-eight surrounding communities the hospital today remains situated amid of forest. The sense of respite and the views from within, has been of therapeutic value to patients for eighty years. A series of interconnected, linear wings is bisected with vertical circulation elements. Aalto paid almost excessive

attention to harnessing and directing light, given Finland's proximity to the Arctic Circle and TB's reliance on the powers of the heliotherapy. Great care was given to window design, view orientation, aperture size and placement, their operability, and the amount of sunlight transmitted to be the interior reaches of the patient room. Windows were double-glazed and in three parts: between the double panes were placed a heating element that warms the air as it flows through the exterior. The ceiling contains radiant heat panels so that, as Aalto wrote, 'a weak patient lying in bed does not receive the strongest radiation directly, instead he is in the medium strength radiant sector' (Kucik, 2004) Wall panels of varying materials and thicknesses, and noise reduction measures, were pioneered. Public realms were similarly bathed in sunlight, with views of the surrounding landscape (Verderber, 2010). At Paimio, respite terraces were of two types: one accommodating 24 patients adjoining each ward, and a large terrace seating 120 on the roof, combined with a roof garden that allowed for seating or strolling not unlike at the Royal Sea Bathing Infirmary, in Margate, Kent, England (1878 – 1882), built fifty years earlier. Covered sunbathing balconies were also provided for the resident staff. It is both a serene and exhilarating atmosphere. In the 1960s, it was converted from a TB treatment facility to the Paimio hospital. Perhaps the most remarkable aspect of this place was that it was built in the era of pre-world war II urban skyscraper hospital being and remains a major influence on the emerging sustainable healthcare architecture movement.



A. Satelite image (google maps)

B. Psimio Sanitorium (Wikipedia)

C. Hospital typical plan (http://68.media.tumblr.com/tumblr_ljmeyiSuCU1qe0nlvo1_1280.jpg)

D. Section (https://www.architectural-review.com/pictures/420x280/5/6/7/3046567_palmiodrawingindex.jpg)

E. A daytime photo for the hospital (https://espaciollenovacio.wordpress.com/2013/07/12/sanatorio-antituberculoso-de-paimio-alvar-aalto-paimio/800px-paimio_3/)

F. Hospital Model (http://www.dochitect.com/wp-content/uploads/2010/08/Paimio-Model.jpg)

Figure 12. Illustrations for Paimio Sanatorium

12.1. Summary

Previously findings in our analysis of historical hospitals in middle east and Europe show that it's possible to benefit from ambient weather conditions to achieve an acceptable degree of comfort in case of the suitability of ambient weather and efficiency of the used techniques without bending on active techniques, which could be sometimes a

must.

There are a lot of passive techniques that could reduce the distance from comfort zone such as building orientation, shape and size of openings and building and interior geometry and many other aspects. It's preferred to study the performance of the designed building using simulation tools and have the expert consultations to ensure having the best performance of the building in light of the existing weather condition.

Historical passive techniques could be useful approaches, but ambient air fluctuations and the need of constant indoor air quality and thermal comfort raise the need of use our technology to deal with ambient weather and control indoor thermal condition and to activate mechanical and active techniques when needed. In addition, there are several constraints and limitations in ambient weather such as air pollution, noise and safety which should be considered when using ambient weather as main source of fresh air and heat exchange.

13. References

1. Belakehal, A., Aoul, K. T., & Bennadji, A. (2004). Sunlighting and daylighting strategies in the traditional urban spaces and buildings of the hot arid regions. *Renewable Energy,29*(5), 687-702.

2. Billings, J. S. (1893). *Ventilation and heating*. London: The Engineering Record. Reprinted in book orm from *The Engineering Record.*

3. Bruegmann, R. (1978). Central Heating and Forced Ventilation: Origins and Effects on Architectural Design. *Journal of the Society of Architectural Historians,37*(3), 143-160.

4. Calkins, M., & Cassella, C. (2007). Exploring the Cost and Value of Private Versus Shared Bedrooms in Nursing Homes. *The Gerontologist,47*(2), 169-183.

5. Currie, J. M. (2007). *The fourth factor: A historical perspective on architecture and medicine*. Washington, D.C.: American Institute of Architects, Academy of Architecture for Health.

6. Dweik, G. J., & Shaheen, W. S. (2017). Classification Of Residential Buildings In The Old City Of Hebron. In V. Echarri & C. A. Brebbia (Authors), *Structural Studies, Repairs and Maintenance of Heritage Architecture XV*(Vol. 171, pp. 111-122). Southampton, Boston: WIT Press.

7. Elgood, C. (2010). *A medical history of Persia and the eastern caliphate: From the earliest times until the year A.D. 1932*. Cambridge: Cambridge University Press.

8. Fathy, H., Shearer, W., & Sultan, A. A. (1986). *Natural energy and vernacular architecture: Principles and examples with reference to hot arid climates*. Chicago: University of Chicago Press.

9. Galton, D. (1997). Destruction of a hospital. *Journal of the Royal Society of Medicine,90*(7), 406-408.

10. García Granados, J. A., Girón Irueste, F. & Salvatierra Cuenca, V. (1989). El Maristán de Granada : un hospital islámico. ed. Asociación Española de Neuropsiquiatría/Asociación Mundial de Psiquiatría, pp 106

11. Gilkeson, C. A., Camargo-Valero, M. A., Pickin, L. E., & Noakes, C. J. (2013). Measurement of ventilation and airborne infection risk in large naturally ventilated hospital wards. *Building and Environment,65*, 35-48.

12. Hannen, S. (2007). *Healing by design*. Lake Mary, FL: Charisma Media.

13. Jackson, K. T., Keller, L., & Flood, N. (2010). *The encyclopedia of New York City*. New Haven, CT: Yale University Press.

14. Kaf Al-Ghazal, S. (2007). *The Origin of Bemaristans (Hospitals) in Islamic Medical History*. FSTC Limited.

15. Kucik, L. (2004). *Restoring Life: The Adaptive Reuse of a Sanatorium.* (Electronic Thesis or Dissertation).

16. Miller, A. C. (2006). Jundi-Shapur, bimaristans, and the rise of academic medical centres. *Journal of the Royal Society of Medicine,99*(12), 615-617.

17. Nagamia, H. F. (2003). Islamic Medicine History and Current Practice. *Journal of the International Society for the History of Islamic Medicine,2*, 19-30.

18. Paimio_Terrazacubierta [Digital image]. (2013, July 11). Retrieved from https://espaciollenovacio.wordpress.com/2013/07/12/sanatorio-antituberculoso-de-paimio-alvar-aalto-paimio/800px-paimio_3/

19. Rahman, H. H. H. A. (2004). *The development of the Health Sciences and Related Institutions During the First Six Centuries of Islam*. Islam: Past, Present AND Future, 973.

20. Reinarz, J. (2007). Corpus Curricula: Medical Education and the Voluntary Hospital Movement. In H. Whitaker & C. U. Smith (Eds.), *Brain, Mind and Medicine: Essays in Eighteenth-Century Neuroscience*(pp. 43-52). Boston, MA: Springer.

21. Shanks, N. J. & Al-Kalai, D. (1984). Arabian medicine in the middle ages. *Journal of the Royal Society of Medicine,77*,(1),60-65.

22. Short, C. A. (2017). *The recovery of natural environments in architecture. Air, comfort and climate*. UK: Taylor & Francis.

23. Verderber, S. (2014). *Innovations in hospital architecture*. Place of publication not identified: Routledge.