Hospital as a City: Reorganization of Future Healthcare Environments in the context of Twenty-First Century Civilization Challenges

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The IAFOR Conference on Heritage & the City – New York 2018
Official Conference Proceedings

Abstract
The twenty-first century is a time of tremendous technological breakthrough. Simultaneously with finding ourselves in the innovative world, we have to face the reality of major shifts and social problems on the global scale. Comparing to the last century, the most essential problems are demographic changes and the complexity of population. Staggering density increase in urban centers can be observed, due to a high migration rate. Furthermore, people in the world are rapidly becoming the ageing societies. According to the enormous innovations in medicine industry, which happened in terms of postwar development, humans were given additional thirty years of life. People are living longer and qualitatively better. Notwithstanding this fact, hospital units are overcrowded with people – similar to cities being overpopulated. The study explores an approach for improving future healthcare. With such strong structure resemblance between hospitals and cities, the main purpose was to identify and reveal the most critical aspects of hospital spatial organization. Research investigates both patients and medical staff. Medical personnel is particularly important, because of being literally a main employer and economic engine in societies, what was proven in the research result. Mixed methods research has been undertaken in order to compare both quantitative and qualitative data. The collected information through surveys was juxtaposed with peculiar design examples within healthcare facilities. Spatial organization and its efficiency plays a meaningful role in advancing care quality and overall hospital performance, what impacts significantly on public city infrastructure, sustainability and the local environment.

Keywords: *healthcare architecture, medical technologies, hospital optimization*

Introduction

To design a well-working hospital nowadays is remarkably challenging responsibility. Designing a healthcare facility differs significantly from other architectural buildings, due to highly advanced medical technology in the building structure. The proper hospital planning equals to optimal spatial conditions creation needed for realization of medical procedures. In every architectural design field architects are obligated to use the Vitruvius rule: "firmitas, utilitas, venustas". "Function, form and construction" is a classic definition repeated for centuries and its meaning is particularly essential during hospital design. The space within hospital facility should be organized in the way to let users function naturally and perform duties easily.

When the key objective is human life and health, the perfection of functioning is crucial.

It is well known fact, that medicine and architecture change and develop constantly. More and more research is being conducted among scientists involving those two disciplines. After analysis and adaptation of the results, solutions for hospital optimization are developed in order to increase recovery effectiveness and ameliorate patient's treatment.

There are several researches and projects carried out in the world, which make people aware of a revolution that is slowly taking place in the field of healthcare. Along with the significant advances in *medical technology*, responsive progress must be made in *architectural technology*. Most importantly, architecture must adapt to these technologies, as well as the city must adapt to the new hospital structures.

Hospitals are the inherent fabric of cities and self-sufficient organisms that are inseparable with the other urban parts. City and hospital affect each other, sometimes mutually exclusive but mostly beneficial. In this article the bilateral effect between two urban fabrics named as: "city agglomeration" and "medical agglomeration" is studied.

HOSPITAL AS A CITY: Columbia University Medical Center Case Study

Columbia University Medical Center in New York City is a perfect example of circulation between the two mentioned above organisms. The "city agglomeration" describes the parts of the city, that are not directly related to health, but should be health-promoting, whereas the "medical agglomeration" is the hospital areas, that are characterized as illness-fighting, disease-related. The total area of the medical center is over 130,000 square meters[1]. It is comparative to a city district, the size of a few modern housing estates. For instance, the CUMC area is 8 times bigger than a block from Manhattan. The average number of people living in one block would be circa 1,400 people per block[2], what gives 11,200 citizens. By comparing the data, it can be observed, how extensive exposure into the surrounding environment is made in the case of CUMC campus and how valuable is the presence of such massive medical center in strict urban fabric. What is more, other hospital units correlated to this center

[1] Columbia University Irving Medical Center (CUIMC) site: https://www.cuimc.columbia.edu/about
[2] Department of New York City Planning site: https://www1.nyc.gov/site/planning/index.page

are scattered all over the city, giving the impression of entering and affecting the close, concentrated urban pattern. The highly advanced hospital campus is composed of multiple hospitals, institutes, schools and colleges.

It is a strong fact, that hospital is a place, which is rather not friendly associated. Yet, it has a major power to control the city balance. Hospitals as buildings should be transfigurative and adaptive from the viewpoint of the function. They are a main employer for a lot of citizens. The way hospitals are located in the city structure influences significantly the local environment. What is more, the existence of well-working functionally healthcare facility is a strong economic impulse and it brings profits to the city. Hospital should be a place entirely opened to people. Also, as an institution, it is probably the only one, that must work constantly 24 hours per day, the whole week, the whole year. All of the mentioned features describes perfectly the work inside of the Columbia University Medical Campus, that might be exemplified wider as an outline for future hospital urban planning, which completes well the urban city context with its extensive form and cubic capacity.

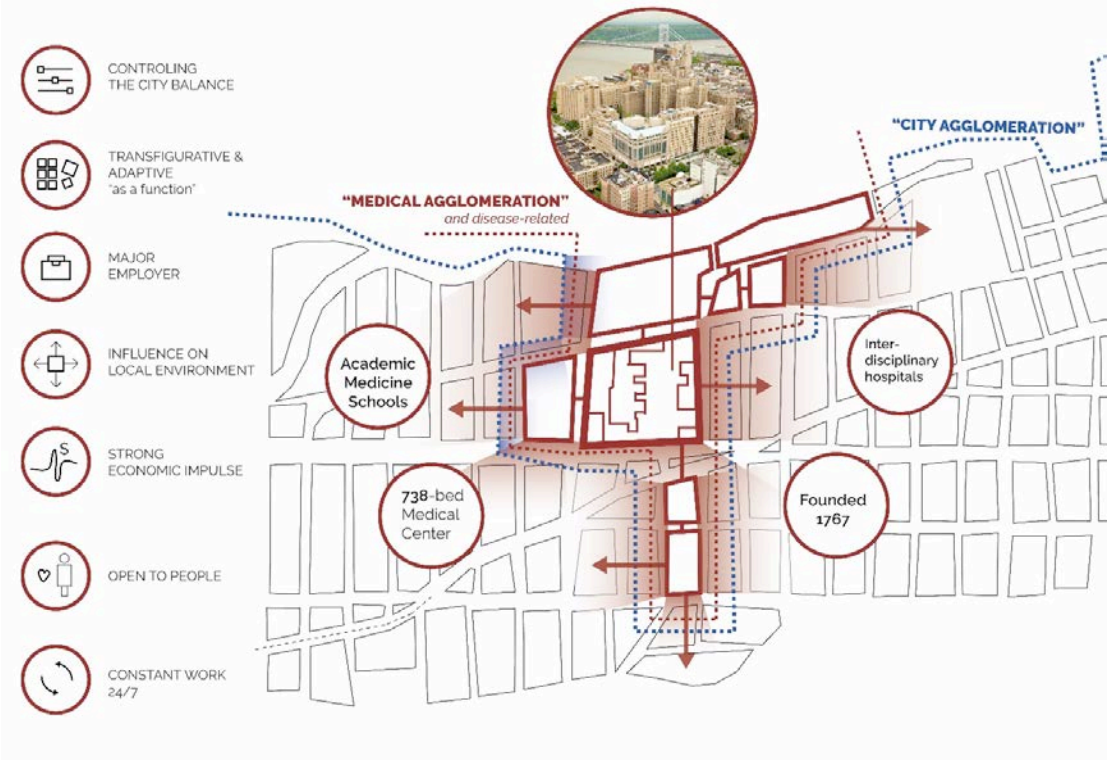

Figure 1: Columbia University Medical Center as a case study. Author's graphic design.

Healthcare in the light of social problems and challenges of XXI century

Characterizing the work of hospital structures and trying to place them upgraded in the future planning is not scientifically sufficient. Multiple external factors influence the current condition of healthcare.

There are particular issues and challenges occurring in XXI century, which are observed to exacerbate in the next years. As a result, the vision of healthcare from the viewpoint of both patients and personnel will be spectacularly changed. The three

main problems to cope with, are: ageing population, increase of urban areas and migration.

One of the problems result as staggering demographic changes in comparison to the previous century, also, as well as population complexity. All European countries are aging societies, what is associated with the phenomenon of less children being born and people living approximately one generation longer than before, due to appealing career perspectives and better healthcare provision. Already in 2020 majority of nations will have over half of the populations visibly aged, with a low birth indicator[3]. As a consequence, much more adults and elderly people will require professional medical care and hospitalization.

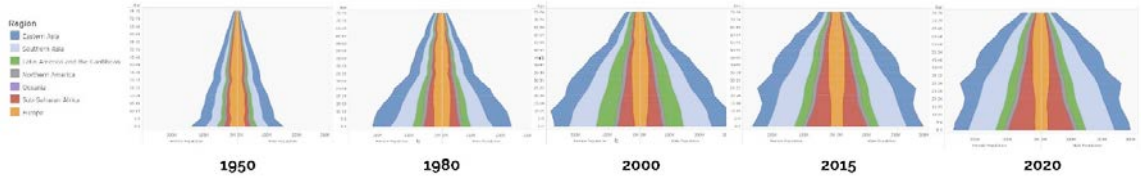

Figure 2: Population structure through centuries.

Moreover, there is a constantly increasing density of metropolitan areas around the world. Almost half of humanity live in developed urban centers. Statistics show a rapid urban grow, already in 2050. Up to 2,5 billion of people (that is 13% more of the whole world population) are projected to live in urban areas, newly designed or expanded. It is estimated, that 90% of areas around the globe will become urbanized in the end of the 21st century.[4] Resultantly, the priority and mission of metropolitan healthcare services will be the establishment of new healthcare facilities capable of hospitalize more citizens in the most efficient way.

Another prognosis pertains to migration. People struggle with war all over the world in order to defend their own homes and neighborhoods, simultaneously with seeking for safety and better life somewhere else. In the figure 3, the amount of people abandoning their homelands can be observed[5]. This situation creates questions on how to help quickly recreate what had been destroyed and how to provide care in a modular and mobile way.

Furthermore, the health policy has changed radically. The breakthrough in development of medical achievements, such as: implementation of hygiene and sterility principles, genetics, diagnostics, transplantation, antibiotics, geriatrics, balanced nutrition and new management methods allow for longer and dignified life. However, the protection against diseases from the last century did not excluded the occurrence risk of the new ones. The generation of longevity have to face new health issues - civilization diseases.

[3] The Oxford Institute of Population Ageing: https://www.ageing.ox.ac.uk/publications
[4] United Nations World Urbanization Prospects 2018: https://population.un.org/wup/Publications/Files/WUP2018-PressRelease.pdf
[5] United Nations World Urbanization Prospects 2018: https://population.un.org/wpp/

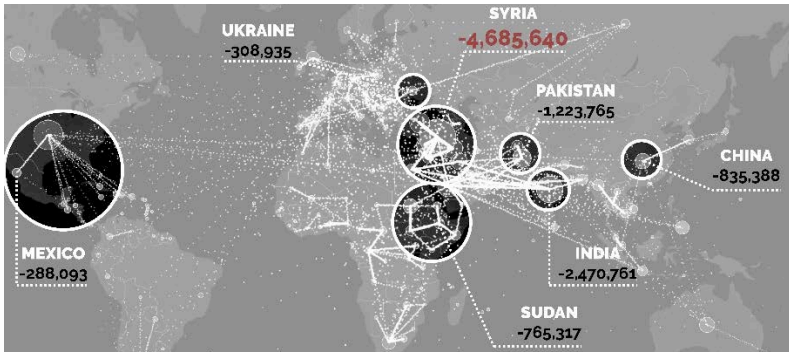

Figure 3: Migration map. Author's graphic design.

The priority concerns for 2019 are still elemental, for instance, the expansion and upgrade of water systems, educational and employment opportunities for everyone. There are also adopted safety programs, like "Strengthening Security Standards for Refugee Resettlement". The most essential one is concessional financing to build schools and hospitals[6].

All above-mentioned factors pursue questions: How to design a city for the sick and aging citizens? How to act nowadays and in the future, in the context of new diseases and social problems occurrence? In the conducted studies, the problem was analyzed starting from architectural space planning, to specific solutions to ensure users of the maximum comfortable life, with a healthy, multifunctional form, conducive for recreation, balanced lifestyle and promoting prophylaxis. As much as city changes, twice this much hospitals and healthcare policy should innovatively change.

In the light of all the problems of 21st century, the unnecessary errors, which could endanger the health and life of medical personnel and patients must not happen.

"The Personnel-Centered Study for Advancing the Hospital Care" Research - methodology and results

The carried out research on advancing the hospital care is founded on empirical observation, case studies and inferences from data collected via questionnaires. The research was done by the author in the scientific team at Faculty of Architecture in Poznan University of Technology in Poland, published on the poster at European Healthcare Design Conference in London[7], June 2018. The meaning behind the title "The Personnel-Centered Study for Advancing the Hospital Care" refers to author's theory, that w*hen personnel has a chance to perform at the workplace easily, the patient will recover and rehabilitate easily.*

The object chosen for research is Pediatric Hospital in Poznan, Poland. Among 3.484.975 citizens of the region, who the hospital services, there are 11.000 doctors and twice as much of nurses employed. It is discernible, that there are only 32 employed doctors and 13 nurses for 10.000 citizens, while the whole number of citizens in the Poznan agglomeration is 647.018[8]. The part of methodology was a 12-

[6] Table of Contents Congressional Presentation Document Bureau of Population, Refugees, and Migration (PRM) FY 2019: https://www.state.gov/documents/organization/285785.pdf
[7] Poster: http://www.salus.global/article-show/ehd2018-p08
[8] Data from the Polish Central Statistical Office GUS: stat.gov.pl/

item questionnaire, which respondents were polish doctors, nurses and other personnel management.

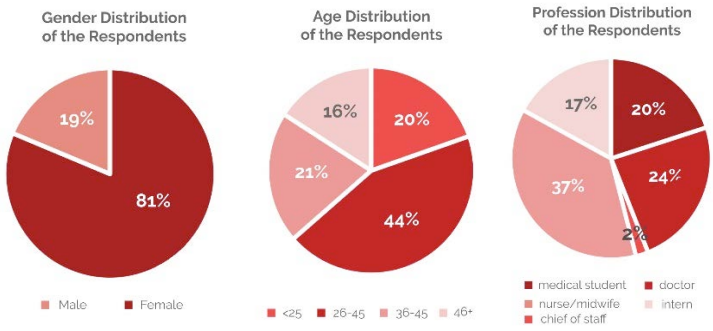

Figure 4: Part of a questionnaire: respondents characteristics.

It is inferred from the concluded questionnaire, that medical personnel in polish hospitals is encumbered with physical work in predominantly non-ergonomic environment, with an extensive need for improving the working space and necessity for new technologies implementation. The personnel had a chance to comment on what exactly is unsuitable during their work and in the hospital architecture. Analyzing the results, it is clear, that lack of integrity dominates in polish hospitals, quoting: "lack of designated space for patient consultations", "cramped spaces", "no access to the bed from any of 3 sides", "too narrow doors", "too little space dedicated to examine a patient", "lack of overall architectural cohesion".

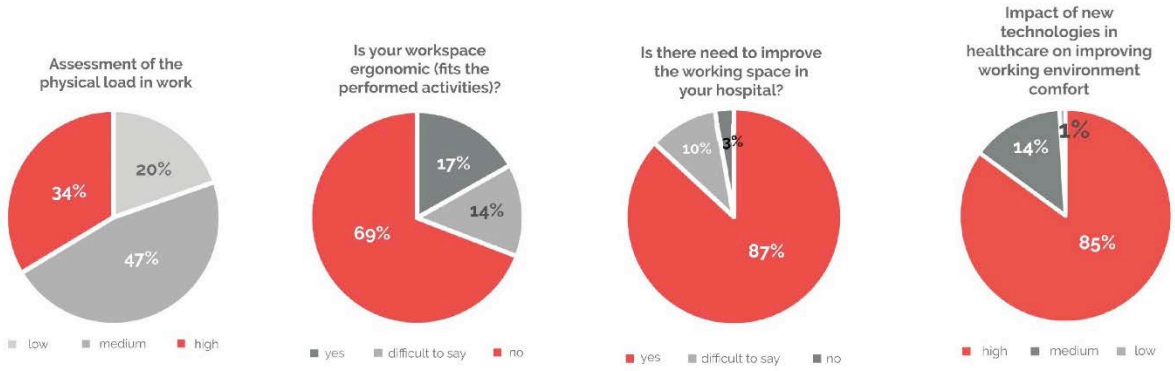

Figure 5: Part of a questionnaire: graphs illustrating personnel working conditions.

The second item to mention from the questionnaire refers to perpetration of medical errors. Respondents say, that the causes of medical errors are mostly exhaustion at work, lack of time and space to rest, unsuitable equipment but also lack of knowledge. In the era of technological peak, there is still a lot of work to do in the area of providing an humane place to work and to heal. The statistics show that 24,7% of medical treatment in Germany ended with medical errors in which 19,9% ended with direct health damage.[9] From the 2017 data, there are 251,000 lives lost due to medical errors in the United States.[10] However, in Poland, it is impossible to observe the quantity and frequency of medical errors, while the official register does not exist.[11]

[9] Statistics on medical errors in Germany: https://aok-bv.de/presse/medienservice/politik/index_20679.html
[10] Statistics on medical errors in the USA: https://www.ncbi.nlm.nih.gov/pubmed/28186008
[11] Statistics on medical errors in Poland: https://rejestrbledowmedycznych.pl/

All in all, the presented data are the apt summary of how the innovative achievements in healthcare architecture design created parallel variety of other problems in the last decades.

Hospital Optimization. ***Optimized hospitals study cases.***

According to Gensler Research "Impact by Design: Resilience strategies shaping the future of cities"[12] from 2018, the term *resilience* is, in fact *the new sustainability*. Optimization is an upgrade to functionality, by merging two factors: operational performance and human experience. These combined, optimized systems will also connect to other urban systems and infrastructure. Those two systems can be dynamically managed in response to real-time conditions either by building medical staff and automated algorithms (AI, machine learning); or a combination of the two.

The history of forming the hospital interiors proves how strong is the correlation between patient and personnel and also implies how to maximize and humanize the correlation.

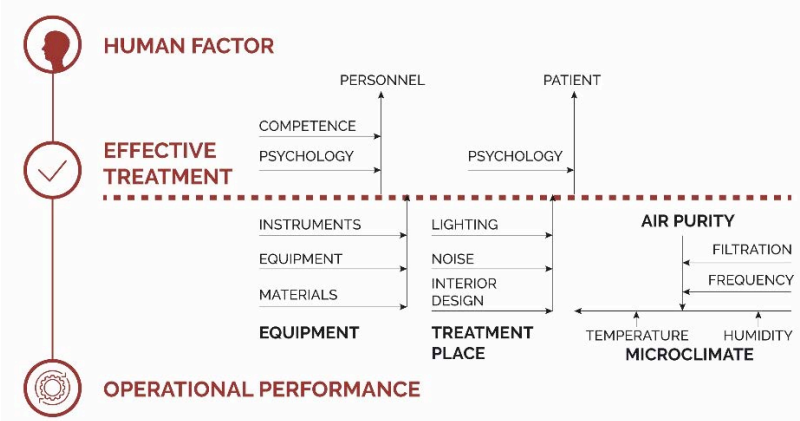

Figure 6: Hospital optimization components. Author's study and schema design.

Already in XIX century, when a shortage of dignified hospital care commonly existed, a world-famous nurse and caregiver, known as Florence Nightingale developed a comprehensive publication "Notes on Hospitals". She collected mistakes made by architects then and commented on them from her own viewpoint - a viewpoint of an experienced nurse. During the elaboration, she specifically paid attention on room ventilation issue, capacity of a ward and a patient room, equally with location of hospital wards to administration section. She distinguished functional forms such as two wards in line, central administration, with projecting center or separable wards. What is more, she precisely wrote, that architects should avoid designing long corridors in hospitals and overloaded rooms with patient beds in case of minimizing infections. In 1890, John Marshall, British anatomist and surgeon, Professor of Surgery at University College and Anatomy at the Royal Academy in London invented the system of circular wards for hospitals. Marshall's strongest arguments pro-circular wards were similar to Nightingale's opinion: improving opportunities for light, air, and ventilation. With the ward's openings and corridors disposed evenly around it, Marshall made an analogy with the circular tent, and the

[12] Gensler Research on Impact by Design: https://www.gensler.com/research-insight/sustainability/2018

freedom of natural ventilation. Professor's research can be seen as marginal in terms of the overall hospital-construction programme in England. Yet, the eight of his projects were built. Though, as a variation in ward planning, and in the manipulation of the form of the ward space in hospitals, the idea launched by Prof. Marshall had achieved a recognizable place in healthcare design of the 1890s.

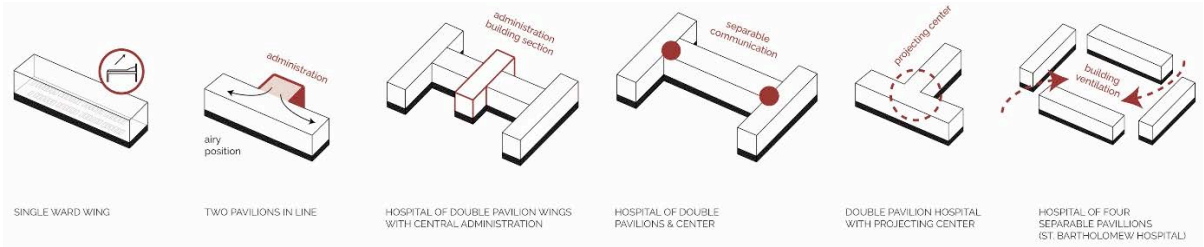

Figure 7: Florence Nightingale's 1863 research on
Hospital wards space optimization. Author's study and schema design.

Over 100 years later, Jane Jacobs, American journalist, and activist who influenced urbanism studies, sociology, and economics, made a research on rapidly increasing in number circular nursing floors. She tried to reveal if there is a relevant idea between the theory that, "*if nurses and their equipment can be stationed at a point absolutely central to the patient they serve, travel time and energy can be reduced to minimum and if the proportion of patients who can be seen from the station is increased, fewer trips are presumably necessary.*"[13] It is claimed, that a circle is the most economic form for enclosing an area. An interesting research conducted in 1958 by Herbert P. McLaughlin and analyzed by Jacobs, considers series of comparisons between round and rectangular schemes of nursing units in three area sizes: 40-bed nursing unit (7379 sq. ft.), 24-bed nursing unit (4866 sq. ft.) and 12-bed nursing unit (3635 sq. ft.). The result of the research comparing round and rectangular nursing units shows, that average distance of nurses station to patients' bed is 53 ft. in round and just 46 in rectangular. Total area is much bigger as round one, but the perimeter of exterior wall is smaller than in rectangular one. There is also smaller distance to check all of the patient beds. Apart from that, the cost variations between round and rectangular units are not significant enough to influence and change the major considerations regarding design for better optimized nursing unit. McLaughlin's efficient rectangles suggest possibility, that it might be "purer" to achieve better circular nursing floor inside rectangular than inside literal circles. Furthermore, the esthetics of circular units are rather questionable. In plan, they look architecturally reasonable, because of the completeness of the form and solid simplicity. However, in elevation they become buildings in the shape of cylinders.

All in all, the trend of making nurses wards in round faded away, but one thing lasted - the concept of round nurse station. Due to accessibility and working convenience, the circular form allows to facilitate monitoring all of the patients.

In 2015, the TIME magazine published the results of research on future hospital interiors, involving vice president of SKANSKA company - Andrew Quirk and design office NXT Health. SKANSKA contributed to implementation of the design

[13] Jacobs, J. (July, 1961). Hospitals in round. Architectural Forum Magazine, Volume 115, Number 1. p: 98-102. Time Inc. New York, N.Y.

by building the prototype of the model future-patient room, designed by NXT HEALTH design office.

The space in "Patient Room 2020" is adapted and designed in the way to improve the quality of care and the performance at most. By doing the observation of future design hospital interiors from the past, it can be noticed, that the research was based on one constantly being repeated aspect: changing the details of composition in terms of interior architecture. For instance, many research papers exist, concerning color as an influencing factor on patients mental health. For this reason, majority of hospital renovations consist only of repainting hospital interiors. Project Patient Room 2020 is not only about modernizing patient room, but more about the perspective of futuristic technology-oriented design.

From patients' psychological point of view, they wish to stay in the hospital the possible shortest period of time. However, when it is a necessity and there is no other choice, than to recover in the hospital, it is wished that the place, where patients are staying would be a clean, neat one, designed in a comfortable and friendly environment.

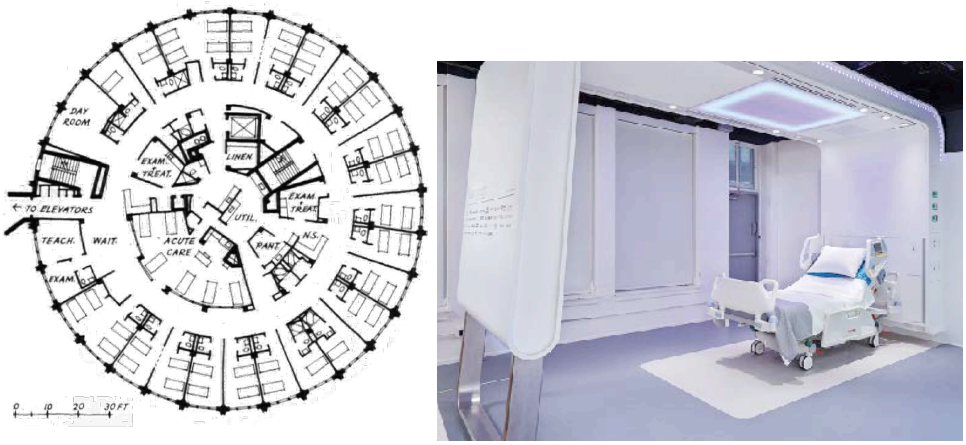

Figure 8: Round shaped nurse ward from Jacobs's analysis and Patient Room 2020 design.

The essential aspect is patient's safety. Unsafe surroundings are a major issue for healthcare institutions. Data provided in Health Management in 2014, show that "*In the U.S. an estimated 1.7 million Hospital Acquired Infections (HAIs) occur each year in hospitals, leading to about 100,000 deaths and $28-$33 billion in excess costs.*"[14] Infections are completely preventable, thus hospital room design can have a positive effect on medical personnel work ergonomics and comfort, as well as the proper design provides good hygiene conditions and infection control. Especially when the entirety is architecturally cohesive.

One of the innovative ideas used in the project is special flooring, that prevents patients from falling and injuring. This concept creates simplified correlations between patients and personnel. The floor monitors patient's steps and sends alarming

[14] Campbell, L. (2014). The Patient Room 2020: Next Generation In-Patient Care. Health Management, Volume 16, Issue 1/2014.

report to personnel in case of accident. Moreover, the other facilities, like: computer station located in the room and Wi-Fi network provide insight into the patient disease history.

To sum up, the idea of modern "Patient Room 2020", is a surely proper way to strengthen medical personnel state of mind and gives more upgraded perspective on hospitals, than those that are within reach nowadays. As Andrew Quirk said: "If we even have one element in here, that is incorporated into a hospital, that is a success".

Conclusion. Results of research and implementation.

The final diagnosis of critical areas research and their spatial sense in existing hospital modernization shows, that architects should take care mainly of redesigning patients' rooms, areas dedicated to the personnel, completing areas dedicated to treatment rooms and reorganizing through improvement of communication channels.

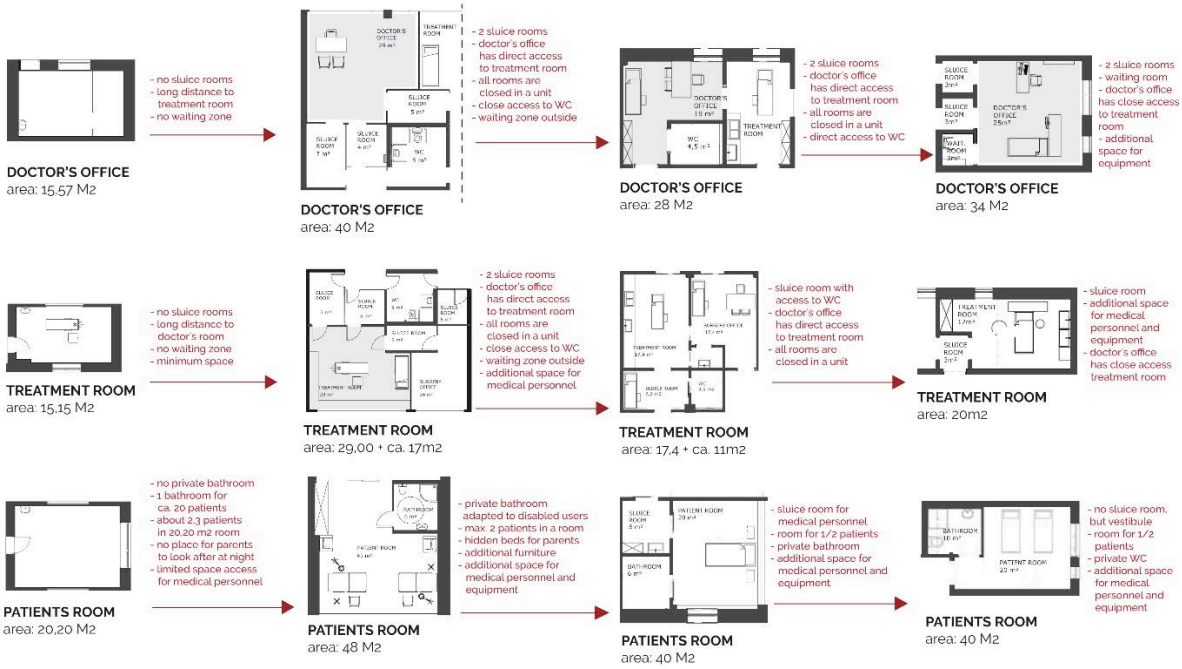

Figure 9. Diagrams of arrangement problems in the concept of modernization project of Sporna Hospital. Author's study and schema design.

Figure 10. Analysis of communication channels and paths. Author's study and schema design.

It must be noted, that apart from implementing the innovations, hospital should have a positive impact on environment, by its good form or adaptation, materials used, energy consumption and intelligence. The technology used in hospital should be exploited at most and properly. It should become upgraded from sustainability to resilience – the capacity to recover quickly from difficulties and supported by sustainable policies and strategies.

Hospital itself is a heritage, a history of humanity in a nutshell and it should be created with responsibility and concern for surrounding environment, with a view to building humane environment for future generations.

Hospital is a place, which accompanied people strictly from the cities foundations. In the past, hospitals were just poorhouses located near churches. People came there not exactly to be cured, but more to die peacefully. Hospitals' walls and workers had seen so many pain and illnesses that no one ever should experience. But also, they were witnesses of miracles and the majestic force of life. The tremendous breakthrough of hospital technology began in XIX century. There were icons like Nightingale, Sklodowska - Curie, Lister, Roentgen, Fleming and many more, who changed the vision of today's medicine. It is relevant to mention, that every hospital should take an example from Presbyterian Hospital in New York City. A slogan "Amazing things are happening here"[15] is a signature sign of this hospital, and amazing things should happen in every example of architecture craft, that architects create those days, especially in the wake of so many social challenges, especially in hospitals.

[15] "Amazing things are happening here" Project: https://www.nyp.org/amazingthings/

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