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INNOVATIVE APPROACHES IN FURNITURE ASSEMBLY AND SUSTAINABILITY IN DESIGN

M. Lütfi HİDAYETOĞLU[1] Kemal YILDIRIM[2]

[1] Selçuk University, Faculty of Fine Arts, Department of Industrial Product Design, 42250, Konya, TURKEY
[2] Gazi University, Faculty of Technology, Department of Woodworking Industrial Engineering, 06500, Ankara, TURKEY
mlhidayetoglu@selcuk.edu.tr

Abstract- Furniture design trends are moving toward furnishings that user can customize to suit their needs and approaches that allow them to determine the final form of design and furnishings. However, manufacturer is disposed to lower costs of transportation, assembly and service. This requires the dispatch of furniture without being assembled in small boxes, assembly without the need for expertise, and dynamic design features. This study intends to reveal innovative assembly techniques that will replace conventional furniture assembly techniques and demounting equipments in the near future. For this purpose; international literature has been examined, and innovative assembly techniques and advantages of these techniques compared to traditional methods have been revealed. In addition, problems related to the sustainability of the furniture due to the assembly skills required by the furniture demounting equipments and repeated demounting practices have been discussed. In the evaluation part of the study, the contribution to the sustainability of the "Triple Eccentric Fastenings" design and the "Fixing Magnetic - Use of the Magnetic Couplers in Furniture Assembly" project whose design and patent belong to the authors was examined. In the final part of the study, alternatives of the designs proposed by the authors to being innovative furniture assembly techniques that will inactivate traditional furniture assembly techniques, materials and assembly skills in the future were discussed.

Key Words- Furniture, Construction, Assembly, Sustainability, Innovation.

MOBİLYA MONTAJINDA İNOVATİF YAKLAŞIMLAR VE TASARIMDA SÜRDÜRÜLEBİLİRLİK

Özet- Mobilya tasarım trendleri; tasarımın son şeklinin kullanıcısı tarafından belirlendiği yaklaşımlara ve daha kişiselleşmiş mobilyalara doğru hızla ilerlemektedir. Bununla beraber üreticiler ise nakliye, montaj ve servis maliyetlerini aşağı çekmek için mobilyaların küçük kutularda birleştirilmeden sevkini, uzmana gerek olmadan montajını ve tasarımın dinamik özelliklerini öne çıkarma eğilimindedir. Bu çalışmada, yakın gelecekte geleneksel mobilya montaj teknikleri ve demonte birleştirme gereçlerinin yerini alacak inovatif montaj yöntemlerinin ortaya çıkarılması amaçlanmıştır. Bu maksatla, yenilikçi birleştirme teknikleri ve bu tekniklerin geleneksel yöntemlere göre avantajları irdelenmiş, mobilya demonte gereçlerinin gerektirdiği montaj ustalığı ve tekrar eden demontaj sonunda mobilyanın sürdürülebilirliği ile ilgili sorunlar tartışılmıştır. Ayrıca, tasarımı ve patenti yazarlara ait olan "Üç Başlı Mafsallı

Bu makale, 4. Uluslararası Mobilya ve Dekorasyon Kongresi'nde sunulmuş ve İleri Teknoloji Bilimleri Dergisi'nde yayınlanmak üzere seçilmiştir.

Eksantrik Bağlantı Elemanı" tasarımı ile "FixingMagnetic - Mobilya Montajında Manyetik Birleştiricilerin Kullanımı" projesinin mobilyada sürdürülebilirliğe katkısı ele alınmış ve sonuçta bu tasarım önerilerinin gelecekte geleneksel mobilya birleştirme tekniklerini, gereçlerini ve montaj ustalığını devre dışı bırakabilecek inovatif mobilya montaj tekniği olma alternatifleri tartışılmıştır.

Anahtar Kelimeler- Mobilya, Konstrüksiyon, Montaj, Sürdürülebilirlik, İnovasyon.

1. INTRODUCTION (GİRİŞ)

Changeovers as technological innovations, easy access to information, increase in consumption, relative improvement in life standards and trends, have changed the ways of product design and presentation to consumers. Rapid decline of natural resources and awareness of ecological imbalance, with increasing consumption, have necessitated a change in design processes. Trends in furniture designs are rapidly advancing towards the approaches, final designs of which are set by the user, and towards more personalized furnishings. Manufacturers, on the other hand, tend to lower transportation, installation and service costs. This brings out consignment of furniture without being assembled in small boxes, installation without specialists and dynamic design features. In this context; sustainability functionality and end-user involvement approaches have begun to gain importance.

Sustainability has emerged as an important concept in the 20th century, marking global county policies, economies, energy resources, technology, production, planning and architectural design [1]. After the industrial revolution, design was described as an activity that was merely aimed at achieving commercial gain. Thus, all products are designed, manufactured and consumed without considering the fact that natural resources, in general, are not infinite.

In his book Design for the Real Word, Papanek [2] emphasized that the designing profession should undertake social responsibilities instead of meeting commercial demands. This approach, which led to debates during the period, was later developed by the concepts of Design for Environment and Sustainable Product Design [3].

Sustainability is the way in which a resource is processed or used so as not to be consumed, finished or destroyed forever [4,5]. In his study, Norman Foster states that sustainability is not about fashion, but about survival as well as approach to doing business with as few resources as possible [6]. Sustainable design, in its respective conditions and in every period of its existence, is all of the activities designing environmentally sensitive, energy-efficient, water-efficient, materials that effectively prioritize the use of renewable energy resources, taking future generations into account and protecting the health and comfort of people. In other words, it is the art of fulfilling the needs of people, without putting the existence and the future of natural systems in danger [7].

1.1.Sustainabilty Approaches in Furniture (Mobilyada Sürdürülebilirlik Yaklaşımları)

At the core of the trend towards sustainable design, there are destruction and socio-economic factors in the natural environment. Rapid consumption of resources and repetitive need to recycle resources, time and production processes for production and processes affect the ecological balance and the balance between economic life span and costs of the products negatively. For this reason, sustainable application orientations have become imperative in all processes of design.

Yeang [8] emphasizes the importance of perceiving design as an environmental impact when opening sustainability principles. To use the least amount of power and materials, to use original and needed technology, to use renewable energy in design, to reduce resource need, to adopt principles of reuse and recycle, to question need and demand and direct them to easy-improvable design are basic principles of sustainable design [8].

Sustainability approach in furniture; design, material and production processes are discussed below.

1.1.1. Sustainability in design (Tasarımda sürdürülebilirlik)

The first step in sustainable furniture is the design. The topics such as which intended population to be addressed, what function to perform, which materials and production processes to produce, how to recover the economic life after completing the entire life cycle are all determined at the design stage. It is believed that the most concrete design decision for sustainability is ensuring functionality and user involvement in design. It is expected economic life of furniture to be longer and to be adopted more, which are shaped and customized according to the demands and requirements of the users.

Figure 1. Customizable bookcase "Tangram Bookcase" [9]
(Kişiselleştirilebilen kitaplık "Tangram Bookcase")

Figure 2. Use of functional equipment for narrow spaces [10]
(Dar mekânlar için fonksiyonel donatı kullanımı)

Thanks to the flexible and changeable design of the furniture, the user can use one piece of furniture instead of having many different furniture for different actions. Moreover, users can continue to meet their needs by making changes to existing furniture rather than buying new furniture for changing needs.

1.1.2. Sustainability in material (Malzemede sürdürülebilirlik)

The developments in advanced technology and chemistry have promoted the use of many different materials such as metal, ceramics, glass, plastic, textile as well as wooden material

which has been improved in furniture design. This diversity has also made it possible to design different types of furniture with the same function. The proliferation of material options and the development of shaping technologies have also affected the structure of the furniture, thus making it possible for designers to make new designs by developing new carrying systems. However, serious environmental problems have necessitated the development or use of materials that would not harm the ecological balance [11].

The use of materials that require less maintenance and repair (nano-technological polymers, etc.), which are recoverable (aluminium, plastic, etc.), and those obtained from rapidly renewable sources (industrial forests etc.), are the first alternatives that come to mind. In addition to these preferences, the inclusion of designing waste and scrap material in the end of mass production can be given as an example of the use of sustainable materials in furniture design. Çagatay Afşar's "Mammellastool" stool was produced from the combination of inert parts left from furniture production (Figure 3). Likewise, the "PaperBricks Pallet" series of seating elements obtained by WooJai Lee's processing and compacting waste papers can be given as examples of materials that can be reused after filling the life span (Figure 4).

Şekil 3. "Mammellastool" [12]

Şekil 4. "PaperBricks Pallet" [13]

1.1.3. Sustainability in manufacturing (Üretim süreçlerinde sürdürülebilirlik)

The resources of a furniture can be enhanced by the right planning and management of production, as well as design and material decisions, with the potential to use it correctly. Measures such as the use of common parts in modular production and serial production, the reduction of used equipment, the attenuation of parts, the ergonomic production line, the operation of machinery and equipment with renewable energy sources play an important role in increasing the sustainability and in the shortening of the energy and the energy consumed for production.

2.FURNITURE ASSEMBLY TECHNİQUES (MOBİLYA MONTAJ TEKNİKLERİ)

Along with the industrial revolution, new machines and rapid production have allowed a large number of affordable furniture to be placed on the market. Today's changing needs and rapid increase in consumption have strengthened the concept of mass production furniture and brought new dimensions.

In addition to materials and manufacturing methods in sustainable, functional, modular and customizable furniture design, another important factor is the methods used for assembly and disassembly of furniture. The furniture mounting method influences the economic life of the

furniture and therefore its sustainability. In addition, the selection of the joining method for furnishings that can be transformed and customized over time, which is particularly suitable for foreign trade and provides flexibility in design, has a critical importance. In this part of the study, the techniques used in the assembly of the produced and demounted furniture are examined.

2.1. Traditional Furniture Assembly Techniques (Geleneksel Mobilya Montaj Teknikleri)

Conventional furniture uses combination of dowel and mortise in connection of traditional furniture elements, and mechanical fasteners made of metal or metal+plastic for assembly of demounted furniture [14]. The economic life span of furniture mounted via these fasteners is directly related to the strength of the joints. In studies on the strength of joining points of box-structured furniture [15-19], the effects of many factors on the strength such as material type, surface roughness, glue usage, tool sizes etc. have been examined. In these studies, it was emphasized that furniture mounting techniques in general depend on critical preferences in achieving the strength performance that furniture should exhibit against the loads it is subjected to.

These studies and practical applications show that they are driven to the market with a certain economic lifetime according to the qualities of the furniture, their workmanship and the target population. At this point, furniture joining techniques affect the sustainability performance of the furniture in the design, production, shipment, installation and repetitive disassembly phases in use. In the assembly of traditional demounted furniture, elements like eccentric fittings (minifix), dowels, trapezes, t-joints, fused joints, corner joints are used (Figure 5). Many of these joints become ready for assembly with processes involving very precise aligning, drilling, cutting. At the same time, a furniture to be installed with these tools needs an experienced assembly member. However, the external appearance of the furniture after installation may not be satisfactory. As a result of repetitive disassembly and assembly applications of all these tools, it is seen that their strengths are seriously lowered. These considerations above may cause the sustainability performances of the furniture used by traditional furniture assembly technicians to be low.

Figure 5. Trapeze, minifix and butterfly fasteners [20]
(Trapez, minifix ve kelebek bağlantı elemanları)

2.2. Innovative Furniture Assembly Techniques (İnovatif Mobilya Montaj Teknikleri)

Traditional furniture mounting techniques appear to have many disadvantages which have significant effects on sustainability such as workmanship, production process, strength, service life, assembly skill and aesthetic problems. To overcome these disadvantages, some innovative joining techniques have been developed to produce long-lasting and economically-long

furnishings. This part of the study will focus on some innovative joining elements that are mass produced and presented to the market and their advantages.

The first of the techniques that is the subject of this study is the joining technique named "Wedge-Dowel" developed by Ikea company. Ikea generally sells its products in flat boxes, as demount, and it is strategically adopted that the assembly of the products is done by the customer. In this approach, it is assumed that the user has a certain skill and experience. Installation of a wide variety of assembly materials in the box must be done in the correct order and the parts must be installed in the correct order. The company has improved a joining technique named "Wedge-Dowel", to reduce the number of these tools, shorten the assembly process and create a more robust joining method.

With this technique, in the Lisabo series, presented on the market; the feet, instead of the complex table foot tray joints (Figure 6), are mounted directly to the table and fastened with screws and a screw (Figure 7).

Figure 6. Conventional foot tray mounting methods [21] (Geleneksel ayak kayıt tabla montaj yöntemleri)

Figure **7.** Ikea Lisabo series table and Wedge-Dowel combination [21] (Ikea Lisabo serisi masa ve Wedge-Dowel birleştirme)

Similar techniques have been used for Regissor coffee table by Ikea, and the eccentric joining tool, which has complex parts, was disused. Thanks to the special dowel being used, the furniture can be dismounted and mounted many times when necessary, without decreasing the strength, and there are no holes or screws visible after mounting (Figure 8).

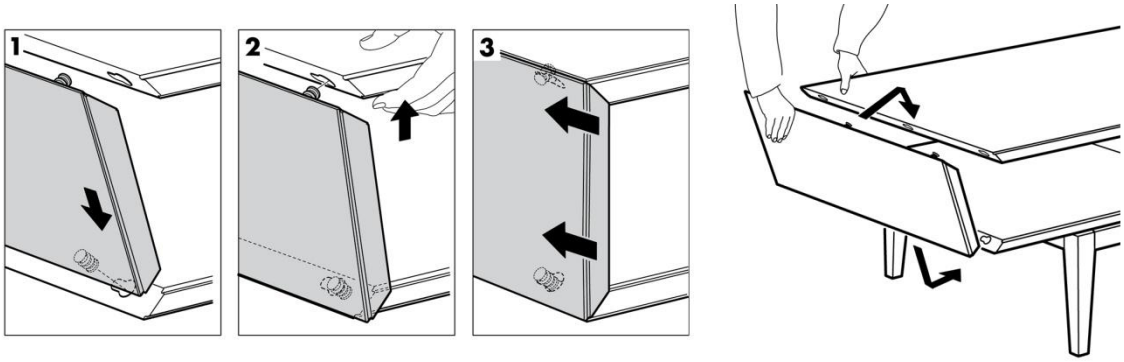

Figure 8. Ikea Regissor series coffee table assembly detail [22]
(Ikea Regissör serisi sehpa montaj detayı)

Another innovative and sustainable assembly tool is a joining element that works with magnets called "Invis Mx 2" developed by Lamello. A magnetized pin is fixed to the surfaces of the parts and the parts are screwed by magnetization. When viewed from the outside, no holes are visible in the construction details (Figure 9).

Figure 9. Lamello Invis Mx2 joining element [23]
(Lamello İnvis Mx2 bağlantı elemanı)

Another merging regenerator developed by Lamello is Tenso-p, which provides a creative connection between the part to be processed and the connection element. (Figure 10). The most important advantage of this system is that it is a locking and fixing system which operates without adhesive or screws. The special hole/groove is opened on the part to be processed and then the connecting element is inserted into this groove. The greatest advantage it provides is that the apparatus is placed only manually by hand in a second without the use of tools [24]. The number of innovative furniture combining techniques described in this section and offered for use can be increased.

Figure 10. Lamello Tenso-p series joining element [25]
(Lamello Tenso-p serisi birleştirme elemanı)

3. INNOVATIVE INSTALLATION RECOMMENDATIONS FOR SUSTAINABLE FURNITURE (SÜRDÜRÜLEBİLİR MOBİLYALAR İÇİN İNOVATİF MONTAJ ÖNERİLERİ)

Sustainability problems encountered in traditional furniture assemblies, developments in innovative fasteners and the proliferation of such new products reveal that there is a need for sustainable furniture mounting tools that can be used particularly in the assembly and disassembly of demountable furniture and efficiently utilize resources. In this part of the study, the design "Triple Eccentric Fastenings", the "FixingMagnetic - Use of Magnetic Couplers in the Assembly of Furniture" project, design and patent of which belongs to the authors will be mentioned.

3.1. Triple Eccentric Fastenings (Üç Başlı Mafsallı Eksantrik Bağlantı Elemanı)

The eccentric fasteners, which are described as a ground-breaking invention in the field of fasteners, are fast mounting elements that combine the edges of two furniture tables 90 ° -180 ° in corner and edge-joint. With the existing single-head socket and double-head articulated eccentric fasteners, wide-angle edge fitting of three tables is not possible. However, in the furniture sector, it seems to be an important requirement that the edges of three tables can be fixed angularly in a firm and dismantled manner.

The furniture sector often meets this need by gluing tables at the production site or using external wood / metal fittings (Figure 11). These applications create a bad image at the junction of the three tables and eliminate the ability of the furniture to be installed at the place of use. As a result, there are problems in the quick assembly of the angled edge joints of the three panels of the hexagonal (etc.) shaped boxes.

Figure 11. Available solutions for wide-angle mounting of three tables [26]
(Üç tablanın geniş açı ile montajı için kullanılan mevcut çözümler)

It is possible to quickly mount the angled edge joints of three boards of the furniture with the "Triple Eccentric Fastenings", registered by the Turkish Patent Institute to the patent registry with the number 2016/04950 on behalf of the designer Kemal Yıldırım (Figure 12).

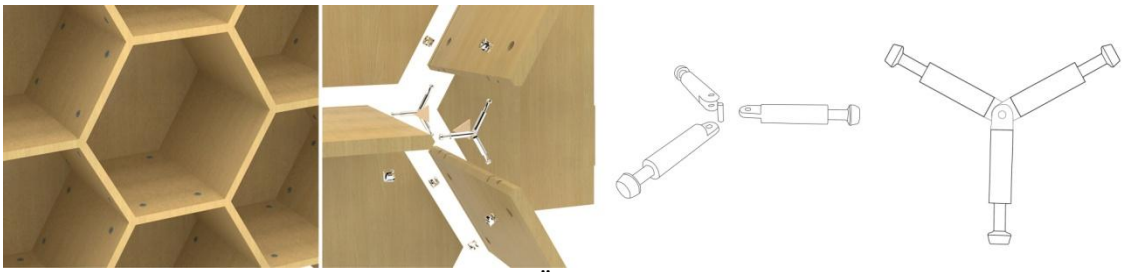

Figure 12. Triple eccentric fastenings (Üç başlı mafsallı eksantrik bağlantı elemanı)

This joining element reduces the waste of the side table by 50-80%, and makes the furniture look more elegant and beautiful in terms of aesthetics. In addition, the negativity which removes the demounting feature of the resultant furniture by gluing the angled edge joints of the three panels of the box furniture at the production site is also removed with this connection member. The "HexBOX" file cabinet design in which this joining element was used, was awarded the "A Design Award" in the category of Furniture and Decorative Products and Home Appliances in the A Design Award and Competition held in Italy in 2016 (Figure 13).

Figure 13. HexBOX file cabinet design (HexBOX dosya dolabı tasarımı)

3.2. FixingMagnetic- Use of Magnetic Couplers in Furniture Assembly (FixingMagnetic- Mobilya Montajında Manyetik Birleştiricilerin Kullanımı)

The aim of the "FixingMagnetic - Use of Magnetic Couplers in Furniture Assembly" project is to enable the assembly and disassembly of the furniture repeatedly in the furniture, to implement the appliance by the user and without tools and to provide flexibility and customization in the design. The project is foreseen for contemporary furniture in which the end user is included in the design process, where changes can be made in the form of design, units and use, if desired. The prototypes of the project were tested in the 3rd Furniture R&D Project Market (Figure 14).

Figure 14. "FixingMagnetic" project prototypes (“FixingMagnetic” projesi prototipleri)

"FixingMagnetic" is an innovative furniture mounting technique designed with powerful neodymium magnets and completely disengaging traditional furniture joining techniques, utensils and assembly skill. It is a different alternative to existing fittings for demountable and customizable furniture. Today, minifix, socket, hinge, corner joints and other joining tools used in demountable furniture require expertise in production and installation. In addition, these tools become very deformable and unusable during subsequent demounting and mounting of the furniture. The magnetic couplers developed at this point reduce the cost of production, installation, service and extend the furniture life.

The project was developed by Mehmet Lütfi Hidayetoğlu and the designer received the third prize in the 3rd Furniture R&D Project Market realized in 2015. In addition, the "Add+it" bookcase design, which was proposed as the "FixingMagnetic" project concept, received the

"Silver A Design Award" in the Furniture and Decorative Products and Home Appliances category in the A Design Awards and Competition in Italy in 2016 (Figure 15).

Figure 15. Add+it bookcase bookcase design (Add+it kitaplık tasarımı)

4. CONCULUSION AND DISCUSSION (SONUÇ VE TARTIŞMA)

Furniture design trends are rapidly advancing towards the approaches, the final design of which is set by the user, and towards more personalized furnishings. It has been found that the furniture which is mounted or lastly shaped by the user is seen more valuable and beautiful by the users and is more adopted by the users of the furniture [27]. The manufacturer, however, tends to reduce transportation, installation and service costs by adhering to sustainability principles within the scope of social responsibility activities, as well as legal restrictions. These changes necessitate the assembly of the furniture, without the need for specialists, and dynamic design features without being assembled in small boxes.

New design requirements and long-lasting disassembly requirements increase the importance of furniture joining techniques. Traditional furniture mounting techniques appear to have many disadvantages which have significant effects on sustainability such as workmanship, production process, strength, service life, assembly skill and aesthetic problems. Sustainability problems encountered in traditional furniture assemblies, developments in innovative fasteners, and the widespread use of such new fasteners, reveal the need for new mounting methods and materials, which can be used particularly in the mounting and dismounting of sustainable demountable furniture.

The Triple Eccentric Fastenings proposed in this study can be used to design a more aesthetic / light furniture, to save table amount needed, while the demountable feature of the designed furniture is maintained.

With the "FixingMagnetic - Use of Magnetic Couplers in Furniture Assembly" project, it is possible to customize the furniture design in particular and to make it possible for a furniture to be mounted and demounted repeatedly in different ways without deformation. In addition, it is provided that furniture can be assembled without any need for tools or skills. With R&D activities to be performed on this concept; notions such as every-way openable door and frictionless rail in furniture can be mentioned.

In conclusion, it is envisaged that the proposed designs will change the existing furniture design, production and usage habits with the specified features and potentials. The use of these joining methods and equipment is recommended for efficient use of limited resources, high value added, user-adopted, long lasting and particularly sustainable furnishings.

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