# The Role of Contemporary Innovations on Flexible Residential Furniture with Smart and Green Materials

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Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the Degree of

Master of Science
in
Interior Architecture

Eastern Mediterranean University
July 2014
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

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# ABSTRACT

Sustainability, being comfortable, having innovative technologies in terms of furniture, especially in residential spaces, are important factors in interior architecture, for better future life and lifecycle. Togetherness of these factors is complicated, in order to achieve all mentioned features within a furniture design, however, some companies attempt to create innovative furniture having all desired features together. It seems that there are a number of problems, such as high cost or lack of knowledge on smart and green materials etc. This study tries to explore these problems to enlighten new solutions and recommends positive points for various kinds of creative residential furniture. Through this way, contemporary innovations in residential furniture have diverse aspects such as flexibility besides using smart and Green Materials.

The aim of this research is to investigate the role of contemporary innovations on flexibility of residential furniture and innovative materials such as smart and green materials and to make suggestion on togetherness and combination of these features. Chapter One makes an introduction about subject's background and defines research problems. In Chapter Two, flexibility and its positive influence on residential furniture are examined. Recent developments on innovative materials and their effects on residential furniture are concerned in Chapter Three. Chapter Four of this research compares fifteen selected companies among a hundred residential furniture companies in terms of innovative furniture, who attended in ICFF (International Contemporary Furniture Fair) in 2014, which are using flexible design and smart or

green materials. Finally in Chapter Five, recommendations are proposed for future researchers and production of residential furniture.

**Keywords:** Flexible Furniture, Contemporary Innovations, Residential Furniture, Smart Materials, Green Materials

# ÖZ

Sürdürülebilirlik, konfor ve özelikle yaşam alanlarındaki mobilyaların yenilikçi teknolojilere sahip olması, iç mimarlıkta daha iyi bir hayat standardı ve yaşam döngüsü için gereken önemli etkenlerdendir. Mobilya tasarımında tüm bu faktörlerin bir arada bulunmasını sağlamak kolay olmasa da, bazı şirketler, aranan özelliklerin tamamına sahip olan yenilikçi mobilya üretebilmek için çaba sarfetmektedirler. Yüksek fiyat, akıllı ve yeşil malzemeler üzerin bilgi eksikliği gibi bir çok sorunla karşılaşılmaktadır. Çalışmada, bahsedlen sorunlara yeni çözümler bulmaya çalışılmış ve yaratıcı ev mobilyaları için öneriler sunulmuştur. Bu sayede, ev mobilyalarındaki çağdaş yeniliklerin akıllı ve çevre dostu malzemeler kullanımının yanısıra esneklik gibi çok yönlü bakış açıları doğmahtedır.

Bu alışmanın amacı, çağdaş yeniliklerin ev mobilyalarındaki esneklik ile çevre dostu ve akıllı malzemeler üzerindeki rolünü incelemek ve aynı zamanda bu özelliklerin bir arada bulunabilmesi için öneriler sunulmuştur. Birinci bölümde konunun temeli ile ilgili giriş yapılmış ve araştırma sorunları anlatılmıştır. Ikinci bölümde esneklik ve esnekliğin ev mobilyaları üzerindeki pozitif etkisi incelenmiştir. Üçüncı bölümde, yenilikçi malzemeler üzerindeki son yenilikler ve ev mobilyaları üzerindeki etkilerinden bahsedilmiştir. Dördüncü bölümde 2014 yılında, Uluslararası Çağdaş Mobilya Fuarına katılan, aynı zamanda esnek tasanım, akıllı ve çevre dostu malzemeler kullanan yüz adet ev mobilyası şirketi arasından secilen şirketler karşılaştırılmıştır. Son olarak beşinci bölümde, mobilya üretimi ve bu konudaki araştırma aılar için öneriler sunulmuştur.

**Anahtar Kelimeler**: Esnek Mobilya, Çağdaş Yenilik, Ev Mobilyası, Akıllı Malzemeler, Çevre Dostu Malzemeler

# ACKNOWLEDGEMENT

Foremost, I would like to express my sincere gratitude to my advisor Assoc. Prof. Dr. Özlem Olgaç Türker for the continuous support during my MS study and research, for her patience, motivation, enthusiasm, and immense knowledge. Her guidance helped me in all the time of research and writing of this thesis. I am lucky to have her as my advisor and mentor for my MS study.

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# Chapter 1

# INTRODUCTION

All the time, human beings, made new changes in education and science, in movement and complexity dimensions.

Flexibility and mobility are ideas for architectural spaces for future and they deserve to take attentions. After some disasters that threaten housing, using flexibility has benefits in emergencies, changing structure and furniture that should be in part of function and performance. The history of flexible design refers to early human, when they started to build their own shelters with opening and closing in structure of spaces. Their structure included flexible frames beside various materials that they used in their first habitat tent (Emamgholi, 2011).

In structure design, spaces are identified with elements, although these elements refer to separation or movability in furniture. Most of useful multipurpose furniture is for mobility and combination of spaces specially in limited spaces as a modern technology to achieve combining, shrinking, moving and folding together while they should be accepted and satisfy customers. From 18$^{th}$ Century until late 19$^{th}$ century, designers concluded the removing interior wall gives a beneficial space through flexible design. In 20$^{th}$ Century which is named as Modern period of architecture, " Le Corbusier" designed "Plan Liber" as " Domino House" that it did not have any interior walls, floor and roof, and stairs to connect them together. In this step, he has

used just a partition frame to achieve flexible design. As “Theo Van Does Burg’s” says in 2011 about Flexible Architecture “Modern architecture is an open one” that it could be as a flexible design in dividing house frame. “Mies Van der Rohe” designed a residential complex where the interior walls were joining floors and ceiling with locks, Beside it had the ability to enter in each part while changes and become multipurpose. In that time, the flexible design was paused because of high cost usage and technical factors. Through this, extra expenses in flexible rules have been avoided (Emamgholi, 2011).

## 1.1 Problem Definition

Furniture problems include burning easily, being hard to clean, hard to move, easy to scratch, repairing hard, health problem, time consuming and unchangeable. Beside the high price of furniture, is concerned as a big problem that forced designers to solve these points. If their materials are not appropriate to clean easily or when they are too heavy to move, in one hand they need more time and in another hand, they will create health problems for consumers. Using flexibility as well as smart technology materials in furniture systems to improve nature-friendly and sustainable features, besides flexibility, is explored recently in limited studies therefore this subject has been studied.

## 1.2 Aim and Research Question

The aim of this research is to investigate the role of contemporary innovations on flexibility of residential furniture such as multifunctional, modular, movable and foldable furniture systems and innovative materials such as smart (Nano materials and Nano coating) and green materials (natural and recycled materials) to make suggestions on togetherness and combination of these features. Flexible contemporary innovative for residential furniture, are the concepts of this study.

Through analysis of companies which are dealing with flexible and smart furniture design and production, some of the research questions are:

- What is the effect of contemporary innovative technologies on smart, flexible and green residential furniture?
- Is there relation between flexibility and the nature-friendly and/or smart residential furniture?

## 1.3 Methodology and Limitation

In spite of lack of enough case studies, researcher will be concerned on commercial websites, smart shops and some published sources as books, articles, papers around this issue to collect the required information. Actually, in a successful study, methodology and the way of research have core role. Three beneficial choices between methods are selected as concerned below:

- Correlation research: This type of research will be used in the literature review part and to achieve the relationship between factors in each keyword (contemporary innovations, flexible furniture, residential furniture, smart materials, Nano materials, and nature friendly materials), Correlation research is selected.

- Action research (Step by step improvement): After collecting data by correlation method, action research systematically will be implemented through the improvement of comprehensive factors (smart materials-flexibility- contemporary furniture). For example at the first step, the most important points are selected and explained in detail. In the next step, the related data will be found and attached to each other, so, in the last part they will be ready for comparison.

- Comparison research: This method is chosen because of case studies limitation that forced this research to compare smart and flexible features in residential functions between numbers of related international companies that sell furniture.

The figure below shows the logic of the study which forms the basis for case study evaluation methodology (Fig.1).

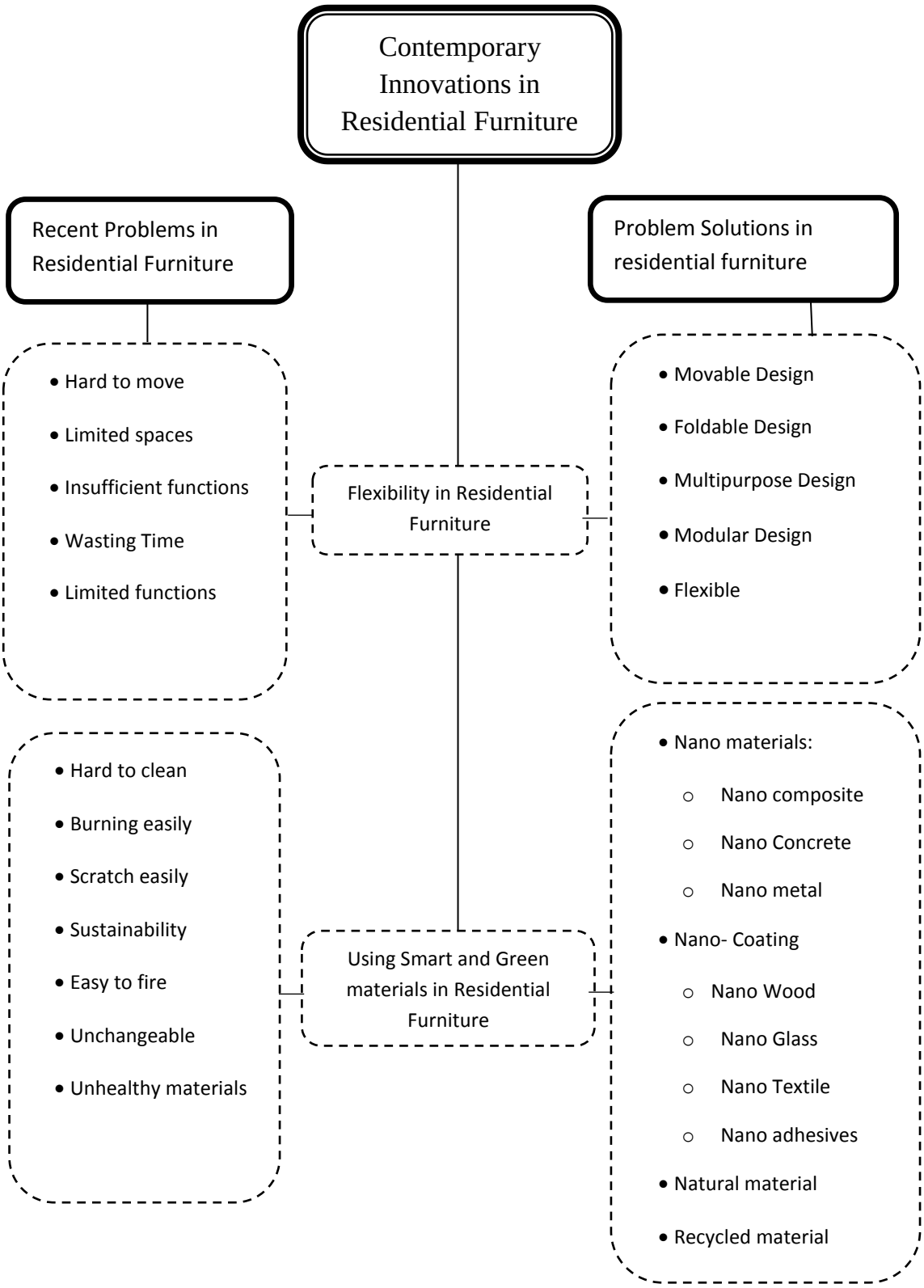


Figure 1. The schema to show the logic of the study

## 1.4 Structure of the thesis

| Introduction | | | |
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# Chapter 2

# FLEXIBILITY IN RESIDENTIAL FURNITURE

## 2.1 An Overview Of Furniture

History of designing furniture belongs to “Neolithic” period (3100–2500 BC) that residential furniture in this time were made by available natural materials like wood and stone without any fundamental change . These processes have been improved until 18th century that designers started to think about flexibility in furniture as a concept of sustainability and adaptability. Flexibility has various aspects as multipurpose, foldability, modularity, and movability.

In 19th and 20th Centuries, through modern and postmodern period in 2000, designers started to make a company to work on life-cycle and nature friendly design ( Wikipedia, 2013). By furniture, there is a delay between modern and post-modern period for using colorful rooms, traditional form and columns, that would be more symbolic because of their decoration. One of useful materials in this period is wood that designers used it naturally or they painted them to seem natural (Giovannini, 1983). As opposed to modern design that in industrial view, Graves (1979) states that "The chairs look as though they were intended to support the frame of a human being. The leg is a leg, not a support" and his furniture which shaped from human body concept, explored that his table legs are like architectural columns in fluted format (Giovannini, 1983).

The term furniture has different meaning that can be classified as below:

- ❖ Movability subject for that can be used to prepare a place for living, working etc.
- ❖ Small equipment and accessories that are necessary for special task, i.e. door furniture

Categories of social furniture use involved (Postell, 2012), (Wikipedia, 2014):

- ❖ Health care
- ❖ Hospitality
- ❖ Institutional
- ❖ Office
- ❖ Recreational
- ❖ Religious
- ❖ Residential
- ❖ Retail
- ❖ Storage

Categories of residential furniture are:

- Seating: single seat (chair) - multiple seat (sofa, bench)
- Dinning (dining table, buffet )
- Storage (bookcase, closet, drawers, shelves, cabinet)
- Sleeping or lying (bed, bunk bed, sofa bed)
- Study (desk, chair)
- Entertainment ( billiard table, TV table)

Furniture is a name for movable stuff, which is used in order to support diverse human actions, i.e. seating and sleeping. In addition, furniture can be utilized as a horizontal surface in order to keep stuff at an appropriate height for working or for storing. Furniture designing depend on various factors such as insight, judgment, designing proficiency, engineering rules and good information of rules for problem solving. Different requirement for furniture designing are vision, idea and obligation to satisfy the user. Furniture designing substantially associated with human condition. Furniture designing is an interdisciplinary science since it is related to humanities, applied art and good knowledge of working with material and manufacturing method that leads to have broad range of designing rules (Postell, 2012). In order to furnish a home appropriately, it is necessary to have a good wisdom of various furniture styles like a person who should have enough grammar knowledge for good speech (Kimerly, 1912).

In addition, furniture itself involves variety of moveable parts, which are classified as below (Postell, 2012):

- Devices to support human body
- Divers faces and part to support different activities
- Parts with storage and display ability
- Spatial moveable parts

A flexible atmosphere can be achieved through flexible furniture and their organization, flexible panels, change of color through lighting, etc. Through making flexible atmosphere in interior spaces, light as a valuable factor that can influence user is concerned. Choosing an appropriate model of furniture and their organization has the ability to make interior decorating exploit, especially in living room. Another

most important factor in interior design is color that impact user's sensation (news interior design, 2014).

Changing function in multi-purpose spaces involves more staff to arrange the various furniture and partition organization. For multi-functional spaces, storage spaces should be supplied. In addition, purpose of designing flexible furniture is to move, slide and reconfigure the components etc. Some of the designers believe that "flexible" means an open and unobstructed space and as the first step of designing, it is excellent. If it is necessary to keep a part of space, fix whenever it is possible, i.e. keeping perimeter of the center floor fix and open. The most important implication in this case is that a multipurpose space requires more than open space, i.e. multipurpose support of infrastructure involving lighting, electric power, acoustic and HVAC (Fawcett, 2012; Epstein, 2014).

The list below shows a few items that should be considered in flexible organization. (Fawcett, 2012; Epstein, 2014):

- Technology: To achieve most of technology influences on spaces such as using large touch-screen monitors, digital devices and wireless, etc.
- Demountable partitions: This kind of partitions is used for amortization purpose and they are installed after construction but they have the reconfiguration ability.
- Lightweight internal construction: Using acoustic insulation and drywall and metal studs which are easy to reconfigure.
- Heat Ventilation and Air Condition (HVAC)
- Electrical: Power of electrical points is one of important problems in public places; it can use electric in all perimeter walls.

- Lighting: Consideration to lighting in multipurpose spaces.
- Frame vs. bearing wall construction
- Fixed vs. operable walls: To join different spaces together in a large space besides paying attention to ST (Sound Transmission).
- Furniture

## 2.2 Flexibility in Residential Furniture as Concept

Many people believe that flexibility is a good parameter to be considered for designing furniture to answer different events when they reveal in unpredictable ways. Flexible design means, 'supply different future decision chances purposely'.

In abroad, adaptability of the constructed space to climate change is of interest. Since, it is hard to know about the climate change in future without any accurate information; adaptable designing can be useful parameter for future designer by supplying different lifespan option in order to have the best suitable answer to future climate change. In order to find the building potential adaptability, exploring and evaluating its embedded lifecycle option. Relationship between flexibility and sustainability will start with being able to adapt to change that can give us the chance to use furniture for different (multi-functionality) and changing (adapting) functions. Besides, In order to assess the sustainability a long-term outlook should be provided. Assembling a whole-life cost helps predicting the future and presents a new method which clarifies the unpredictable events of future considering flexibility. (Fawcett, 2012)

The definition of flexibility is different in various zones i.e. biology, economics, engineering, architecture etc. In architecture, flexibility is a feature of designing

system, which could be useful for probable ongoing in both interior architecture and architecture that could be affected by cost aspects. In addition, flexibility has the ability to improve sustainability value factors. In other words, flexibility makes valuable attribute beside doubt in prospects and risks (Wikipedia, 2013).

In this chapter flexibility of residential furniture is investigated. House as a valuable space for human and in different aspects is generally studied such as phenomenology, psychology, environmental behavior, and sociology, though; this study will focus on Design side of Residential Furniture. Evaluation of flexibility should be concerned besides organization and variation form because of their usages in different spaces. Bernard Leoupen says: “Flexibility and changeability are the keywords when faced with the unpredictability. Flexibility became a theme in western architecture when architects embraced mass housing at the onset of the 20$^{th}$ century. It was the issues surrounding the ‘minimum dwelling’ that initially stimulated the thinking on flexibility in the 1920 and ‘30s”.In the other word, flexibility relying on dependence and independence happen that can be foreseen in each condition or space intention.

**2.3 Flexible Furniture Design**

The usefulness of the flexibility is its capability to response expected and unexpected proceeding. In order to manage all final aspects of designing flexibility is the only way for which it can be used. Since it is not easy to define the factor of the flexibility, designing and all its requirement will be harder for designer and experts, although it can be different with various perception of lifecycle and examining (Fawcett, 2011).

In order to solve the problem of space-limited places, which can be explained by dining room, one solution that could be utilized is deducting dining table as one of the largest furniture in home. Dining room is often consider as an extra comfort room in homes which have multiple reception rooms and could be used usually for serving dinner in front of TV instead of on a dining table to be formally (N.A.Home Designing , 2014).

Foldable dining tables have been used for a long time in order to solve the problem of the small houses that is impossible to put a big table permanently inside. Some of the new designed foldable table has the characteristic to be stored like a set of spoons and forks in a handy drawer.

### 2.3.1 Movable Furniture

Moveable designing is an intelligent kind of designing that lets you modify your furniture to have different movable features depending on your needs.

One of the best solution or choices about flexibility of space is about movable walls productions. In economic aspects, to achieve convenience in flexible furniture, designers should investigate about collecting all technologies with their initial costs. (Kim, Young-Ju, 2008). Costs of furniture systems are related to the function of each furniture and to prepare their long-term developments. In Bill Davies's opinion considering about flexibility in furniture are as important as the quality of them, indeed the sustainability and furniture costs should be investigated. Furniture systems with some lower consumption production such as lower glass panels or lower panel heights have the ability to be sustainable furniture (Zimmermann.R., 2007). Flexible designs allow using some contemporary technology to have new elements in interior design like floors, walls, furniture, and non-rigid ceilings, as well as being more

flexible and unlimited change (Emamgholi, 2011). In some researches, Flexibility tries to be profitable for each productivity and structures, which can answer to call reads even in economic aspects. Advantages and disadvantages should be through technical and social.  A chair can be changed to a table as well (Fig2) (Shelterness, 2011).

Figure 2. Movable chair and sofa that can be used in different shapes (Shelterness, 2011).

Movable kids bedroom furniture such as on wheels bed and table provide the ability of sharing and modifying the space by means of moveable furniture in small spaces and houses (Fig 3).

Figure 3. Movable closet, desks, chairs and beds that are used in area with space limitation for kids (brunellbc, 2013)

New designing feature of kitchen is developed, which is convenient for houses with limit spaces by providing a big range of flexibility. Kitchen furniture can be modified and be used according to the user needs (Fig 4) (Alter, 2009).

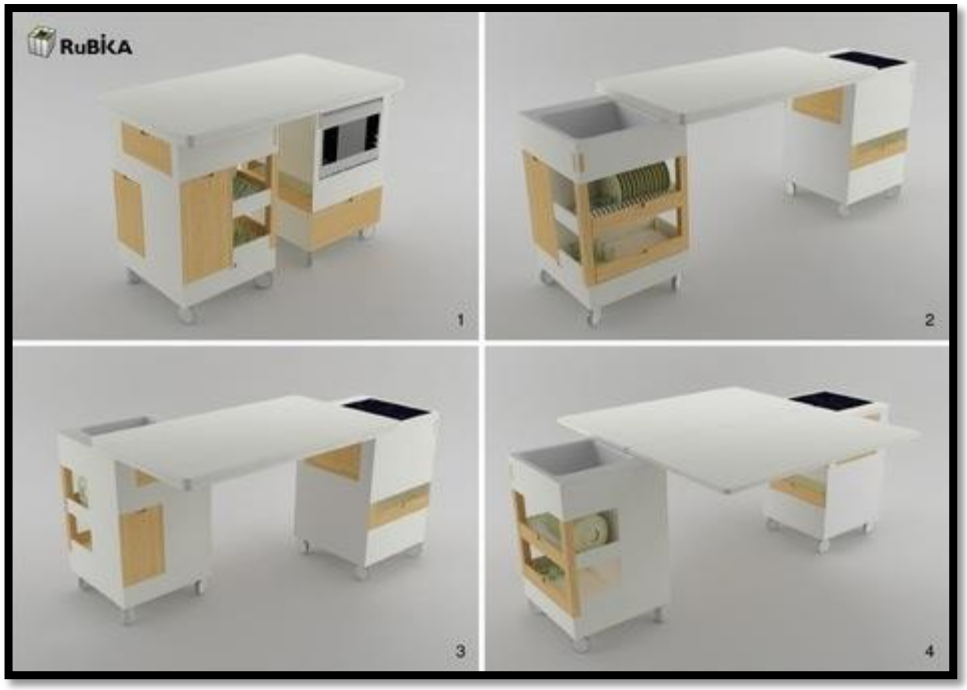


Figure 4. A compact and multi-purpose box for limited spaces for kitchen that can be moved and folded easily (Alter, 2009)

Figure 5. Big movable box, which includes desk, two chairs and a little library that can be used in limit spaces either at home or office.(Home Tone, 2011)

Figure 6. Movable Desks and Chairs that can be used in different spaces (Epstein, 2014)

Figure 7. Movable and Foldable Table and multifunctional Dinning package which can be used in limit spaces (N.A.Home Designing , 2014)

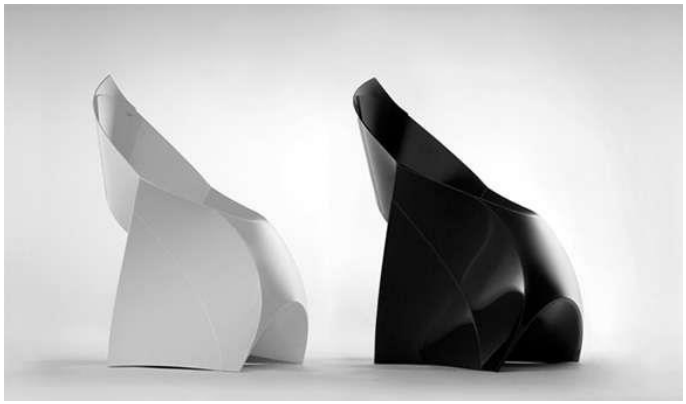

Figure 8. Movable and Foldable chairs are used for places where they have limited space (fluxfurniture, 2013)

### 2.3.2 Foldable Furniture

Foldable furniture design in furniture systems is used to preserve the maximum free space for those places does not have the ability of full furnishing which need to have various furniture in small places, to put more furniture. In residential places with limit space, especially in apartments and rooms that need to make decoration by means of combining furniture and flexible furniture in frame of multifunctional and foldable furniture are beneficial. Furthermore, foldable furniture is a helpful factor that let people who are interested in decoration modification to change furniture styles easily (Fig 9) (Fig10) (Fig11) (Makmanee, 2013).

Figure 9. Foldable chairs which are used in limited spaces (Makmanee, 2013)

Figure 10. Modern Sofa, which can be bunk bed after folding (OSTOIN, 2014)

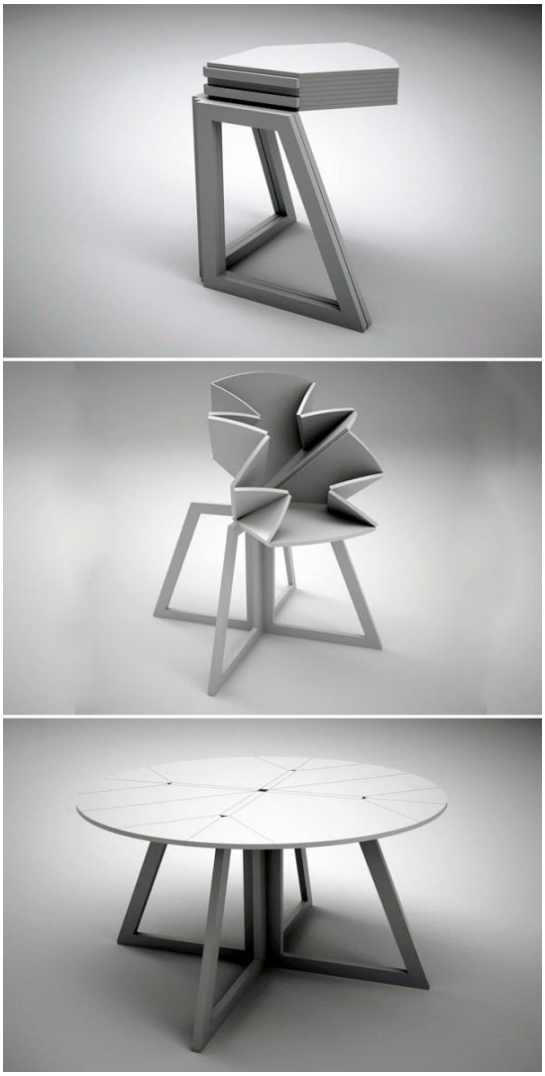

Figure 11. Foldable single and multiple table. (N.A.Home Designing , 2014)

### 2.3.3 Modular Furniture

Modular furniture design is a furniture system of designing which include many small parts or subsystems that are known as modules with specific dimensions. These parts are used in variation function of building i.e.:

- Functional partitioning which are self-organized system
- building designing organization as modular functionality
- Using standards in technology for choosing easily

Modular design can add or remove elements and architects have the ability to use walls, ceilings, doors, or even windows. Sometimes they can use desks as a partition to divide each parts of planning design (Fig12) (Krol, May 2012).

Figure 12. Modular cube that provides a kitchen area by movable and foldable design. (Makmanee, 2013)

Modular Furniture can be described as following points below (Dazzle, 2009) (Fig 13), (Fig14) and (Fig15):

- Separable and Joinable : Modular furniture consist of divers parts which are designed to be connected together in such a way that can be divided and

assembled together without many damage easily and frequently with joined points.

- Modularity: all parts of modular furniture can be changed since they are produced by machines. For example, one side plate of a cabinet can be changed with side plate of another cabinet. Therefore, there is no concern about mark the sides and other part.
- Design flexibility: two aforementioned factors provide easier and better flexible designing. It is possible to change, reduce, and extend the furniture's shape whenever it is required.


Figure 13. Modular furniture design for kids room (Dazzle , 2009)

Figure 14. Multi-functional, movable and modular furniture which becomes bed, sofa, table and closet (Ostoin, 2014)

Figure 15. Multi-functional, foldable, and modular furniture that can be converted to a sofa, bed, bunk bed and table in a limit spaces. (Ostoin, 2014)

## 2.4 Technology of Flexibility

Whether movable, foldable, and modular, using flexibility technology in production does not have precluded in each steps except in one condition that would be unsuited with industrial series. One of the best ways to achieve benefits of technology in spite of high price is using industrial series production. A unique invention has novelty in both organizational and technological level that mentioned machinery, logistics (avoiding stockpiling), administration and quality management beside a particular management between dealer, creator, and designer. Flexible character of inventions makes series to be modified in results that is shown in Ford's production lines. Computer-controlled would be the next step to increase flexibility in results with production machinery. Finally, industrial productions are expected to be converted from individualized to automatize with a various manufacturing in future (Vreedenburgh, 1994) (Fig16). Emamgholi (2011) investigated one of the other advantages of flexibility in walls, elements and furniture (Fig17).

Figure 16. Movable and Multifunctional boxes that can convert to bed, kitchen, closet and table (Makmanee, 2013)

Figure 17. Movable closet chairs and table (Godrej, 2013)

Flexible furniture is developing for designing to have a comfortable place for moving easily and changeable space. Flexibility makes spaces to have movable furniture, which help you to change residential lay out easier with adding roller and electronic devices. Another effect of this new technology is changing people treatment when residential furnishing are different and new. Kauntze (2005) is looking for more relax

meeting environment. *"The old prejudice that comfy sofas equal lying around doing nothing has gone"* (Kauntze, 2005).

## 2.5 Concluding remarks of chapter 2

As previously mentioned in this chapter, houses require privacy, safety and comfort space, which can be made by suitable furniture design. Flexibility has various aspects as multipurpose, foldability, modularity and movability. Therefore, one of the best methods to get flexibility is having various spaces to be more productive. This method is a kind of modern technology to have privacy with flexible furniture systems. Besides using flexibility to serve sustainability, using smart materials would be beneficial in this way. Recently, designers tried to improve flexible furniture with new materials to make them more functional and sustainable in interior design issues. In the next chapter, innovative smart materials such as Nano, Nano-enhanced, natural and green materials that have the ability to be used in residential furniture, will be investigated systematically.

# Chapter 3

# INNOVATIVE FURNITURE TECHNOLOGY AND MATERIALS

## 3.1 Recent Developments in Residential Furniture Technology

Environment is influenced severally by all human actions. The environment has the capability of surviving from some of the human action without leading any harm ( Field III, 2001).

Nowadays, through the contemporary developments based on new designs, technology introduces innovative furniture such as smart furniture. These new systems, improve the quality of life, and ecologic character that are achieved through the adaptability and nature friendly materials. Hence, this research aims to investigate smart and nature-friendly aspects of flexible furniture in interior design especially for residential spaces.

Among the most important aspects of furniture for customers are cleaning, moving, and changing easily. Some of customers are still using old-fashioned methods for cleaning, washing, moving and they can change the furniture in a long time because of high cost of new furniture. However, by using modern technologies in furniture production to make them sustainable and easy to use, most kind of customers, will be satisfied (Broekhuizen, 2012). Another aspect that affects successful furniture production is customer satisfaction feedback.

Flexibility as a new design has the ability to manage the design that can be solid or non-solid forms. Re-configuration is one of the ways to achieve flexible form where suitable structure coordination and appropriate function would be two important conditions (Dboer, 2009). In addition to re-configuration factor of flexibility, multi-function, life cycle, and sustainable character of flexibility will be explored.

## 3.2 Recent Developments in Residential Furniture Materials

There had been a quite simple association between architecture and materials until the Industrial Revolution. Materials were chosen parametrically or formally, for their usefulness and accessibility or for their form and decorative characteristic (Addington & Schodek, 2005).

Furniture and architecture in Post-Modern period use traditional and symbolic shapes instead of tabloid as opposed to Modern Period. Wood is the common material that architects used in that time because of visual and natural character.

California's architects (R. M. Schindler and Richard Neutra) made their individual pieces which are suitable for house furniture, because until late 1940's and early 50's, Marcel Breuer and Mies van der Rohe were concerned about chair with tubular steel material for their house in United States but they did not have commercial availability (Giovannini, 1983).

Wide range of introducing steel in 19$^{th}$ century led to appearance of wide range and high building, so materials usage characteristic changed from its old role of being less important in architecture to a new functional performance (Addington & Schodek, 2005). To make a creative product, designers use materials, and one of the flexible and comfortable materials in changing, using and designing is textiles.

Nancy Webster state that: “we do not change structure too often. With textiles you can redecorate every 10 years, every two or secondly”. Textile material has no limitation in therapeutic, soft aspects and color changes (Pepitone, 2012). Characteristically, in spite of conservative factor in Nano-materials, the price of this new invention is high. Applying Nano-materials is a core level for each part of furniture and their function usage and then using various Nano-coating for different layers should be changed (Berger, 2013).

Nanotechnology makes wide activities and many benefits for furniture industry. This technology includes materials, which are 10.000 times thinner than human hair. Most of European furniture factories investigated on recognizing nanomaterial, use it in furniture besides working with the other companies, and get their useful information (Fig 3.1) (Broekhuizen, 2012).

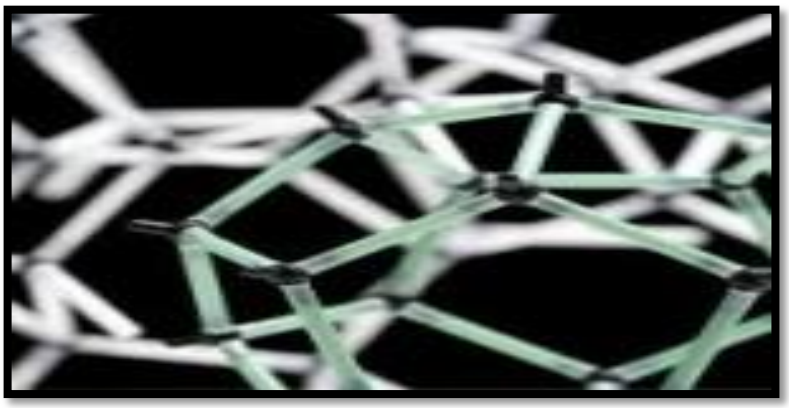

Figure 18. nanoparticles (Broekhuizen, 2012):

In Ritter’s study Ritter (2007), innovative materials are classified as:

- Nano-materials
- Biomaterials (bio-inspired materials such as self-healing effect)
- Bio-gradable materials (return to compounds found in the eco-system)

- Smart materials (engineered and high performance materials and intelligent systems)
- Recyclable materials
- Hybrid materials
- Functionally gradient materials

Houses should provide all of people's need in interior spaces, so in this way, it has to have the ability of developing or changing through regulations and all changing refers to environment technology and people (Bayram, 2012). In other words, another advantage of flexibility is providing space with variation function especially in modern compact apartments, where there are obstructive lacks of private space.

### 3.2.1 Smart Materials in Residential Furniture

Smart furniture are kind of devices that they can heat themselves when it is cold and after that they can change color in sunshine. There are some places that preservation of furniture is very important, so in public places such as offices, hospital or other places, the price for choosing appropriate materials for employers are more expensive than the others used in houses.

Furniture design attempt to create a product which has lower consumption to achieve better usage and product and in this way, nanomaterial has essential role to create a smart furniture to provide all needs and solve most of the problems with low price. When nanomaterial are made professionally and with light potential, it may be expensive at the end, while the other standard furniture materials can be produced well enough. Some points that are expected from this kind of Nano-materials are listed as below (Broekhuizen, 2012):

- ❖ Easy to clean, to prevent bacteria to enter.
- ❖ Focus on the scratches on glass or wooden furniture
- ❖ Protect materials from uv-protective coating
- ❖ Lower consumption
- ❖ Easy to change
- ❖ Safety
- ❖ Novel flame retarding methods (fire resistance)
- ❖ More durable and stronger
- ❖ Sustainable characteristic and processes of production
- ❖ More light materials

Smart materials are listed as (Ritter, 2007):

- composite materials
- property-changing materials:
  - optical properties of materials
  - mechanical properties of materials
  - chemical properties of materials
  - electrical properties of materials
  - thermal properties of materials
- phase-changing materials (PCM):
- color-changing materials:
- multipurpose materials:
- electro generating materials
  - thermo-electric materials
  - photovoltaic materials

    - piezoelectric materials
- Light emitting materials

Another kind of smart materials in Self-healing material that are combination of microcapsules which include different arrangement of 5-ethylidene-2-norbornene (5E2N) and bicycle open tadiene (DCPD) monomers reacting with ruthenium Grubbs' catalyst. These materials are known as having a good characteristic of reconstructing their mechanical properties when damaged, so they have a good lifespan. Successful examples of these materials are polymers, ceramics and their composites (B. A¨ıssa et al, 2012).

Polymers are kinds of material that are made up of plastic that used to be common a lot for their popularity of having a long life. Polymers have other material characteristics which look like some other types of material, i.e. their color is like ceramics, having printing characteristic like wood or fabric and metalized. In addition they have good property of forming, since they are plastic and can be colored so easy. Their transparency characteristic can be in range of glass or lead and parallel to this, their stiffness behavior can be as tough as aluminum or as soft as rubber. Besides these characteristic like other wide range of materials, adaptability is their special property. (Karana et al, 2013).

Material different behavior can be controlled accurately in Nano-scale. Nano-technology will affect various aspect of architecture industry deeply at all scales, so, interior, building, and urban design obviously will take advantage of this technology. Nano-technology will change our environment, so it is necessary to take advantage

of it and produce healthier, comfortable, and humane material. In future, we will have an environment, which is filled with Nano-materials (Niroumand et al,2013). Nowadays, Nano technology has a lot of ability such as manipulation, changing and even designing around objects and their materials in the scale of Nano (0.0000001-0.000000001 m) (Fig21).

Figure 19. The shiny surface that nanocubes display under the microscope (Sylvia Leydecker, 2008)

This technology can investigate on furniture products and for control of their quality, cleaning points or air filter and lubricants. Nano products involve some nano particles like TiO that it has 1-100 nm size and it's chemical characteristic, so some of these materials are like coating to improve amount types of products with different functions in furniture.

Through finding a relationship between Nano materials and furniture, there is no direct relation because they work together due to completing each other in a new system (Broekhuizen, 2012).

In different situations, safety issues about nano-materials for different customers are concerned, for example, public or private spaces are not the same. These concerns

care about the  dangers of exposure to nonmaterial at different period, i.e. usage and end of life. (Broekhuizen, 2012; Gilman, 2009).

Most of Nano materials have 1, 2 or 3 dimensions and the design size average are 1-100nm (Broekhuizen, 2012).

- The first dimension is about a material like GRAPHENE that has Nano-thin sheet. For this example, the reflecting window has this character
- Second dimension has the ability to be cone or tubular, same as materials or Nano-rod and Nano-tube or multi walled Nano-tube (MWNT) with their differences that a tube is hollow as opposed to rods.
- The third dimension is about all shapes of substance in the average of Nano size such as triangular, globular, rectangular, and ellipsoidal. It may be frame or metal structure with some Nano bubbles Fig22.

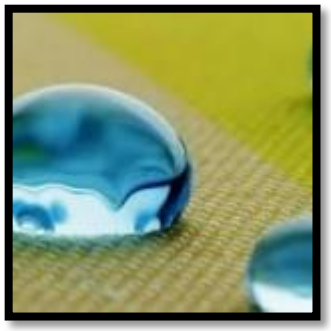

Figure 20. Liquid on Nano-Tex treated fabric (Sylvia Leydecker, 2008)

#### 3.2.1.1 Nano-materials used in residential furniture

Nano technology is utilized for material and product improvement, i.e. special textiles and stronger wood and concrete. In addition nanotechnology is employed for enhancement coating that can be designed for different purposes in order to be used

on any material. Nano-Materials are explained as, composite, concrete, and metal (Broekhuizen, 2012).

#### 3.2.1.1.1 Composites

In the R&D process, there are some steps of activities for each plastic and wood composite. Wood composites need to have particular potential like Nano wood fibers to improve and optimize the benefits of using composite materials, though it is not achieved in markets, indeed hereof costly and non-effective enough. The effectiveness level to attach Nano composites on fibers to achieve the best surface product is at the constructive level (Fig 20).

Some benefit results of using nano composites for future from SPE are discussed (Society of plastic engineers, 2012)

- To Improve the Strength and the Structure Of Materials (durability)
- Coating Preservation (durability)
- Wear Resistance (durability)
- Caring About Safety(safety)
- Flare Determent (fire resistance)

Nano-cellulose fibers are applied to the wood composites and make them as a renewable material; hence, it will be used as finding composite layer material for reaching more sustainable level. The extraction of waste wood or waste from wood production that is made by natural sources, caused to create Nano-cellulose (Broekhuizen, 2012).

#### 3.2.1.1.2 Concrete

Often, concrete materials are used for exterior spaces more than interior spaces. one of the Self-Cleaning factor in concrete would be reliable with UHPC (Ultra High Performance Concrete) that is made by silica fame and 24nano- TIO 2 . On the whole the concrete that is used for furniture in kitchen should be enough density UHPC to prevent spots and water. On the contrary, UHPC will be used in new lighter furniture products or with slim size (Broekhuizen, 2012)

#### 3.2.1.1.3 Metal

Nano-metal amelioration accrued when the modification is in the structure level instead of surface edit level, through this proses, metal will be sustainable and durable. In another view, while using Nano-materials in structure level, it will be enough and appropriate for the metals (Broekhuizen, 2012).

Surface cladding metals are not stable since they can easily be damaged during usage. But their advantage is that they can be recycled by melting, however they have hazard of emitting dioxins since they are coated by polyvinyl chloride (Berge, 2009).

### 3.2.1.2 Nano-Coating In Residential Furniture

As far as nanomaterial technology is a new science and therefore expensive, Nano coating method has been studied and applied on recent developments. These Nano coatings, basically use a property of nanomaterial in a specific application and can be changed according to the functionality.

Usually to achieve different layers and functions, the coating can change in spite of similar partials in all of them.

- Scratch resistant coatings
- Anti-graffiti coatings
- Easy-to-clean and water repellent coatings
- UV-protective coatings
- Bactericidal coatings (Self-cleaning)
- Fire- Resistant coating (Broekhuizen, 2012)

Even though current knowledge is still insufficient to predict toxicity based on the "Nano-material's composition and morphology, one can expect that the toxicity profile is at least partly related to the unique chemical and physical behavior that makes them interesting for product innovation in the first place. The health effects of nanomaterial observed most frequently are induced via inflammation or via oxidative stress. At a sufficient dose, these then may lead to cell death, scar-tissue forming (for example in the lungs) or the formation of mutations that again may lead to deformations or cancer." (Broekhuizen, 2012). In spite of Nano materials' abundance in the market, merely few of them that used in furniture products,

Table 1. Nano materials domaining the nano-products used in furniture (Broekhuizen, 2012)

| Nanomaterial | Scratch resistance | Easy-to-clean | Anti-graffiti | UV/light stability | Self-cleaning properties | Anti-micro |
|---|---|---|---|---|---|---|
| $SiO_2$ | X | X | X | | | |
| $TiO_2$/ZnO | | | | X | X | X |
| $CeO_2$ | | | | X | | |
| Ag | | | | | | X |
| CuO | | | | | | X |

#### 3.2.1.2.1 Glass

Different types of glasses use Nano technology recently and furniture manufactures prepare the fine products. The function of new technology like nano is applying a coating on each kind of normal glass. This layer has 98% effect on the glass materials. To achieve a privacy glass, there is a liquid crystal between the glass sandwich layers, which makes a high opacity while it is opaque. A thin layer of metal oxides makes one kind of glass that can collect infrared radiation. Furniture surface should be controlled in interior building about preventing slow heat up around heat-sources.

There are different types of Nano-glass such as non-reflectivity, privacy-glass, thermal isolation and biocide glass, which can be implemented for various applications, i.e. glass-cabinets, lamps, tables, office furniture or medical furniture. Using these types of glass will be beneficial lower production cost for furniture (Broekhuizen, 2012).

Biocide glass has easy-to-clean benefit and this is caused by using a thin layer like Nano-$Tio_2$ that brakes-down natural pollution and decrease the need for cleaning , but it doesn't use door interior space except for lower services like swimming building, office building or some medical centers. During a baking process of a nano glass, a Nano material is added to a thin layer of glass because it is in melting process. In furniture systems, the Nano particles is not appeared, these Nano particles are not produced in large scale as a glass (Broekhuizen, 2012).

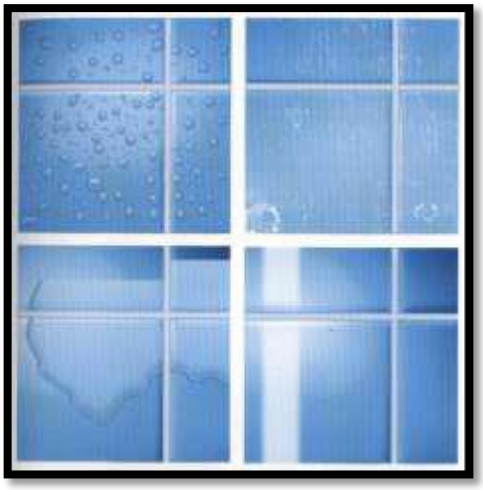

Figure 21. Before and After using Nano surface. (Leydecker, 2008)

Some benefit results of using Nano composite for future from SPE (Social of plastic Engineers) are discussed (2012).

**3.2.1.2.2 Wood**

Wood has the ability to use phases of it through Nano technology. Applying nanotechnology to the forestry wood production phasing is to achieve more sustainable wood and protect them from fungi, pest and biocides. These processes can be like co-biocides to protect the deep inside of the wood in the system named Nano-cannier. Also some Nano metals have been worked on these subjects, these metals are such as: cooper-zinc and Nano-silver that release biotical caused by oxide, hereof wood can be protected by long-term sources like Nano-metals.

An important matter about long life of wood and wood composite is their surface swelling when they are disposable to water that may even be caused by cleaning. In addition, pesticide that are used during wood growth period may be still remaining in during usage. To increase sustainability, in some wood products like MDT or OBS, Nanotechnology is the best choice. When amount of activities or cleaning are

happened in wood productions, the thickness of normal wood are swelling. To solve this problem, using Nano technology in various ways are available:

- ❖ Mantanis (2010) states that Nano technology is beneficial to use for wood panels that is a kind of coating technique to keep the water and surfapor that is a coating systems by nanophos SA, diverse the thickness swelling up to 13-14%.
- ❖ Liquid glass can be used for covering all sides of wood panels
- ❖ To keep water from going deeper in panels, hydrophobic is a layer that can be applied on surface. (Broekhuizen, 2012)

Nano technology attempt to decrease protection techniques for wood such as Nano coating that is used in water-protection or using biocide system implanted (Broekhuizen, 2012).

**3.2.1.2.3 Textiles**

Textiles are the other kind of beneficial materials to preserve spots that are explored in furniture systems. To draw on these furniture textiles performed by covering, UV active Nano-titanium, Fluorocarbon polymer and liquid-Glass coating are applied on them. To achieve the other biotical textile, using Nano-silver coating to the yarn is beneficial and also, durability and quality of textiles are affected from three types of Nano-silver that are “lose coating”, direct attachment to fiber and it heaped itself by using silver.

- Yarn Silver can be brought onto the textile surface as a “loose coating”.
- The textile fibers can be individually impregnated.
- The Nano-silver which can be chemically connected to the textile fiber.

These three different types of textile treatment do largely affect the quality of the textile and the durability of its performance Nono-clay is a class of nanomaterial which is known to have fire resistant characteristic. Anti-stain furniture textile can be produced by coating the material with liquid-glass, i.e. coating by nano-titanium dioxide or by Teflon (Broekhuizen, 2012).

#### 3.2.1.2.4 Adhesives

By the whole, adhesives in furniture production have been used in spite of low information about their optimization that will be possible with Nano-materials. In addition one of the effective factors in furniture durability is about the interplay between strand surface conduction and glue constitution to preserve the base from the erosion comfort and decreasing glue usage, the dispensation coating has been effective to keep Nano-roughrning (Broekhuizen, 2012).

### 3.2.2 Green Materials in residential furniture

One of the other nature-friendly solutions for furnishing is using green furniture that has a substantial effect on plant. Frequently, this kind of furniture are signified by a tree and sustainable forest that means they have little toxic and it will be durable in long term. Green Furniture is a term that is used for furnishings that have a significant impact on the ecology of the planet. "Green" Furniture, often symbolized by a tree, are products that use materials from sustainable forests, have low toxic material levels, locally manufactured and are durable enough to last (Wikipedia, 2013). Green materials can be handled under two sub-headings as natural eco-friendly materials and recycled materials.

Sustainable furniture design is an effort to address the environmental impact of furniture products on the environment by considering all aspects of the design and manufacturing process. Design considerations can include using recycled materials

in the manufacturing process and using products that can be disassembled and recycle after their useful life. Sustainable furniture design strives to create a closed-loop cycle in which materials and products are perpetually recycled to avoid disposal in landfills. The Think Chair by Steelcase is a recent example of sustainable furniture design (wikipedia, 2013).

Figure 22. Contemporary, eco-friendly and sustainable furniture for home interior design and furnishings (Mario Stadelmann 2014)

### 3.2.2 1 Natural Eco-friendly Materials

In ancient times, Chinese cabinetmaker took advantages of solid bamboos as sustainable material not to use any screws and nails, another eco-friendly material which is so useful that gives furniture shine and beauty is mango wood. One of the bamboo properties, which make it to be convenient and useful in bath and kitchen appliances such, is its anti-bacterial characteristic (Fig25) (Fig26) (crateandbarrel, 2014).

Characteristically, bamboo is a kind of grass that can be grown in different whether, both hot and cold in all over the world, Latin America, Africa and Asia also. Bamboo as natural plants  in spite of the ability to use in  building material throughout world,

it is known as ‘poor man’s timber’ caused by the most beneficial material for poor people instead of using concrete and stone which are expensive for them (architecturein development, 2012).

Mango wood is very popular because of its natural hardwood and spectacular sustainability in comparison with oak and teak. It belongs to the sumac family of trees and its evergreen. According to its Latin name “Mangifea”, it is known to be originally from India. Distributed from India, now it is cultivated in south east Asia, Australia and south pacific islands. (Fig 27) (melange decoration, 2013).

Figure 23. Bamboo wood, that is useful as natural eco-friendly material in residential furniture that is explored by Chinese for the first time. (e-Cork Flooring, 2006)

Figure 24. Black Bambo wood that is useful as natural eco-friendly material in residential furniture (the artful life, 2010)

Figure 25. Mango wood as a natural naterial in residential furniture (harvestwoodworks, 1999)

Figure 26. Mango tree that is known as natural  green materials that is used in residential furniture.( Edison Ford Winter, 2013)

### 3.2.2.2 Recycled materials

The history of the salvaging material goes back to a long time before Roman who have used salvaged building materials. Nowadays we have been having this ability to use science in order to investigate salvage materials. Therefore, customers can take advantage of recycling old building parts of craftsmanship and buy them with a good price. In all around the world, vendor has been taking advantage of the best recycling building material to supply customer needs. If the materials are unusable, recycled them can be a way in order to optimize them. Materials such as clean timber, metals, gypsum wallboard, and cardboard/paper that are produced during construction can be recyclable materials. A pre-recycling procedure, which is necessary in some cases, is to divide waste hauling at site. Sometimes it is possible to prepare a container for all mixed recycling in order to categorize them later in recycling site. The advantage of on-site dividing of recycled material is to increase total quantity of material recycled and lessen pollution (recycling the past) (Seattle public utilities associate, 2013).

According to nature friendly approaches and concerning about different factors about environment and structure procedure in furniture design, sustainability issues are the point. Concerning about smart design contains consuming kind of material that can be salvage and isolate after they are non-use in structure method will be investigated. A closed-loop cycle between crops and materials is a recycle way to prevent removal materials in landfills that sustainable furniture always attempt to generate it. One of the recent examples of sustainable furniture is The Think Chair by Steelcase that is made by 98% eco-friendly and 37% recycled add-up materials (Fig 3.8), (Fig3.9), (Fig 3.10) (wikipedia, 2013).

Figure 27. A bed and interior wall made by recycled materials by using recycle plastic instead of trashing them. (Inhabitots, 2010)


Figure 28. A home that designer used recycled materials inside [ (bottle houses, 2013)]

Figure 29. A table and chairs made by natural materials (wood and bonus) [ (Phillips, 2014)]

Advantages of salvage and recycled materials are listed below:

- Give usable items another life;
- Save money;
- Support the local material reuse and recycling industry;
- Reduce natural resource use;

- ❖ Cut greenhouse gas emissions;
- ❖ Earn green building rating system points (e.g., Built Green™, LEED™);
- ❖ Send less waste to the landfill;

## 3.3 Concluding Remarks of Chapter 3

On the whole, for future furniture both quality and sensitivity on environment have major indications that in this case, water pellet, anti-bacterial, UV protection and high resistance to scratch can be mentioned as benefits of covering layers and innovative materials. Besides, all kinds of positive factors such as flexibility, amount of huge problems which are obvious that includes price, inexact health and safety issues, customer excitement and sustainable quality performance are still investigated by researchers.

# Chapter 4

# COMPARATIVE ANALYSIS OF RESIDENTIAL FURNITURE COMPANIES IN TERMS OF FLEXIBLE, SMART AND GREEN ISSUES

The figure below shows the categorization of residential furniture according to contemporary innovations. By the influence of content, this chart is separated into three parts as Flexible Residential Furniture, Green Residential furniture and Smart Residential Furniture (Fig 32).

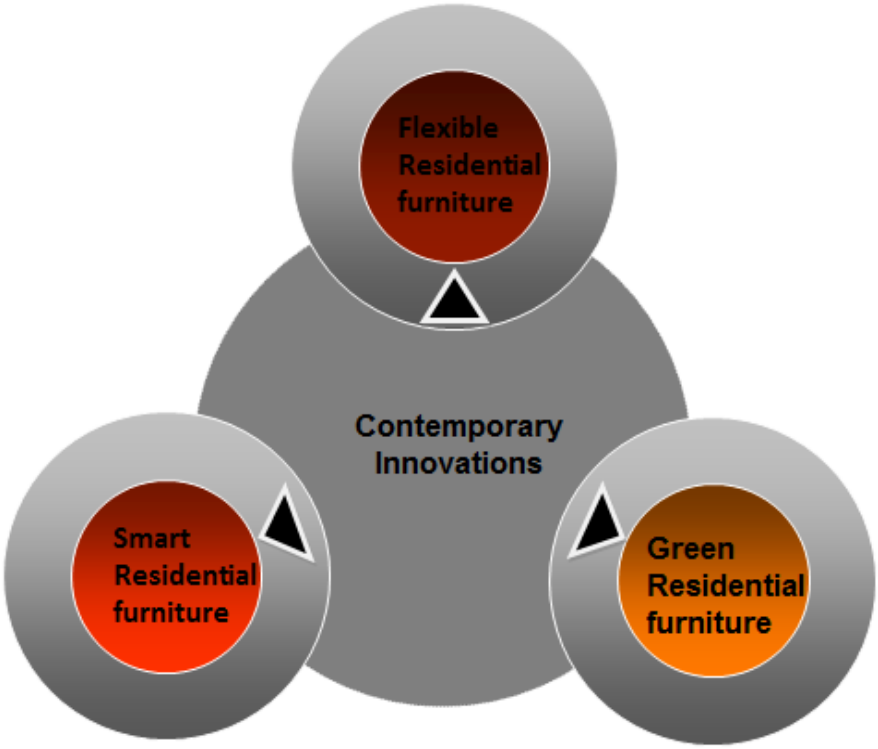


Figure 30. Schema to show contemporary innovations and their relations with residential furniture

Categories of contemporary innovations are shown in the figure below (Fig 33), within the frame of flexible residential furniture, smart and green residential furniture materials features in detail.

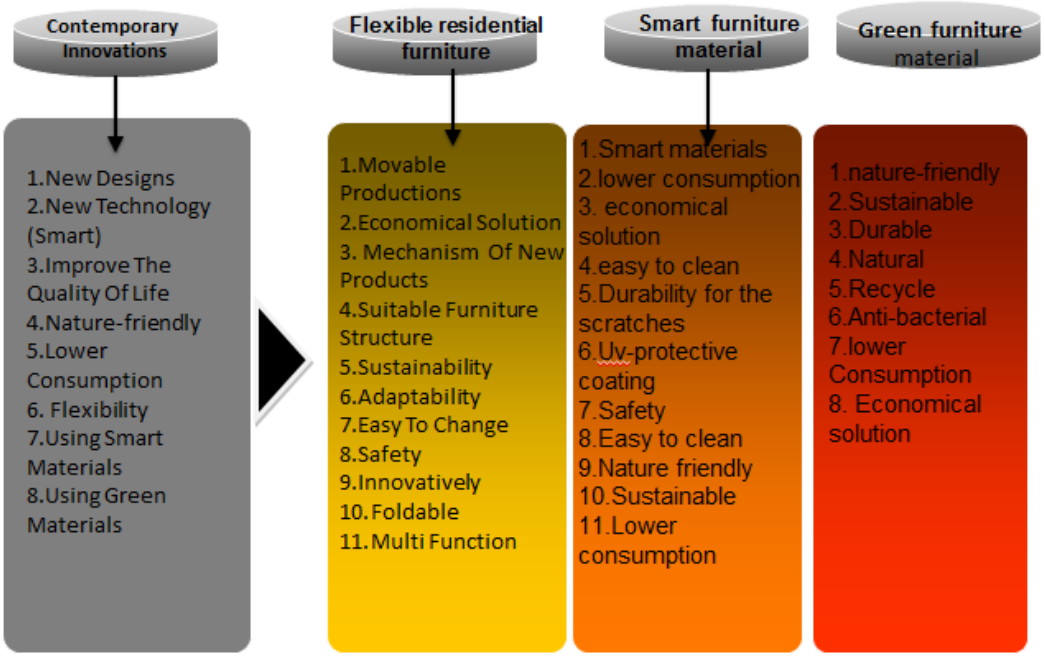


Figure 31. Features and categories of residential furniture in relation to contemporary innovations.

### 4.1 Case Study Definition Limitation and Sampling

According to theoretical discussions on contemporary innovations and flexibility in residential furniture that are investigated in the previous chapters with action research systematically, this chapter encounters with the investigation of furniture including both concepts. Because of the subject's uniqueness, these kinds of furniture are very limited among international companies. Through this study, companies will be compared in terms of features of smart materials (Nano material, Nano enhanced) and green materials (Natural, recycled) and also Flexibility (Movability, Modularity, Multifunctionality and Foldability). Selected furniture companies will be used as

case studies to make suggestions for innovative future of furniture, besides smart flexible residential characteristic.

This study through the frame of flexible residential furniture companies for comparison research is concerned about various flexible factors such as Movability, Fold ability, Modularity, Multi-functionality that indirectly serve to Sustainability.
The Keywords, which are used to analyze the web sites and the products of selected companies, are mentioned below together with related keywords:

- Movable : Easy to carry / change location / to move / simple movment
- Foldable : Space-Saving and storing
- Modular : Module _ Small components _easy to change situation
- Multifunction: Multipurpose _ multiuse _ change the function / adaptable to various uses / serving variety of ages / multiple combination

One of the other major innovations in furniture is about innovative smart materials or systems that are used in furniture recently. In spite of abundance of smart features, sustainability, eco-friendly, and green issues are investigated in this thesis. The keywords that are used to analyses the web sites of selected companies are mentioned below together with related keywords:

- Technology: Electronic systems_ Innovation
- Nano Material: Inorganic _ Fullerenes _ Graphene_ Nanocrystals
- Nano enhanced : Polypropylene_ Polyethylene_ sustainable coating
- Green furniture: Eco-friendly _ Health impacts_ Energy efficient
- Natural material: Bamboo _ Original wood
- Recycled material : Salvage _ Reusable _ Rebuilt _ Eco-friendly_Energy efficient

### 4.2 Case studies

In spite of lack of enough case studies, the research concerns on commercial websites, smart shops and some published sources as books, articles, papers around this issue to collect the required information. In this part, eight international companies that sell flexible or innovative smart residential furniture (from actual shops and websites) are explored.

Through finding the best case studies for this issue, international furniture fairs in all around the world are searched and the one which has highest number of companies attended (500) is chosen as known as ICFF 2014 in USA. A numerous (100) residential furniture companies have been selected randomly from the first 100 which include companies from various countries from 500 international furniture companies that are selling all residential furniture categories which were introduced in Chapter 2, and they attended to International Contemporary Furniture Fair in 2014 (ICFF). The list of companies which is given in appendix I is achieved by sorting according to country in category of furniture in ascending order. In terms of various companies that produce flexible furniture or which are related to using smart technologies and materials, the next step should be an analysis to distinguish common features between them to achieve the best results from them. The core comparison to obtain the consequences occurs in the third step. In one hand, vital keywords as sub keywords of flexible furniture and sub keywords of smart materials and green materials are chosen and on the other hand, they are compared within selected companies to find out reliability for further suggestion and presented in a chart. Eight companies which sell flexible furniture exists in selected first 100 companies and through this finding, eight companies which use smart and green

furniture are chosen to become parallel for comparison. Hence one common company is explored between them as company number 15.

Table 2. The list of furniture companies which are randomly selected from ICFF (ICFF2014)

| Company Name | Website | Flexible/Smart |
|---|---|---|
| 1. Ash Allen | ashallen.com | - |
| 2. Austrian Federal Economic Chamber | advantageaustria.org | - |
| 3. WittmannMoebelwerkstaetten GmbH | wittmann.at | - |
| 4. LichterlohKunsthandels GmbH | http://www.lichterloh.com/2 | - |
| 5. Neue Wiener Werkstaette | nww.co.at | - |
| 6. haraldbichler_rauminhalt | rauminhalt.com | - |
| 7. Tamawa | tamawa.be | - |
| 8. UniversoPositivo | universopositivo.com | - |
| 9. Atelier Vierkant | ateliervierkant.com | - |
| 10. Bensen | bensen.ca/ | - |
| 11. Bernhardt Design | bernhardtdesign.com | - |
| 12. Bespoke Global | bespokeglobal.com | - |
| 13. Bilijardai JSC | balticbilliards.com/ | - |
| 14. Blu Dot | bludot.com | - |
| 15. Boca do Lobo | bocadolobo.com | - |
| 16. BOWER | bowernyc.com | - |
| 17. BRABBU | brabbu.com | - |
| 18. Brazilian Furniture | www.brazilianfurniture.org.br | - |
| 19. Brendan Ravenhill | brendanravenhill.com | - |
| 20. British European Design Group (BEDG) | bedg.org | - |
| 21. Capdell | capdell.com | - |
| 22. Thomas Riley Studio | thomasrileystudio.com | F |
| 23. The Chair Factory | thechairfactory.com | |
| 24. Cherner Chair Company, LLC | chernerchair.com | S |
| 25. CODAworx | codaworx.com/awards | - |
| 26. ConcreteWall | resourcefurniture.com | F |
| 27. Cool Kids Company | coolkidscompany.com | S |
| 28. Cosmopolitan Glass, INC | cosmopolitanglass.com | S |
| 29. Council | councildesign.com | - |
| 30. Lacrau | visilek.com | - |
| 31. Daniel Heath | danielheath.co.uk | S |
| 32. David Gaynor Design | davidgaynordesign.com | - |
| 33. Diane Paparo Studio | dpstudiousa.com | - |
| 34. Dlv | dlvdesigns.com | - |
| 35. Egg Collective | eggcollective.com | - |
| 36. Emeco | emeco.net | S |
| 37. Ensconce Design | ensconcedesign.com | S |
| 38. Ercol | ercol.com | S |
| 39. Eskayel | eskayel.com | S |
| 40. Fabrica Mexico | fabricamexico.com | - |
| 41. FabrizioConstanza Design | fabrizioconstanza.com | S |
| 42. Folditure | folditure.com | F |
| 43. Fluxfurniture | fluxfurniture.com | F |
| 44. Fermob | www.fermob.com/en | S |

| | | |
|---|---|---|
| 45. Fort Standard | fortstandard.com | - |
| 46. Fred&Juul | fredandjuul.com | - |
| 47. Fritz Hansen | fritzhansen.com | - |
| 48. The Furniture Guild | thefurnitureguild.com | - |
| 49. Furniture New York | furniturenewyork.org | - |
| 50. GABRIEL SCOTT | gabriel-scott.com | - |
| 51. Galanter& Jones | galanterandjones.com | - |
| 52. Ge Yang | geyangwood.com | - |
| 53. Gentner Design | gentnerdesign.com | - |
| 54. GIN Art & Design | ginartdesign.com | - |
| 55. Graf Brothers Table Tops | grafbrostabletops.com | - |
| 56. Grain | graindesign.com | S |
| 57. HagitPincovici | hagit-p.com | |
| 58. Harbour Outdoor | harbouroutdoor.com | S |
| 59. Hästens | hastens.com | S |
| 60. Hastings Tile & Bath | hastingstilebath.com | - |
| 61. Hearth Cabinet | hearthcabinet.com | - |
| 62. Hinterland Design | hinterlanddesign.com | - |
| 63. Heller Incorporated | helleronline.com | - |
| 64. HiroOdaira / Precious Pieces | precious-piece.com | S |
| 65. Home Trends & Design | www.htddirect.com | S |
| 66. Hue Collection | huecollection.com | - |
| 67. Iacoli& McAllister | iacolimcallister.com | - |
| 68. iglooplay by Lisa Albin Design | iglooplay.com | F+S |
| 69. Immersion Design | immersiondesign.com | - |
| 70. Imus Design | www.imusdesign.com | - |
| 71. Innermost | www.innermost.net | - |
| 72. Inside Norway | www.insidenorway.no | - |
| 73. Interiors From Spain | www.interiorsfromspain.com | |
| 74. Molo | http://www.molotrade.com/ | F |
| 75. Oasiq | http://www.oasiq.com/ | S |
| 76. J Liston Design | jlistondesign.com | - |
| 77. Jacobsen Collection | www.jacollection.com | - |
| 78. James De Wulf | jamesdewulf.com | - |
| 79. Janosi Designs | janosidesigns.com | S |
| 80. The Office For Lost Objects™ | officeforlostobjects.com | - |
| 81. Jerry Nance | www.jerrynance.com | - |
| 82. Joe Jin | joejin.com | - |
| 83. John Eric Byers | johnericbyers.com | - |
| 84. John Ford | john-ford.com | - |
| 85. John Houshmand | johnhoushmand.com | - |
| 86. John Robshaw Textiles | johnrobshaw.com | - |
| 87. Khouri Guzman BunceLininger | kgblnyc.com | - |
| 88. KOKET | bykoket.com | - |
| 89. KWH Furniture | kwhfurniture.com | - |
| 90. Lake + Wells | lakeandwells.com | - |
| 91. LichterlohKunsthandels GmbH | lichterloh.com | - |
| 92. Lim + Lu | limandlu.com | F |
| 93. Liqui Design | liquidesign.co.uk | S |
| 94. Made Goods | madegoods.com | - |
| 95. Marc Schulthess | marcschulthess.com | - |
| 96. Matter | mattermatters.com | - |
| 97. MAY Furniture Co. | mayfurnitureco.com | - |
| 98. Moran Woodworked Furniture | moranwoodworked.com | - |
| 99. Michael Robbins | mchlrbbns.com | - |
| 100. Min \| Day & MOD | minday.com | F |

Table 3. Eight flexible residential furniture companies, which exists between 100 furniture companies who attend in ICFF2014

| Name of Companies | Companies Web Sites |
|---|---|
| **1.Flux Furniture** | https://www.fluxfurniture.com/ |
| **2.Thomasrileystudio** | http://thomasrileystudio.com/portfolio/fletchercapstan-table/ |
| **3.Resourcefurniture** | http://www.resourcefurniture.com/ |
| **4. Folditure** | http://folditure.com/ |
| **5. Molo** | http://www.molotrade.com/ |
| **6.Lim + Lu** | http://limandlu.com/ |
| **7.Min \| Day & MOD** | http://www.minday.com/ |
| **8.Iglooplay by Lisa Albin Design** | http://iglooplay.com/ |

In these flexible companies, flexible features as movability, modularity, multifunctionality and foldability in terms of economical and sustainability issues are shown.

Table 4. Eight Smart residential furniture which selected between 100 from international furniture companies which attend ICFF2014, are:

| Name of Companies | Companies Web Sites |
|---|---|
| **1. Ercol** | http://www.ercol.com/ |
| **2.Cherner** | http://chernerchair.com/home |
| **3.Coolkids** | http://coolkidscompany.com/about.php |
| **4. Janosi Designs** | http://janosidesigns.com/about.html |
| **5.Eskayel** | http://eskayel.com/ |
| **6.Danielheath** | http://danielheath.co.uk/ |
| **7.Emeco** | http://www.emeco.net/ |
| **8.Iglooplay by Lisa Albin Design** | http://ensconcedesign.com/ |

In these smart materials companies, features in nano materials, nano enhanced , green and recycled material issues in terms of economical and sustainability are explained .

### 4.3 Comparative Analysis of the 15 selected companies

The chart below shows a comparative analysis of selected 15 companies which are selling residential furniture to include most of the categories of flexible residential furniture, smart and green furniture material: In table below, 7 companies (1-7) from flexible furniture companies, 7 companies (8-14) which are using smart materials and one furniture company (15) with both Flexible and Innovative/Smart features are deeply investigated.

Table 5. This comparison is shown in frame of a table

| **Innovative Residential Furniture** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Residential Furniture Companies In ICFF 14** | Flexible Residential Furniture | | | | Innovative Furniture Materials & Technology | | | | |
| | | | | | | Smart materials | | Green material | |
| | Movability | Fold ability | Modularity | Multi-Functionality | Innovative Furniture Technology | Nano Material | Nano technology Enhance surfaces | Natural material | Recycled material |
| Company1 | ● | ● | | ● | | | | ● | ● |
| Company2 | ● | ● | | ● | | | | ● | ● |
| Company3 | | | ● | ● | ● | | | | |
| Company4 | ● | ● | ● | ● | ● | | | | |
| Company5 | ● | ● | ● | | | | | | |
| Company6 | ● | ● | ● | ● | ● | | | ● | |
| Company7 | ● | ● | ● | ● | ● | | | ● | |
| Company8 | | | | | | | ● | | ● |
| Company9 | | | | | | | | ● | ● |
| Company10 | | | | | ● | | | ● | ● |
| Company11 | | | | | ● | | ● | ● | ● |
| Company12 | | | | | ● | | | | ● |
| Company13 | ● | | | | ● | | | ● | ● |
| Company14 | | | | | | | | ● | ● |
| Company15 | ● | | ● | ● | ● | | ● | ● | ● |

After the analysis of 15 companies according to the determined keywords, three companies are examined further where the first company focuses on flexible furniture, the second one focuses on furniture with smart and green materials and the third one includes both characteristics.

### 4.3.1 Flexible Furniture

Table 6. Flexible Furniture

| **Flexible Furniture** | **Company no.** |
|---|---|
| flux products you can fold it down to a flat package that takes up little space in transport and storage, expandable partitions | 1,3,7 |
| multidisciplinary design, changes from one mode and appearance to another, space-saving Living, Multiple combinations suit | 2,3,4,6,8 |
| freedom to compose, presenting flexibility, movement | 4,5,7 |
| simple rectangular low table, modularity | 5,6, |

### 4.3.2 Smart Furniture with Smart Materials that used by Company

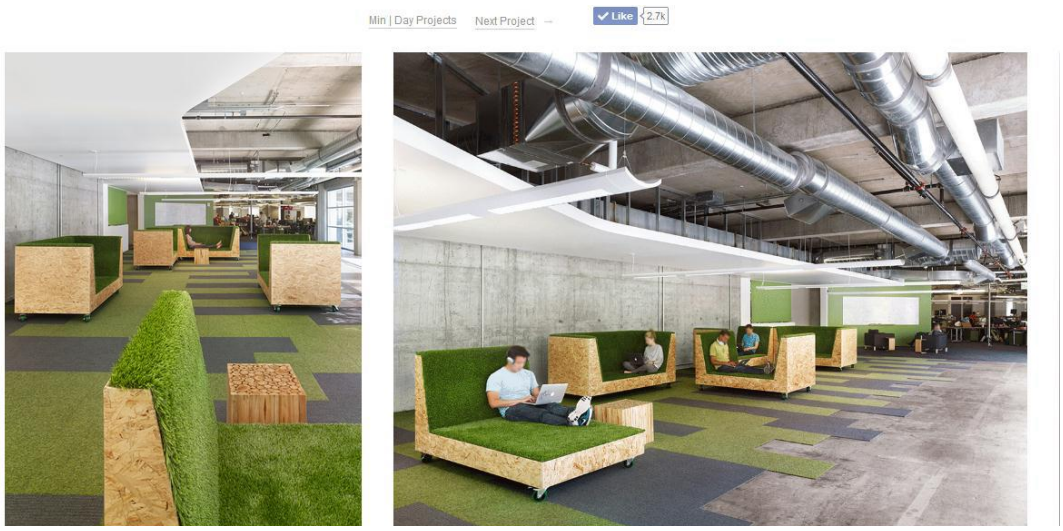


Figure 32. A flexible furniture company that sells movable and foldable furniture

Table 7. Smart Furniture with Smart Materials features

| **Smart Materials** | **Company no.** |
|---|---|
| energy efficient, environmentally-friendly, protect environment. environmentally responsible | 8,9,10,12,13 |
| Natural finishes, Caring for the environment, natural materials, natural earth friendly | 8,10,11,12 |
| Smart materials, polypropylene, sustainability, woven metallic polyurethane | 15 |

### 4.3.3 Flexible Furniture besides using smart and green materials used by Eskayel company

Table 8. Flexible Features That are Used In This Company

| | Flexible Features That are Used In This Company |
|---|---|
| **1.** | Multi-functional + multi-generational design - elegant for any interior |
| **2.** | Modular soft seating that integrates well with contract + residential design |
| **3.** | Tea Pods are an organic, growing system of various sizes and shapes conceived as sculptural and moveable furniture for children and adults. |
| **4.** | It is to be gently moving while having a personal-size |

Table 9 Smart material features Concluding remarks

| | Smart material features Concluding remarks |
|---|---|
| **1.** | High density foam, upholstered in rich and durable wools, eco textured vinyl or woven metallic polyurethanes |
| **2.** | Meets or exceeds the applicable recommended industry standards for child safety; high durability for contract use |
| **3.** | Recycled ultra-suede: designer palette, plush nap + durable; spot cleans with brush, mild soap + water |
| **4.** | Crypton suede: designer colors, highly durable + anti- microbial; ideal for contract use |
| **5.** | Tray: resource-efficient molded ply with hard maple face: natural finish, walnut or amber bamboo veneer |
| **6.** | PVC-free vinyl alternative: colorful, non-toxic + easy to wipe clean; ideal for contract use |
| **7.** | All wood obtained from sustained yield forestry practice |
| **8.** | Meets or exceeds the Consumer Product Safety Commission Standards for child safety; high durability for contract user |
| **9.** | 100% wool slipcover |
| **10.** | Bamboo/poly fill, encased in an all-cotton liner. Fabric manufacturing - reduced environmental impact |
| **11.** | Heavy metal-free dyes, reduced emissions |

Figure 33. A flexible furniture company which produce flexible furniture beside using smart and green materials

### 4.4 Concluding remarks of chapter 4

In this study, the main aim is about how contemporary innovations on flexible furniture systems can have positive effects on functionality and makes a better life for future with new technology beside their comfortable usage.

As a result of this chapter, contemporary innovative technology for residential furniture, such as using smart and green materials within the frame of flexibility and ecologic features, is investigated in this study. From figure28 and figure29 , it can be stated that both flexible furniture companies and smart furniture companies are common in sustainability factors to achieve the highest quality in innovative residential furniture and one of the companies have most of the factors as a flexible furniture with smart materials. In terms of these points, it is realized that the companies which create particular flexible furniture have the potential to use different smart (Nano material or Nano-enhanced) and green materials (Natural or recycle material) in new products.

# Chapter 5

# CONCLUSSION

In consequence, this study has been investigated contemporary innovations that focused on flexibility issues to serve sustainability, especially in case of residential furniture. In spite of Flexible design advantages in residential furniture include movability, modularity, multi-functional and foldable design, they might have their problems that are considered in this study. Innovative factor's influences on flexible furniture and various types of them are explored to catch problem solutions as they were mentioned in problem definition(include burning easily, being hard to clean, hard to move, easy to scratch, repairing hard, health problem, time consuming and unchangeable). In addition, specific materials to use in furniture such as innovative material ( Nano- Materials or Nano-Coating) and their advantages in order to achieve sustainability and flexibility such as green materials (natural and recycled), has been investigated by researchers in various fields and this study is expected to contribute to limited researches within interior architecture .

In terms of research improvement, 100 residential furniture companies which are selling most of the categories that are explained in chapter 2, have been selected as case studies between 500 international companies who attended in ICFF 2014 (International Companies Furniture Fair) and have been analysed by keywords. There are some beneficial features, which are explored from selected companies (table.9):

Table 10. Flexible furniture, Smart and Green materials Features that are Used in case studies

| | **Flexible furniture , Smart and Green materials Features That are Used in case studies** |
|---|---|
| **1.** | Multi-functional + multi-generational design - elegant for any interior |
| **2.** | Modular soft seating that integrates well with contract + residential design |
| **3.** | Organic shapes and ease-of-use to enhance the spontaneous |
| **4.** | use eco-friendly materials that will sustain families and the environment for many years to come. |
| **5.** | use of more environmentally-friendly water based finishes |
| **6.** | Natural products are made with natural earth friendly materials |
| **7.** | Based design studio that focuses on applying a uniquely artistic and environmentally responsible approach to interior surface design |
| **8.** | easy to clean and can be customized using stickering, embossing |
| **9.** | self-positioning as it changes from one mode and appearance to another |
| **10.** | Modern, modular and customizable, the space-saving |
| | |

In concluding remark, combination of both flexible design and smart materials as beneficial innovative points can suggest new furniture design for better future life. There are some recommended points that are achieved from conclusion:

- Increasing the quality of future life is the most common factor in this comparison.
- Suggesting multi-functional furniture besides, having smart materials to be recycled and sustainable.
- Recommending flexible and easy movable/ foldable or modular furniture with Nano-coating, which is eco-friendly or natural reusable with the least disadvantages, to reach durability.

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