EMERGENCE OF NANOMATERIALS IN INTERIOR ARCHITECTURE OF HEALTHCARE DOMAIN

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ABSTRACT
In the light of contemporary advancements in technology, architecture and interior design have been immensely progressing every day. While emphasizing the superiority of nanomaterials in favor of sustainability and maintenance, this paper focuses on these advanced materials and their specialties through their use in healthcare design, specifically their use in the patient rooms. The key reason behind this decision is that, healthcare centers are the most energy consuming building type after food industry, which use more material and resources. For this purposes the role of embodied energy and embodied carbon emissions are getting important for this case. The aim of this research is the analysis and discussions about the types of the nanomaterials that are used particularly in the patient rooms, and reveal their impacts in relation with indoor comfort conditions regarding self-cleaning and hygiene; thermal comfort (insulation as well as filtration of excessive natural light); indoor air quality (not causing pollution, lack of VOC's) etc. This paper further deploys case-based research methodology by selecting the contemporary hospital examples from Istanbul, where both nanomaterials and conventional materials are utilized, in order to set the material performance comparisons. Istanbul based LIV, Kolan and Medicana hospitals' patient rooms have been chosen as the case studies of this paper to reveal the discussion.
Keywords: *nanomaterial, interior architecture, healthcare design, case studies*

I. INTRODUCTION

By playing a significant role in the field of architecture and interior design, materials not only affect building forms and functional performances, but also perform immense impacts on environment as well as human health. Earlier times, materials appear as simple followers of the functional and formal configuration of space, and reciprocally affecting the form language of the design output due to their characteristics. However, technological advancements and rapid developments in the realm of material sciences have paved the way to the emergence of new design practices like in the case of shifting aspect from modern architecture into nano-architecture. These technological advancements have also triggered the development of novel synthetic materials, such as composites and nanomaterials, whereas these novel materials have begun to play an active role in both early phases of design process, as well as the thought of architecture and the way how architects think.

Materials that are made out of nano-matter that are the substances, which possess extraordinary physical and chemical characteristics in the nano-meter scale in terms of intrinsic and extrinsic capacities. These differences of characteristics cause the differentiation of the nanomaterials in type. This paper, describes and analyzes particularly these different types of nanomaterials, and discusses their impact within the architecture and interior architecture realm at first by generally, then by specifically through the contemporary cases from healthcare facilities, meanwhile particularly by focusing on the use of nanomaterials in the patient rooms.

Recently, the manufactured nanomaterials (MNMs) or nano-composites, which are produced by manipulating their physical and chemical properties have been deployed in diverse fields of construction and design. These materials in architecture and interior architecture are mostly utilized as coatings, like insulators and air-purifying surfaces; or in furniture and related products, which enhances flexibility, physical durability and strength of the materials; or in the implementations related with the maintenance like energy conservation, self-cleaning and anti-bacterial properties. Therefore, nanomaterials open up a brand new page in design, both by being reliable and sustainable alternative for natural materials, as well as for the environmental sustainability in global terms in the presence of counter and indirect relations of consumption and maintenance facilities.

Departing from these facts, this paper focuses on majorly unfolding the range of the nanomaterials and their properties and the frequency of their use in interior architecture, particularly in the milieu of healthcare domain and the patient rooms. The key reason behind this decision is that, healthcare centers are the most energy consuming building type after food industry, which use more material and resources. For this purposes the role of embodied energy and embodied carbon getting important for this case. This paper also deploys case-based research methodology by selecting the contemporary hospital examples from Istanbul, where both nanomaterials and conventional materials are utilized, in order to set the material performance comparisons.
In this regard, LIV Hospital-Istanbul, Kolan Hospital-Istanbul and Medicana Bahçelievler Hospital-Istanbul are selected as the case-studies, to dismantle the use of nanomaterials in the patient rooms; the material characteristics, the frequency of the material use, and the financial dimension of the material use, in order to highlight the superiority of nanomaterial use in healthcare design.

II. TYPES OF MATERIALS DEPLOYED IN ARCHITECTURAL DESIGN AND IMPLEMENTATION

Nanotechnology has been an essential and the foremost technological step in 21st Century, it is worthwhile to notice that significant properties of nanomaterials as well as their characteristical attributes in favor of environmental factors do clearly indicate a vast promise in every fields of architecture and interior design.
We observe wide range of supplementary use of nanomaterial, which are targeted or oriented to enhance the material qualities on behalf of improvement, long term use and maintenance purposes such as: self-cleaning (Lotus Effect and Photocatalysis); air purifying; anti-fogging; thermal insulations (Aerogel); temperature regulation (PCMs); solar and UV protection; protection; fire-proof; anti-graffiti; anti-reflective; antibacterial; anti- fingerprint; scratchproof and abrasion-resistance, which are briefly explained as follows.

a) Self-cleaning qualities
a1) Lotus effect: Lotus effect is one of the best-known means of designing surfaces with nanomaterials. Self-cleaning behavior is normally achieved using hydrophobic surfaces with nanostructured features (Anous, 2014). These products are inspired by the lotus flower leaves that combine a surface roughness at the nanoscale and the water repellent wax at the same time (Leydecker, 2008). The leaves of Lotus plants are coated with minute wax crystals around 1nm in diameter, which repel water droplets falling onto them bead up and, if the surface slopes slightly, will roll off (Leydecker, 2008). So, lotus effect surfaces with water-repelled property could clean the organic dirt, while water droplets are rolling down. For this reason, these products are better to apply on the materials which have more contact with water such as building facades, bathrooms, and toilets etc. surfaces that are open to water contamination.
a2) Photocatalytic: Photocatalytic self-cleaning is the property of surfaces coated with titanium dioxide ($TiO2$) nanoparticles (Anous, 2014). Its properties are super-hydrophilic of the surfaces witch are created by oxygen gaps on the $TiO2$ surface (Anous, 2014). In fact, this substance significantly decreases the number of cleaning times by extending the intervals between cleaning periods (Leydecker, 2008). When the sunlight reaches to the material, the existing organic dirts on the surfaces decompose with the help of catalyst reaction and dirts are cleaned by means of rain water (Leydecker, 2008). Self-cleaning photo catalysis substances are invisible nano-based products, that could be added into concrete or could be applied onto facade panels made of glass and ceramic or to membranes (Leydecker, 2008). For this reason, these products are more effective at outdoors use such as facade design and glass patios than indoor environments.
a3) Easy-to-clean (ETC): Easy-to-clean surfaces, which are mostly confused by other self-cleaning functions are water-repellent products (Leydecker, 2008). Yet, when material qualities are examined, it is observed that there are major differences between ETC with Lotus-Effect and Photocatalysis surfaces (Leydecker, 2008). In one hand, ETC surfaces, at the microscopic scale are smoother rather than rough, and because of their smooth surfaces, easy-to-clean coatings do not have adhesive properties; and furthermore this causes water to be repelled by forming droplets and running off (Leydecker, 2008).

b) Air purifying qualities
The air-purifying nanomaterials have significant impact on improvement air quality and play an important role both for indoor, and increasingly for outdoors environments (URL 1). Air-purifying nano-surfaces not only reduce the unpleasant smells from environment, but also they could decrease air-pollution, such as pollution from smoking or unpleasant food smell etc. (URL 1). This system functions properly, if the volume of implementation of these products are proportional with the volume of environment, which is designed for this purpose and these surfaces should be in contact with air (URL 1). Air-purifying technologies are mostly applied on paints and textiles (URL 1).

c) Anti-fogging qualities

Anti-fogging nanomaterials are ultra-thin coatings of nano-scalar titanium di oxide. While they are performing higher surface energies, they also exhibit grater moisture attractions (Leydecker, 2008). On these hydrophilic coatings, moisture forms an ultra-thin film on the surface instead of water droplets, which causes spots on surfaces (Leydecker, 2008). These films still settle on the surfaces, but remains invisible. Thus, as the film is transparent, it creates fog-free clear appearance. Particularly in indoors, especially bathroom mirrors and glass panels are the ideal surfaces to apply such coatings. These coatings are also suitable for glass surfaces of air-conditioned rooms in the tropic climates, which tend to cloud as soon as outdoor air streams into a room.

d) Insulation qualities

d1) Thermal Iinsulations (aerogel) qualities: Nano Thermal Insulation, which is known as nanogel (a form of Aerogel), not only provides high performance in thermal insulation, but also performs as an effective sound insulation at the same time (Leydecker, 2008). Aerogel composed of air (about 95-99.9%) and silicon dioxide (silica) (Leydecker, 2008). Aerogel thermal insulations are used both in exterior environments such as facade panels, and in interior environments such as separators in conference areas in offices. The main goal of producing this nano-based product is attaining energy efficiency, which reducing life expenses of the built systems in order to reach sustainability.

d2) Temperature regulating qualities: Latent heat storage, which is known as Phase Change Material (PCM), can be used as effective means of regulating indoors temperature (URL 1). Thermal retention of PCMs could be applied not only on new constructed buildings, but also to the old ones (Leydecker, 2008). These products also act as a thermal insulation and prevent unwanted air infiltration and exfiltration. The main substance of PCMs is paraffin and salt hydrates (Leydecker, 2008). “Minute paraffin globules with a diameter of between 2 and 20 nm are enclosed in a sealed plastic sheeting”, which could be injected into typical building materials (Leydecker, 2008).

e) UV and solar protection qualities

Titanium di Oxide ($TiO2$), Zinc Oxide (ZnO), Cero Oxide (CeO), are the main three elements of these products (Leydecker, 2008), which are well suited for this purpose and each of these combination have their own tasks, to maintain the protection against powerful and harmful UV-A (Ultraviolet long rays) and UV-B (Ultraviolet short rays) that damage building materials and also causes skin cancer (URL 1). UV protection products, like other nano-coatings are transparent, so the coloring and structure of material beneath is restored (Leydecker, 2008). This product could be a proper selection for exterior use on the facades, as well as in interiors like, patios, atriums, exhibition areas, offices and etc.

f) Fire-proof qualities

Nanotechnology researchers have also developed fireproof glass panels with 3mm thickness, which resist to flames with a temperature of more than 1000 degrees centigrade for more than 120 minutes (Leydecker, 2008). The main element of this product, which causes to emerge fireproof quality, is Flerosil (pyrogenic silic acid), and this element is injected between two glass panels (Leydecker, 2008). In case of fire, the fire resistant layer between the two glass panels expands in the form of foam, to prevent fire spreading and keeps the roots accessible for people and firemen (Leydecker, 2008). This product is also known as a proper material for interior design, especially in exhibition stands, foyers, corridors, meeting areas and places, where fire safety is of utmost importance.

g) Anti-graffity qualities

Anti-graffiti nano-coatings are intended as a protective layer on materials to prevent unsightly graffiti on buildings or constructions such as noise barriers, walls, and bridge piers. These materials when applied on other existing surfaces, are sealed with object material and it is impossible to remove it again (El-Samny, 2008). This act causes the emergence water-repellent (hydrophobic) and anti-graffiti materials (El-Samny, 2008). This extremely hydrophobic property provides the removal of graffiti more easily with appropriate detergents. It could be suitable to apply on floor surfaces indoor and outdoor environments. In this situation, rain will have a certain rinsing, self-cleaning effect.

h) Anti-reflective qualities

Recently, it is observed that, anti-reflective glasses are utilized in larger amounts in the construction realm in order to benefit from the increased solar transmission resulting from broadband spectral de-reflections (Leydecker, 2008). Transparent nano-scalar surface structures, consists of minute 30-50nm large silicon dioxide

(SiO2) balls, which offers not only an innovative but also a cost effective and efficient anti-reflective solution (El-Samny, 2008). These products could be appropriate selections for the places such as patios, glass atriums, for glass cabinets in exhibition design, or in treatment rooms for those who need more sunlight like the specialized spaces in hospitals that need to prevent the spread of radiation (Leydecker, 2008).

i) Antibacterial qualities
Based on silver nanoparticles, antibacterial nano-products destroy microbes and bacteria that emerge on the surface of the objects. For this reason, in order to prevent this act, which new bacteria could eventually grow up, the surfaces are modified with an anti-stick function (Leydecker, 2008). In addition, antibacterial nanomaterials not only reduce the need of chemical disinfectants, but also decrease the amount of cleaning time period (URL 1).
In interior design field, all interior surfaces, such as walls, floor, ceiling, furniture, finishing and textures are suitable for being covered by antibacterial nano-surfaces. Especially healthcare centers are more appropriate cases to use these products, because in these places, harmful bacteria abound in one hand, and weaken patients are on the other.

j) Anti-fingerprint qualities
Anti-fingerprint surfaces are ultra-thin steel coatings that could be easily applied on to objects without any breaking and fracturing (El-Samny, 2008). These product, "alters the refraction of light in the same way the fingerprints itself does, so that new fingerprints have little effect – one can think of the coating as a kind of enlarged fingerprint" (Leydecker, 2008). The light reflections on the coating make steel or glass surfaces appear smooth, giving the impression of cleanliness that many users have come to expect. These products could be favorable selection for both outdoor and indoor environment, where easy to touch such as; facades, kitchens, bathrooms, hospitality and healthcare centers and furniture.

k) Scratchproof and abrasion-resistance qualities
Materials usually are wear out and tear down by being walked on, or by scrubbing and cleaning or similar acts. For this reason, nanotechnology produced nano-based transparent scratchproof Abrasion-Resistance coatings to solve this problem. These products could be applied on different kinds of materials such as wood, metal and ceramics and also they are resistant against corrosion and abrasion. (El-Samny, 2008)
In the architectural context, scratch-resistant stainless steel coatings are also available in transparent or colorful form (Leydecker, 2008). These nano-based products make materials durable, while helping to preserve their original appearance. But, it is also worth to note that, scratch resistance does not mean protection from major mechanical impact such as scratches caused by keys or other damaging implementations (Leydecker, 2008),

III. NANOMATERIALS IN HEALTHCARE DOMAIN AND CASE STUDIES
Nanotechnology has been an essential and the foremost technological step in 21st Century, it is worthwhile to notice that significant properties of nanomaterials as well as their characteristical attributes in favor of environmental factors do clearly indicate a vast promise in every fields of architecture and interior design.
We observe wide range of supplementary use of nanomaterial, which are targeted or oriented to enhance the material qualities on behalf of improvement, long term use and maintenance purposes such as: self-cleaning (Lotus Effect and Photocatalysis); air purifying; anti-fogging; thermal insulations (Aerogel); temperature regulation (PCMs); solar and UV protection; protection; fire-proof; anti-graffiti; anti-reflective; antibacterial; anti- fingerprint; scratchproof and abrasion-resistance, which are briefly explained as follows.
Healthcare centers are the public facilities, which everyone in the society could be a possible user, without an exception of age or gender, socio-economical status or accessibility. Therefore, both physically and psychologically creating healthy places for all users is essential. Medicine and healthcare alone, may not always provide complete physical and mental well-being, therefore especially from the stage of material selection until the final product, the design has a major role on the healing process (Markkanen and Calligan, 2015).
On the other hand, according to a research in USA, healthcare buildings are the most energy and source consuming commercial buildings after the food industry (Kararkaş and Altın, 2015). Since these public amenities, operates 24 hours and 7 days a week, therefore, they consume myriad amount of power and energy, which also means producing CO^2 emulsions and toxic gases, both to its inside and outside environments. By considering environmental issues, architects and designers, should be careful about the great impact on both patient health and sustainability.

As a simple example, healthcare settings require intensive and frequent cleaning with a wide range of products to provide hygienic, safe environments and aesthetic benefits for its users. For this reason, cleaning and disinfection play an essential role in healthcare, while highlighting a serious responsibility and critical determination within this domain. Yet, almost all of the cleaning products are complex mixtures of chemicals and hazardous components, which affect human health and environment. These products, have potential to cause adverse health effect such as serious respiratory ailments, eye and skin irritation, central nerve system disorders, reproductive disorders, blood disorders and even cancer (Markkanen and Calligan, 2015). Thus, ETC and antibacterial surface qualities of nano-materials reduce the number of times needed for cleaning and the amount of chemical detergents, and extends the cleaning period, which cause CO^2 emission and damaging to building materials and in some cases, are not healthy for the patients.

Besides, another basic urge for the deployment of nano-based air-purifying materials in most parts of healthcare centers is the indoor air in hospitals, which contains fungi, bacteria and viruses, usually caused and distributed by poor ventilation and over-heating (URL2). Besides, as CO^2 accumulates due to lack of ventilation inside the rooms and on the corridors, it is examined that this leads to all kinds of complains from patients, staff and visitors. After all, as it is known the daylight has tremendous impacts on the recovery of a sick person or on the mood and comfort of an elderly person. Thus, it is important for a patient to always maintain the contact with the environment. For this reason, it is important to use UV and Solar protection glass panels to not only, filter the dangerous radiations of ultra violet light which damage both building materials and human body specially the patients, but also allowing the patients to get enough sunlight.

By taking all these parameters into account, using nanomaterials in healthcare facilities not only provides great support in making it sustainable, but also posseses a strong healing impact on patients, staff and visitor's environment. These materials reduce the use of natural resources and cause energy conservation on heating, cooling, lighting systems and etc.

Therefore, within the framework of this research, LIV Hospital Ulus, Kolan Hospital and Medicana Bahcelievler Hospital, which are all located in Istanbul, are selected as case studies to identify the nanotechnological applications in interior space, specifically narrowing down the focus to the utilization of particularly deployed nanomaterials and their properties within the patient rooms. Besides, the other reason for selecting these mentioned hospitals as case studies, is to draw out a basic comparison of embodied energy and embodied carbon emissons of nanomaterials and conventional materials and to analyze their environmental impacts.

Thus, in terms of examining the qualitative and quantitative use of nanomaterials in all cases, the related data have been collected through the close contact with the design office, by obtaining the first hand information both through the project documentations and the targeted interviews with the leading design team. The collected information has been blended with the onsite examinations for each cases, and then synthesized accordingly. The goal of the evaluation process is to demonstrate the materials deployed in each design; their essential properties, the specific location of use as well as the amount of use, of the nanomaterials that are utilized in the patient rooms of each hospital, while at the same time, depicting the repetition of the deployed materials in various healthcare projects of the same practice.

IV. CASE STUDY 1: LIV HOSPITAL ULUS, ISTANBUL

LIV Hospital Ulus is located in the center of Istanbul; Ulus, Besiktas, providing a distinctive concept in hospital design, treatment and care focusing for both national and international patients (URL3). The hospital is best known for its expertise on the services of cardiology, oncology, orthopedics and traumatology, neurosurgery, general surgery, and the treatment of eye diseases (URL4).

This Hospital is designed with a patient-based approach, consists of 154 beds, 8 operation rooms and 50 departments in 30.000m² indoor area (URL4). It is designed by ZOOM Office in 2012. The implemented design concept of the hospital is inspired from miraculous "self-recovering" ability of human body diseases (URL5). Designating impenetrable internal fronts due to human body's tremendous self-protection and analyzing tissues and cell behaviors, organic geometrical forms are designed and applied to the architecture structure in terms of aesthetical aspects and functionality as the visual theme for the group's hospitals for higher segments profile (URL5). Furthermore, natural, conventional and nano-based materials are used within the interiors of the hospital not only to provide healthy environments to patients, staff and visitors, but also for attaining sustainability.

Yet, in addition to composite materials, like it is indicated in the Table 1, an extensive use of nano-materials in interior design of hospital is clearly observed. On the other hand, fire proof or easy to clean properties are missing in most of the nanomaterials. Doubtlessly, there are alternatives to prevent accidents and hazards of a fire conditions, but if this property was considered during the design and material selection, there would be no need for additional prevention for this solution. In addition to that, although the air-purifying quality has been the essential demand in the healthcare centers, especially in a patient room, particularly for this case it is observed that this property adjusted mainly on the flooring surface. Besides, one of the most important properties for materials in the case of healthcare facilities is anti-bacterial property, which in this case is used flawlessly, creating a hygienic atmosphere for the users. Moreover, nano-based glass panels with heat and sound insulation as well as solar protection properties, are also deployed as other complementary elements of the patient rooms design.

Furthermore, furniture and finishing elements, acrylic immobile furniture, as well as the curtains with anti-bacterial and fire-proof properties are also selected as nano-based materials throughout the design process.

Material Use Table For LIV Hospital Patient Room

		Material	Brand	Natural Material	Artificial Material		Recyclable	Sustainable	Durability	Anti-Bacterial	Insolation	Easy to Clean	Fire Proof	Easy to Maintain	Anti-Finger Print	Self-Cleaning	Air Purifying	Wear & Scratch Proof	UV and Solar Protection	Anti-Reflective	Design Flexibility
					composite	Nano-composite															
Finishing Elements	Walls	Acrylic finishing	LG HI-MACS			✔	✔	✔	M.T 10y	✔		✔	✔	✔	✔						✔
		Wallpaper	Matrix			✔				✔											
		Wood laminate strip	Formica F6926		✔																
		Laminate	Formica Colors K 3210		✔																
		Plasterboard	Standard		✔																
		Paint water-borne	Jotun Majestic Optima 1453 Vanilla			✔	✔	✔	✔	✔		✔						✔	✔		
		Glass	Saint-Gobain			✔					✔								✔		
	Floors	Vinyle finishing	Tarkett				✔	✔	✔	✔	Noise-Reduction	✔		✔			✔				
	Ceilings	Wood laminate strip	Formica		✔																
		Fiberglass plasterboard	Standard		✔																
		Fiberglass	Standard		✔																
Finishing Elements (Bathroom)	Walls	Acrylic finishing	LG HI-MACS			✔	✔	✔	M.T 10y	✔		✔	✔	✔	✔						✔
		Ceramic	Villeroys & Boch			✔		✔	✔	✔				✔				✔			
	Floors	Acrylic finishing	LG HI-MACS			✔	✔	✔	M.T 10y			✔	✔	✔	✔			✔			✔
		Ceramic	Villeroys & Boch			✔		✔	✔	✔				✔							
	Ceiling	Acrylic finishing	LG HI-MACS			✔	✔	✔	M.T 10y	✔		✔	✔	✔	✔						✔
Furniture & Fixtures	Immobile	Glass laminated zenith unit	Costum design		✔																
		Acrylic wardrobe unit	LG HI-MACS			✔	✔	✔	M.T 10y	✔		✔	✔		✔						✔
		Wood laminate strip wardrobe unit	Formica		✔																
		Wood laminate strip desk	Formica		✔																
		Handeling and wall protection tape	LG (S001 satin white)			✔	✔	✔	M.T 10y	✔		✔	✔	✔	✔						✔
	Mobile	Curtains	Creative bauman			✔				✔			✔								
		Felt fabric seat	Cor		✔																
		Chair	Hag capisco		✔																
Furniture & Fixtures (Bathroom)	Immobile	Closet	Vitra Freedom			✔		✔	✔	✔		✔			✔			✔			
		Shower set	Vitra Istanbul expo			✔		✔	✔	✔		✔			✔			✔			
		Sink	Vitra Ross lon			✔		✔	✔	✔		✔			✔			✔			
	Mobile																				

Table 1. Comparative material use matrix in LIV hospital patient rooms' interiors.

On the other hand, when focused on the bathrooms inside the patient rooms, like indicated on the Table 1, all finishing elements in patient bathrooms are selected from nano-based materials: acrylic finishings with anti-bacterial, easy-to-clean, fire-proof and easy-to-maintain properties; ceramics with anti-bacterial, easy to maintain and wear-proof qualities. In addition to finishing elements, the team has selected the nano-based furniture with common anti-bacterial, easy-to-clean, anti-fingerprint and wear-proof properties. As it is known bathroom are the places, which require further cleaning and disinfection efforts through chemical detergents, therefore, using nano-based materials and finishings with the mentioned properties reduces the period of cleaning cycles and the amount of hazardous chemicals and detergents used, which all have negative impact on both patients and environment. Besides, the lower embodied energy levels of the selected nanomaterials in comparison to the conventional ones are indicated on Table 2 approving the sustainable and environmental friendly properties of the materials.

Material	Brand Name	Embodied Energy Mj/Kg	Embodied Carbon Kgco2e/Kg
Acrylic finishing	LG HI-MACS	22.17	0.94
Wallpaper	Matrix	34.52	1.02
Paint water-borne	Jotun Majestic	NA	2.33
Glass	Saint-Gobain	20.84	NA
Vinyl finishing	Tarkett	NA	0.20
Ceramic	Villeroys & Boch	10.81	0.66
Acrylic surfaces	LG S001 satin white	23.17	NA
Curtains	Creative bauman	NA	NA

Table 2. Embodied energy and embodied carbon emissions figures of LIV hospital.

There are no doubts that this case is not one step, maybe way ahead of the conventional rooms and offers far more features than a room built with conventional materials. But, this does not mean that there is no progress left to be made. This case is a pure example of what difference using nano-based materials can make.

V. CASE STUDY 2: KOLAN HOSPITAL, ŞIŞLI, ISTANBUL

Kolan Hospital is located in Şişli, Istanbul providing relaxing and healing environments for its patients with its modern interior design. It is also known for its cardiology, pediatric cardiology, general surgeries, heart and vascular surgery, internal and eye dieses healthcare services (URL6). This hospital is distinguished not only with its patient-oriented approach, medical staff, modern medical technologies, but also with its modern interior design, sustainable and healthy environments, considering patient, staff and visitors comfort (URL6).

The Kolan Hospital consists of 174 beds, 6 operating rooms, internal surgical, coronary and cardiovascular surgery intensive care units with a total capacity of 58 beds, neonate intensive care unit with 31 incubators more than 40 departments in 20.000 m² indoor area (URL6). Kolan Hospital Şişli, is also designed by Zoom Office in 2013. The main concept of this design is transforming the existing structure by use of technological manufactured materials such as nano-based materials in addition to natural and composite ones, to an environment designed as a “flora”, where makes patients relax and sure about they are in a healing place (URL7).

As it is mentioned on Table 3, natural and composite materials, nano-based wallpaper with anti-bacterial and scratch-proof properties, nano-based PVC finishing with anti-bacterial, easy-to-clean and anti-fingerprint qualities, nano-based laminate finishing with anti-bacterial, easy-to-clean, fire-proof and scratch-proof properties have been utilized in this patient room. Unfortunately, in this mentioned case, air-purifying property has been missing. The lack of this feature in this place not only causes an increase in indoor ventilation, but also supports the need of artificial ventilation systems, where as in most cases it leads to further energy consumption and increases on the maintenance costs at the end. In some cases, this systems are not healthy for patients also, because it requires fresh filters on the system constantly and dirty filters would increase indoor pollutions, which directly affect the patient’s health. In addition to finishing elements, just acrylic part of immobile furniture with anti-bacterial, easy-to-clean and fire-proof properties is selected as nano-based materials.

As it has been summarized on the Table 3 most of the finishing elements in patient bathrooms are natural materials, but the team has selected the nano-based furniture with common anti-bacterial, easy-to-clean, anti-fingerprint and wear-proof properties.

Material Use Table For Kolan Hospital Patients Room																					
		Material	Brand	Natural Material	Artificial Material		Recyclable	Sustainable	Durability	Anti-Bacterial	Insolation	Easy to Clean	Fire Proof	Easy to Maintain	Anti-Finger Print	Self-Cleaning	Air Purifying	Wear & Scratch Proof	UV and Solar Protection	Anti-Reflective	Design Flexibility
					composite	Nano-composite															
Finishing Elements	Walls	Paint water-borne	Ral 9003			✔				✔		✔				✔			✔		
		Wallpaper	Vycon Y46399			✔			✔	✔				✔				✔			
		Wood laminate strip	Merino 503 texmex		✔																
		Glass	Standard		✔																
	Floors	Pvc finishing	Yaktas Gerflor Metallica Colo 3829			✔		✔	✔	✔		✔		✔	✔						
	Ceilings	Wood laminate strip	Gentas			✔			✔	✔		✔	✔					✔			
		Plasterboard	Standard		✔																
Finishing Elements (Bathroom)	Walls	Marble	Myra	✔																	
		Marble	Seben Dark Emperador	✔																	
	Floors	Marble	Burdurbej	✔																	
	Ceiling	Paint water-borne	Ral 9003			✔				✔		✔				✔			✔		
Furniture & Fixtures	Immobile	Acrylic zenith unit	Corian			✔	✔	✔	M.T 10y	✔		✔	✔	✔	✔			✔			✔
		Metal laminate zenith unit	Homapel		✔																
		Wood laminate strip wardrobe unit	Merino 503 texmex		✔																
		Acrylic bench	Costum design		✔																
		wardrobe acrylic unit	Corian			✔	✔	✔	M.T 10y	✔		✔	✔	✔	✔			✔			✔
		Laminate door finish	Interdecor		✔																
	Mobile	Curtains	Standard Fabric		✔																
		Felt fabric seat with laminated wood strip on structure (888)	Costum design		✔																
		Chair with artificial leather (888)	Costum design		✔																
		Patient bed	Hillrom		✔																
		Wood laminate strip desk	Merino 503 texmex		✔																
		Handeling and wall protection tape	LG (S001 satin white)			✔	✔	✔	M.T 10y	✔		✔	✔	✔	✔						✔
Furniture & Fixtures (Bathroom)	Immobile	Closet set (Stainless steel)	Vitra (Arkitekta)			✔		✔	✔	✔		✔			✔			✔			
		Shower set (Stainless steel)	Vitra)System Rain LS25)			✔		✔	✔	✔		✔			✔			✔			
		Mirror 6mm	Costum design		✔																
		Acrylic sink	LG (S001 satin white)			✔	✔	✔	M.T 10y	✔		✔	✔	✔	✔						✔
	Mobile																				

Table 3. Comparative material use matrix in Kolan Hospital patient rooms' interiors.

Besides, as it is examined from the Table 4 the embodied energy and the embodied carbon figures of implemented nano-enabled materials in this room are once again appear lower than the conventional ones. Although in some instance, figures are missing, but through a broader reading, most of the figures are verifying the general statement. As an example, the embodied energy of floor cover is unknown, in this case, by focusing on its embodied carbon figure compared with conventional one, it could be said that, this material by lower embodied carbon figure, is appropriate to use in finishing specially in healthcare centers. As another example, because of missing information about the embodied carbon of nano-based wood laminate strip, just by comparing the embodied energy figure (9.5 Mj/Kg), of this material with the embodied energy figure (16.30 Mj/Kg) of conventional laminate, it could be said that, this material is more sustainable than conventional one.

Material	Brand Name	Embodied Energy Mj/Kg	Embodied Carbon Kgco2e/Kg
Paint water-borne	Jotun Ral 9003	53.31	NA
Wallpaper	Vycon Y46399	33.16	1.18
Pvc finishing	Yaktas Gerflor	NA	3.04
Wood laminate strip	Gentas	9.5	NA
Acrylic zenith unit	Corian	NA	2.54

Table 4. Embodied energy and embodied carbon emissions figures of Kolan Hospital.

VI. CASE STUDY 3: MEDICANA HOSPITAL, BAHCELIEVLER ISTANBUL

Medicana Bahçelievler Hospital, which is located in Bahçelievler, Istanbul, has been established in 2003, in 1000 m² indoor area (URL8). This hospital with the 100 bed capacity consists of 6 operating rooms, 2 delivery rooms, coronary cardiac and general intensive care units, a cardiovascular intensive care unit, neonatal intensive care unit and a dialysis unit with 30 beds and etc., which enfolds all the recent requirements and technologies. This hospital is well known for its cardiology and angiography, cardiovascular surgery, physiotherapy, kidney transplantation, dialysis, obstetrics and IVF Unit, medical oncology and laser treatment center for varicose veins and intensive care units (URL9).

This hospital is designed by Group Medicana's in-house design team. By focusing on the patient rooms, it could be stated that rooms are designed with conventional materials, which are mentioned in Table 5 and there is not any nano-enabled materials in this room. The main goal of selecting this hospital as the third case study is to compare the implemented materials between this case with the used materials in LIV and Kolan hospitals.

Material	Brand Name	Embodied Energy Mj/Kg	Embodied Carbon Kgco2e/Kg
Acrylic finishing	Conventional	25.04	2.58
Wallpaper	Conventional	36.40	1.93
Paint water-borne	Conventional	59	2.54
Glass	Conventional	23.5	0.91
Vinyl finishing	Conventional	68.60	3.19
Ceramic	Conventional	12	0.78
PVC Finishing	Conventional	77.20	3.10
Laminate (Wood Strip)	Conventional	16.30	NA
Cotton Fabric	Conventional	143	6.75

Table 5. Embodied energy and embodied carbon emissions figures of Medicana Hospital.

VII. CONCLUSION AND RECOMMENDATIONS

In this present time, where energy-time-cost-saving-environment and natural sources are the subsets of sustainability, they are all considered as important issues in design. In this regard, the crucial role of nanotechnology and nanomaterials emerges in architecture and design discipline. Doubtlessly, the main goal of deploying nanotechnology in architectural realm is about attaining advanced efficiency and functionality in spatial solutions. This act may also be a bridge to achieve sustainability and higher benefits to humans, environment and economy. The benefits of nanomaterials in design and construction industry are appealing as providing lighter buildings, resistant and robust in front of natural phenomena's, provide a greater economy, saves a flat earth for future generation, maintain the natural resources by reducing the consumption of raw materials and energy, minimize waste and pollutions and comfort.

To summarize, departing from the extensive benefits of the nanotechnology in design and construction industry; this paper revealed the properties, range, and the frequency of the nanomaterials used in healthcare domain particularly in the patient rooms. According to numbers, it is explicit that the acrylic finishing, which is used both in LIV and Kolan hospitals, has lower embodied energy and embodied carbon emission figures in comparison to conventional ones. Besides, ceramic and vinyl finishings that are also used as nano-enable form in LIV Hospital has lower embodied energy and carbon emission in comparison to the conventional form, which is used in Medicana Bahçelievler Hospital. In addition to these, water-borne paint, wallpaper, laminate, glass and cotton fabric, which are used in all case studies, have lower embodied energy and embodied carbon emissions in comparison with conventional one; approving their lesser need for energy during their lifecycle, on behalf of low-cost and low-pollution and etc. than composite or conventional materials. Therefore, nanomaterials emerge as more sustainable and eco-friendly materials. Although, importance of sustainability and energy efficiency have been increased these days, yet there aren't enough precedents of nanotechnology use in the realm of architecture especially in developing countries. It is not surprising to observe, how most of the invertors and the contractors seek to reduce the initial building costs, without concerning about the long-term effects.

To broaden the discussion; imagine designing other spaces within the hospital such as surgery rooms (with use of these properties), or entrance and check-in spaces etc. Without a doubt the impact of every single unit would be massive. Even just by adding for instance, the anti-bacterial material feature, like demonstrated earlier in the studied cases, the need for chemical detergents are almost fading away.

Leading towards a more sustainable environment and with a progressive view, it is recommended to use this limitless possibilities of nanotechnology in all aspects of architecture and be more innovative and create environmental friendly designs. With the growing population rate of the world and increasing consumption of natural resources, there are not so many options left. With the features that this technology hands over, as studied, it is possible to add any property to any kind of materials with a little more initial cost at the beginning, but being totally aware of the long term benefits about energy-savings and long-term maintenance costs, where it becomes the definite answer towards sustainability.

To conclude, like Carl Elefante [16] mentioned; "the 'greenest' building is the one that is already been built!" (URL 10). So, taking these words into account, nano-technology increases the lifecycle of buildings by eliminating the need for reconstruction of what is already been built.

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