INDUSTRY WOOD ENGINEERING

Wood Industry & Engineering

KARADENIZ TECHNICAL UNIVERSITY

KTU 1955 KARADENIZ TECHNICAL UNIVERSITY

2020

VOLUME 2
ISSUE 2

ISSN: 2687-6043
e-ISSN: 2687-6035

Wood Industry and Engineering

ISSN: 2687-6043 **e-ISSN:** 2687-6035

YEAR : 2020 VOLUME : 2 ISSUE : 2

Wood Industry and Engineering (WI&E) is a peer-reviewed international scientific journal and published twice in each year (January-June and July-December). Publication language is English.

Original articles, reviews, technical notes, short communication and extended conference papers on basic and applied research dealing with the science, technology, and engineering of wood and wood based products can be submitted to Wood Industry and Engineering.

Editorial Board

Compliance with Ethic Rules

The papers submitted to Wood Industry and Engineering should not already been published or been submitted to another journal.

Authors should adhere to COPE (Committee on Publication Ethics)'s international standards for editors and authors. More details can be found at journal web page via link: https://dergipark.org.tr/en/pub/wie/policy.

Compliance with the principles of scientific research and publication ethics is evaluated within the framework of the provisions of Article 4 of the Inter-University Council Scientific Research and Publication Ethics Directive, Article 9 of Regulations of the TUBITAK Committee on Research and Publication Ethics and Article 6 of the Higher Education Council Scientific Research and Publication Ethics Directive.

Ethical committee approval should be obtained for studies on clinical and experimental human and animals requiring "Ethics Committee Decision" and this approval should be stated and documented in the paper.

Disclaimer

Authors are responsible for the content of their work. As publisher, Karadeniz Technical University and Department of Forest Industry Engineering do not accept responsibility for the statements made or for the opinions expressed in the Wood Industry and Engineering Journal. Publisher makes no representation or warranty of any kind, concerning the accuracy, completeness, suitability or utility of any information, apparatus, product or processes discussed in this publication; therefore, it assumes no liability.

Copyright

Correspondence

Wood Industry and Engineering Journal
Karadeniz Technical University
Faculty of Forestry, Department of Forest Industry Engineering
Kanuni Campus, 61080, Trabzon / TURKEY

Phone: +90 462 377 2800
Fax: +90 462 325 7499

https://dergipark.org.tr/en/pub/wie
http://www.ktu.edu.tr/woodindustry

ISSN: 2687-6043
e-ISSN: 2687-6035

Contact

engin_gezer@yahoo.com
iaydin@ktu.edu.tr

December 2020, Trabzon, TURKEY

Wood Industry and Engineering

ISSN: 2687-6043 **e-ISSN:** 2687-6035

YEAR : 2020 VOLUME : 2 ISSUE : 2

CONTENTS

Wood Industry and Engineering
ISSN: 2687-6043 e-ISSN: 2687-6035
Year: 2020 Paper Type: Research Article
Volume: 02 Number: 02 Received: 03/12/2020
Pages: 45 - 50 Accepted: 16/12/2020
https://dergipark.org.tr/en/pub/wie

THE EFFECT OF TRADITIONAL AND LASER CUTTING ON SURFACE ROUGHNESS OF WOOD MATERIALS USED IN FURNITURE INDUSTRY

Cebrail Açık[1a]
cebraik46@hotmail.com
(ORC-ID: 0000-0002-1094-6946)

Ahmet Tutuş[2]
ahmedtutus@hotmail.com
(ORC-ID: 0000-0003-2922-4916)

[1] 125th Year Vocational Training School, Furniture and Interior Design Area, Kahramanmaraş, Turkey
[2] Sütçü İmam University, Department of Forest Industry Engineering, Kahramanmaraş, Turkey

Abstract

One of the most important problems in the use of solid wood in the furniture industry is the surface roughness of the furniture elements depending on the cutting conditions. The required processes and efforts to obtain a smooth surface are too much, and besides the loss of time and raw materials in the production line, there are great costs in the creation of the machine park.

In this study, the surface roughness of the materials obtained from some wood species processed with CNC laser and circular saw machine was investigated. Poplar (*Populus canadensis*), scotch pine (*Pinus sylvestres*) and fir (*Abies cilicica*) samples were used as raw material in the study. Cutting processes were applied parallel and perpendicular to the fibers of the samples. In the cutting power of the CNC laser machine was kept constant as 130 watts and two different speeds were used at 10 mm/s and 20 mm/s. The rotation speed of the circular saw machine was adjusted as 4300 rpm without loading and the roughness rates of the traditional circular saw and CNC laser cut surfaces were compared.

As a result, it has been determined that the laser cutting speed is directly proportional to the surface roughness. In addition, compared to traditional cutting, rougher surfaces were obtained in parallel cutting to fibers with CNC laser and smoother surfaces were obtained in perpendicular cutting to fibers. In the results: In laser cutting with CNC, smoother surfaces have been obtained in parallel to the fibers.

Keywords: CNC, laser cutting, surface roughness, wood material

1. Introduction

As time progressed, the understanding of aesthetics in consumers began to show sensitivity by changing compared to previous periods. This change started to meet the expectations of design and consumers. Issues such as surface roughness in production, first of all, metal, steel, etc. became important in material engineering. Factors such as final quality, competition, aesthetics have made the surface roughness return in the wooden material used in furniture production.

The smooth surface of the wooden material to be used increases the preference of the furniture. In addition, it is very important to obtain a good surface quality during the processing of wood material and to solve this with the least cost. In order to obtain smooth surfaces in wood material, an appropriate combination of processing conditions must be applied. Correct processing of wood in the furniture industry and minimizing surface roughness are very important for the national economy (Peker and Ulusoy 2019).

Measuring the surface roughness of wooden products used in the furniture and decoration industry is very important in determining the quality of the final product. Surface roughness significantly affects the aesthetics of wood products and customer demand at the marketing stage. However, the surface roughness of wood needs to be determined in the application of wood surface treatments as it has a significant effect on the adhesion resistance (Tiryaki, 2014).

[a] *Corresponding Author*

Surface roughness poses a problem for both manufacturers and users. Although this defect can be removed with a little over sanding, the loss increases and the production time is prolonged. Therefore, surface roughness measurements should be among the quality control tests that should be applied in the woodworking industry in order to reduce production losses and costs (Aydın and Çolakoğlu, 2003)

Laser was discovered in the world in the 1960s. Laser technology in developed countries steel, metal, fiber, plastic and so on. It has found wide application areas in industries. Although it entered the wood industry later, it has spread rapidly and only laser machines for wood processing have been produced. These developments made the studies for wood processing with laser a necessity.

In recent years, laser technology has been at the forefront of material processing. In the near future it will probably be considered to replace traditional techniques such as sawing (Gaff, M. et al. 2020). In recent years, we see that the use of laser cutting machines has increased rapidly depending on the economic development. Among these areas of use, the wood industry has also taken its place. As it is known, laser has two main functions: cutting and engraving.

In general, cutting theory in woodworking examines the factors in traditional cutting such as metal or steel cutter types, cutter teeth types, cutter diameters, chip cutting and cutting methods, chipless cutting or peeling methods, feed rate. There have been many studies on the effects of traditional cutting factors on the surface roughness of wood.

In this study, the surface roughness of massive materials obtained from some wood species cut by CNC laser and circular saw machine was investigated. The effects of laser cutting speed and surface roughness were compared to traditional cutting and laser cut surface roughness, and recommendations were made to manufacturers.

2. Materials and Methods

2.1. Materials

In the research, Canada poplar (*Populus canadensis*), scotch pine (*Pinus sylvestres*) and fir (*Abies cilicica*) trees purchased by random selection method from Kahramanmaraş industry were used. Samples obtained from sapwood of smooth tree trunks with a diameter of about 25-30 cm and a length of 100 cm were used. While preparing the test samples, care has been taken to ensure that the wood material used is without knots, backs, no growth defects and has smooth fibers.

2.2. Preparation of Experimental Samples

Experimental samples for measuring the surface roughness of wood massive materials were prepared in 4x20x20 mm dimensions. Later, laser cutting was performed on the vertical (max) and parallel (bay window) surfaces of the 4x20 mm^2 sectioned fibers in a 130-watt carbon dioxide tube laser cutting machine with 100% power at 20mm/s and 10 mm/s speeds. In addition, conventional cutting was performed on a circular saw machine rotating at 4300 rpm without loading (dv/min), with a blade diameter of 26 cm including the teeth, 40 teeth number, and 1.5 cm tooth height. As shown in Figure 1 below, surface roughness measurements were made by making a total of six different cuts for each massive type, with three different cutting variables in two different fiber directions. Four measuring surfaces were prepared for each different cut. However, the closest three sample values from some sample groups that gave very different results after measurement were included in the average**.**

Figure 1: Surface roughness experiments of poplar massif in different cuts

2.3. Methods

Surface roughness measurements were made in accordance with ISO 4287 standard. It was applied with 0.5 mm / sec speed, λc = 2.5 mm limit wavelength and 12.5 mm scan length. Test samples were carried out at 12% humidity, ambient temperature 22 ºC, relative humidity 65% normal air conditions. Due to the function of the measuring device, measurement values were determined in three different parameters. In measurement;

Ra = General surface roughness,

Rz = The arithmetic mean of the highest five points and the least five points, a total of ten points,

Rmax = The distance between the highest and least points in micrometers (µm). The findings of the study were evaluated based on the general surface roughness (Ra) data in terms of compatibility with literature studies.

3. Results

The findings of the surface roughness of the cutting surfaces parallel to the fibers of wood massive materials obtained from Canada poplar *(Populus canadensis*), scotch pine (*Pinus sylvestres*) and fir (*Abies cilicica*) tree species are given in Table 1.

Table 1: Surface roughness values of solid wood materials cut parallel to the fibers (µm)

Wood Type	Cutting Type	Laser		Laser		Conventional	
	Cutting speed	20 mm / sec		10 mm / sec		4300 dv / min	
	Surface Roughness	X	SD	X	SD	X	SD
Poplar	Ra	3,49	0,53	3,42	0,95	3,30	0,67
	Rz	18,1	1,7	17,86	4,47	17,76	4,65
	Rmax	26,53	6,65	29,53	5,06	28,76	10,58
Scotch Pine	Ra	3,77	0,42	3,74	0,43	3,28	0,77
	Rz	18,7	1,15	19,86	1,92	19,93	1,30
	Rmax	22,7	2,68	25,8	2,69	27,23	6,87
Fır	Ra	3,53	0,39	2,66	0,59	2,48	0,45
	Rz	19,46	3,91	15	3,25	14,68	3,38
	Rmax	23,96	5,68	17,53	3,95	24,94	13,72

SD: standard deviation

When Table 1 above is examined, the general roughness values (Ra) of laser cutting surfaces at a speed of 20 mm / s were obtained as 3.77 µm in the highest scotch pine massif and 3.49 µm in the poplar massif the least. The general roughness values (Ra) of laser cutting surfaces at a speed of 10 mm / s were obtained as 3.74 µm in the highest scotch pine massif and 2.66 µm in the fir massif. The general roughness values (Ra) of traditional cutting surfaces were obtained as 3.30 µm in the highest poplar massif and 2.48 µm in the fir massif. In Figure 2, the surface roughness (Ra) values of each type of massive parallel to the fibers, at different laser cutting speeds and in conventional cutting are shown.

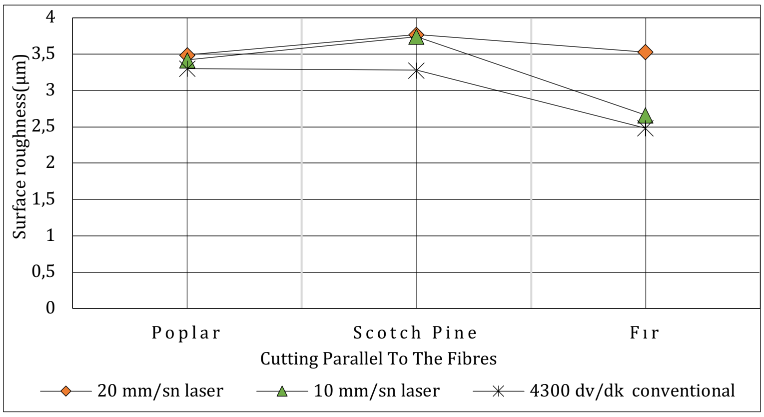

Figure 2: Surface roughness in cutting solid materials with different methods parallel to the fibers

When Figure 2 is examined, it is seen that the laser cut surface roughness of all massive materials parallel to the fibers is directly proportional to the cutting speed. It was determined that the difference in proportionality of laser cut surface roughness values according to speeds is insignificant in poplar and scotch pine massif, and significant value in fir.

Compared to traditional cutting of solid materials with laser cutting parallel to the fibers, smoother surfaces have been obtained in conventional cutting. It has been determined that this difference is significant in scotch pine. It has been determined that in poplar and fir massif, when laser cutting is performed at low speed (10mm/s), surfaces with roughness of approximately the same value as conventional cutting surfaces can be obtained. Findings of the surface roughness of the cutting surfaces of solid materials perpendicular to the fibers are given in Table 2.

Table 2: Values of cut surface roughness of solid wood materials perpendicular to the fibers (µm)

Wood Type	Cutting Type	Laser		Laser		Conventional	
	Cutting speed	20 mm / sec		10 mm / sec		4300 dv / min	
	Surface Roughness	X	SD	X	SD	X	SD
Poplar	Ra	6,27	0,53	6,26	0,36	6,69	3,24
	Rz	39,63	3,15	37,73	1,91	38,76	16,82
	Rmax	47,56	2,27	44,2	1,60	54,63	23,01
Scotch Pine	Ra	5,67	1,25	4,86	0,14	6,91	0,98
	Rz	33,26	7,29	27,4	0,72	43,4	6,35
	Rmax	4,7	15,37	34,66	1,77	68,63	25,15
Fır	Ra	3,63	0,20	3,26	0,29	4,30	1,01
	Rz	22,96	0,56	17,1	45,5	26,59	4,68
	Rmax	38,63	4,39	29,2	8,84	48,46	20,80

SD: standard deviation

When Table 2 is examined, the general roughness values (Ra) of laser cutting surfaces perpendicular to the fibers with a speed of 20 mm / s were obtained as 6.27 µm in the highest poplar massif and 3.63 µm in the fir massif. The general roughness values (Ra) of laser cutting surfaces at a speed of 10 mm/s were obtained as 6.26 µm in the highest poplar massif and 3.26 µm in the fir massif. The general roughness values (Ra) of traditional cutting surfaces were measured as 4.30 µm in the least fir massif and 6.91 µm in the scotch pine massif.

In another study, the surface roughness was measured as 6.87 µm at a value close to the determination in this study (6.91 µm) in a cut made in the radial direction of the scotch pine massif at a feed speed of 9 m / min with 40 toothed circular saw (Kılıç and Demirci, 2003). A roughness value of 6.66 µm on a planed surface in the radial direction of the scotch pine massif was reported to be 6.91 µm (Örs and Baykan, 1999).

In Figure 3, the surface roughness (Ra) values of each massive type at different laser cutting speeds perpendicular to the fibers and in conventional cutting are shown.

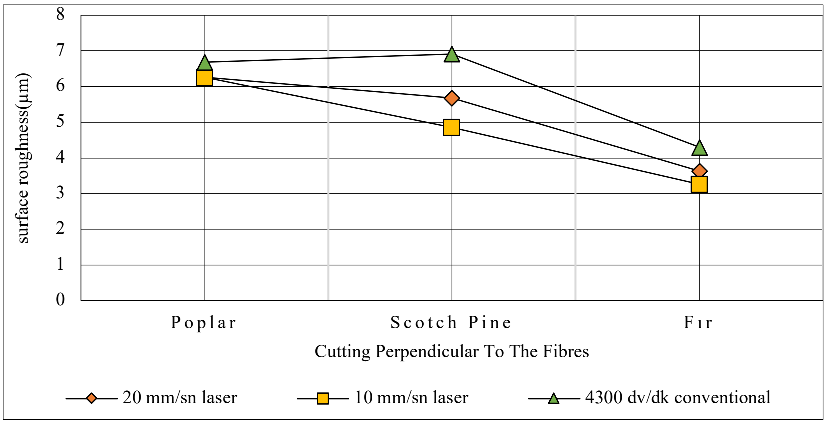

Figure 3: Surface roughness in cutting solid materials perpendicular to the fibers with different methods

When Figure 3 is examined, it is seen that the laser cut surface roughness of all solid materials perpendicular to the fibers is directly proportional to the cutting speed. The difference in the proportion of laser cut surface roughness according to the speeds was insignificant in poplar and fir massif, and significant in scotch pine massif. Compared to laser cutting perpendicular to the fibers and conventional cutting of solid materials, rougher surfaces have been obtained in conventional cutting in all massive types. In addition, this difference is insignificant in the poplar and fir massifs, and more in the scotch pine massif.

Although the poplar massif has a higher value in terms of surface roughness than the average of all cutting parameters, it showed a more stable behavior. It is considered that the cellular structure of poplar tree with large trachea may cause more roughness, and scattered trachea may cause a uniform distribution of the roughness on the entire surface. In addition, it is considered that the wall thickness of the tracheid found in the spring and summer wood in scotch pine and fir and the amount of lumen space are in contrast, giving different values in terms of surface roughness in different sections.

In another study, it was stated that one of the biggest contributors to surface roughness is the size and distribution of the pores in the wood cell. It was stated that the roughness values of the laser cut oak wood samples were 20% higher than the roughness values of the beech wood samples. It has been reported that the surface roughness of saw-cut beech wood is lower than that of oak, due to the wood texture of beech wood, which is thinner than oak. By comparing the two cutting methods, it was explained that the surface cut with laser has a lower roughness than the surface cut with a saw. It has been reported that the reduction in surface roughness due to laser cutting is more pronounced in oak (36%), which is a thin-textured tree than beech (24%) (Gaff, M. et al. 2020).

The average of laser cutting and conventional cutting surface roughness (µm) of three massive materials parallel to and perpendicular to the fibers at speeds of 20 mm/s and 10 mm/s are shown in Figure 4.

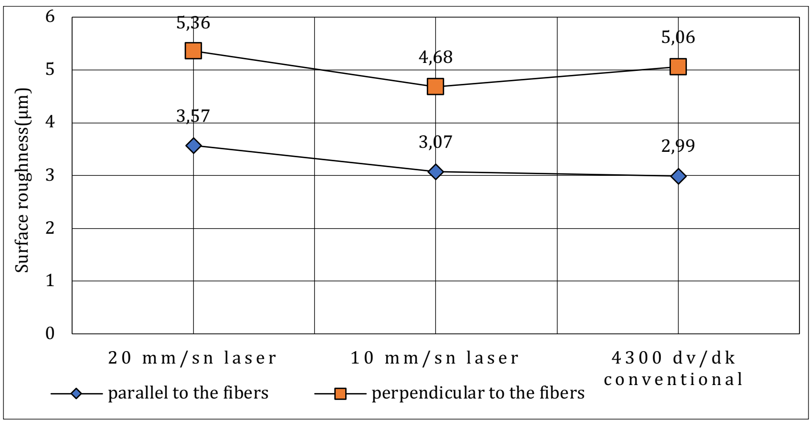

Figure 4: Average surface roughness values of solid materials in different cuts (µm)

When Figure 4 is examined, a 100% speed increase (from 10 mm/s to 20 mm / s) in laser cutting increases the surface roughness parallel to the fibers by 16.2% and the surface roughness perpendicular to the fibers by 14.5% caused. Considering these values, it can be said that a 100% speed increase in laser cutting in all fiber directions in massive materials generally causes surface roughness of approximately 15%. The reason for this may be that the surface roughness values at low speed are also low, the number of passes of laser beams from the process point per unit time increased, and the amount of material per unit cutting decreased.

Conventional cutting surfaces were found to be 16.2% smoother than laser cutting at a speed of 20 mm/s with a surface roughness parallel to the fibers. It was determined that they have roughness values approximately the same (difference 2.6%) with laser cutting at 10 mm/s speed. In addition, it has been determined that conventional cutting surfaces are 7.5% rougher than laser cutting perpendicular to the fibers at a speed of 10 mm/s, and 5.5% smoother surfaces can be obtained from laser cutting perpendicular to the fibers at 20 mm/s.

According to the average of all cutting parameters, the surface roughness of the cutting perpendicular to the fibers is 41% higher than the cutting parallel to the fibers. Generally, in the literature, it has been stated that by processing the wood material perpendicular to the fibers in traditional cuts, rougher surfaces are obtained compared to processing parallel to the fibers.

4. Conclusion

In laser cutting, the overall cutting speed has increased the surface roughness. This result is consistent with other studies on laser cutting of wood materials and wood composites (Barnekov et al. 1989; Eltawahni et al. 2011). Since laser cutting speed increases the roughness significantly, the cutting speed should be kept as low as possible in order to obtain smooth surfaces. However, it should not be forgotten that laser cutting at very slow speeds can cause burns in wood material.

In industrial wood product designs where surface roughness is important in laser cutting, it is recommended to make the production plan in vertical cutting at low speeds, preferring traditional cutting. However, it is not recommended to prefer laser cutting in both fiber directions at high speeds.

In terms of surface roughness in laser cutting, scattered wood species such as poplar massif are recommended when a uniform surface is desired. However, it should not be forgotten that these trees have rougher cut surfaces on average than coniferous tree species whose difference in spring and summer wood is more pronounced, such as scotch pine and cedar, since they are generally large trachea. In general, wood types with high density are recommended when roughness is important.

5. Acknowledgments

This study was supported by Kahramanmaraş Sütçü İmam University Scientific Research Projects Coordination Unit (BAP) (Project No: 2019 / 5-10 D). In addition, this study was presented as a paper at the 6th International Furniture Congress.

References

Aydın, I. and Çolakoğlu, G. (2003). Roughness and Roughness Measurement Methods on Wood Surfaces. "Journal of Kafkas University Artvin Faculty of Forestry, 1-2, 92-102.

Barnekov, V. et al. (1989). Laser machining of wood composites. Forest Products Journal, 39 (10), 76-78.

Eltawahni, H.A. et al. (2011). Investigating the CO2 laser cutting parameters of MDF wood composite material. Optics & Laser Technology 43 (3), 648-659.

Gaff, M. et al. (2020). Interactions of Monitored Factors Upon Tensile Glue Shear Strength On Laser Cut Wood. Composite Structures volume 234 -81116798, 1-10.

Kılıç, Y. and Demirci, S. (2003). Investigation of the surface roughness of scotch pine and chestnut wood. Gazi University Journal of Science 16 -3, 553-558

Örs, Y., and Baykan, İ. (1999). The Effects of Grating and Sanding on the Surface Roughness of Solid Wood Material of Agriculture and Forestry 23 Supplement -3, (577-582) TÜBİTAK.

Peker, H. and Ulusoy, H. (2019). Wood Materials and Surface Roughness. SETSCI Conference Proceedings, 4 -1, 588-590.

Tiryaki, S. (2014). Factors Effective on Surface Roughness in Wood Processing. SDÜ Forest Faculty Journal, 15, 176-182.

Wood Industry and Engineering
ISSN: 2687-6043 e-ISSN: 2687-6035
Year: 2020 Paper Type: Research Article
Volume: 02 Number: 02 Received: 03/12/2020
Pages: 51 - 60 Accepted: 03/12/2020
https://dergipark.org.tr/en/pub/wie

REUSING RESIDUAL MATERIAL OF FURNITURE PRODUCTION IN DESIGN ARTIFACTS BY UNIVERSITY-INDUSTRY COLLABORATION

Mehmet Ali Altın
malilatin@gmail.com
(ORC-ID: 0000-0001-8992-7088)

Eskişehir Technical University, Interior Design Department, Eskişehir, Turkey

Abstract

Furniture design classes in interior design programs mostly lack on production knowledge. Although the knowledge in this area is provided theoretically, tactile knowledge cannot be transferred neither oral nor verbally. At the other hand, furniture industry is the place where this kind of knowledge is utilized continuously. In the global World, the industry must catch up with new trends that are part of the endeavors in design in Universities. Problems due to the nature of industry and design problems of students and teachers meet at furniture itself but industry and University are still not close enough.

In this paper, possible collaborations between industry and University are discussed. The furniture design class which is held in an interior design department is organized at the scope of industry-university collaboration. In this sense, the director of a mid-sized furniture firm is invited as a tutor for one semester. The subject of the class is determined as a typical problem from industry, reuse of residual materials of production. These materials are converted into design artifacts. The output of this study is discussed in this paper. This discussion includes evaluation of the collaboration through qualitative and quantitative data of student reports, surveys, and partner interpretations.

Keywords: Furniture design education, industry-university collaboration, re-use, residual

1. Introduction

Furniture design is a crucial element in interior design and the fact makes it to be an important class in interior design education. Most of the institutions construct the class on verbal basis and in some cases a prototype is produced at the end. Usually students organize the production out of institution and cover the expenses themselves. In this type of education, design dominates over production of the product and lecturers have little voice on production. Low quality products are expected. In most cases design is shown on paper or screen and production is omitted. At the other hand a few of the institutions have workshop facilities and provide the classes on applied basis. Students can produce at the workshop themselves. Materials are provided by the institution or not. In this manner design and production continues together, lecturers have more voice over production and higher quality products are expected. It is difficult to keep a workshop facility running due to high budget demands. For this reason, most of the interior design departments in Turkey are missing a workshop facility. Another way to hold the furniture class in an applied manner is to have cooperation with industry where a facility continues to produce. Classes are adapted to this kind of collaboration. Students experience the production on site. This type of class set-up refers to the term University-Industry Collaboration (UIC).

1.1. University-Industry Collaboration (UIC)

University-industry collaboration is a relation which has benefits for each side. University-industry collaboration (UIC) refers to the interaction between any parts of the higher educational system and industry aiming mainly to encourage knowledge and technology exchange (Ankrah and Al-Tabbaa, 2015).

University and industry have diverse expectations from this collaboration. Expectations of the University can be summarized as supplying contributions, extending industrial experience of the staff, academic publishing, obtaining patents, support for internship from industry, experience for students by developing their projects, support from industry for social gatherings. Expectations of the industry can be summarized as rapid solution to its problems, solving problems without employing high salary staff and high funded R&D facilities, obtaining knowledge from universities for international projects, gaining support for obligatory certificates, bearing in mind needs and problems of the industry for theoretical research (Odabasi et Al., 2010). Usually the collaboration is set up on a project for an invention. By this way University fulfils its responsibilities to the society and science. Industry makes profitable added values which consequent helps to the well-being of the society. It could be indicated that society is the third partner in this collaboration. If the project leads to an added value for industry it would lead to better profits and the industry will reach its main goal. But at the other hand university must confine itself to abstract goals as reputation in science world. The dimension of education, which is one of the biggest missions of the university stays missing. In educational aspect of UICs mostly doctoral or post-doctoral studies are aimed which are going on project driven base. For under-graduates there is the possibility of project-based internship. Other than that, under-graduates could only have the possibility of having the regular internship at industry. This is the outsider's perception for UIC which is partly correct but missing some facts. Ankrah and Al-Tabaa (2015) makes the progress clear in their systematic review on UIC. They mention that organizational forms of UIC starts with personal informal relationships containing academic spin-offs, paid or free individual consultancy, information exchange forums, collegial interchange, joint and individual lectures, personal contact with university academic staff or industry staff, co-locational arrangement. The start of UIC is mostly open to educational income and it is also free from the formal procedures which are required in invention-oriented approach. Ankrah and Al-Tabaa (2015) also mentions their findings about the activities during UIC and the tittle for training is especially remarkable for educational dimension: they have found out that industry involves in curriculum development. This type of activity necessitates a close relation between University and the company. If there will be an involvement to develop the curriculum, involving person must be in close relation with academics, the school, and the students. It can be achieved in two ways: By visiting professor who does an internship in industry to develop a more practical vision from the industry and later pass it to the students. The other way is the so-called Associate Professor who is a professional works part time, teaching at the University (Alfonso et al., 2012) Employing an associate professor from industry can solve many problems in joint action with academics. An example of this kind of collaboration will be discussed in following parts of this paper.

2. Materials and Methods

The study is based on a collaboration between Eskisehir Technical University – Interior Design Department and KYS (Kenan Yeni Sandalyeleri). The collaboration is the continuing phase of a previous collaboration done in 2016. The study is based on the newer collaboration done in 2019.

2.1. Past Collaboration

The collaboration is done in 2016 when interior design department was part of another University. The former University used to have a wood working workshop dedicated to the department. Furniture Design classes were held in that workshop. The collaboration started through personal informal relation with the tutor of Furniture Design class and owner and designer of KYS. KYS is a small sized (less than 50 workers) company dealing with chair making with bent wood lamination technique. The collaboration was based on material grant and support for final production. The class was held at institutions own workshop and final products are produced at KYS. In this collaboration progress of the class was more valuable than the end products. From the survey on student and company owner's thoughts it was clear that expectations of industry which are finding new design ideas, finding new employees and interns from students, and making reputation by this collaboration were mostly fulfilled. And from the University side, expectations as making students experience production and reserving minimum fund for this to happen, having new collaboration possibilities by starting this collaboration are mostly fulfilled. Lecturer published an article out of this collaboration which was also another expectation (Altın, 2016).

2.2. Newer Collaboration

The collaboration is repeated in 2019. This time some revision to the progress was needed because needs and expectations for the University and the industry were changed. Basically, University's expectations are still oriented to education but at lower layers some differences occurred. Anadolu University where the interior design department belongs to was separated into two Universities and interior design department was transferred to the newly established Eskişehir Technical University. The wood workshop which used to belong to interior design department was left at the former University. Consequently, the need for a workshop occurred to hold furniture design classes in an applied manner. At the other hand, there became an increase in student population and decrease in lecturer numbers which made the class inefficient unless the institution hired new staff. In these circumstances the basis of this collaboration was set up. In this new collaboration it is decided to have the owner and head designer of KYS to teach furniture design class as an associate professor with existing lecturers. By this way shareholders expected to have direct transfer of knowledge. While reconstructing the class discussions are made on needs of both sides. KYS specified a common problem in wood working industry, the production residuals of cut-wood (Yetis, 2016) The ongoing production process in KYS is based on wood bending. Slices of beech wood is glued and compressed in moulds under high temperature and pressure. The product is a 2-dimensional profile which is then cut vertically in identical slices to be used as chair legs or arms. If the end-product needs more special shape, which are usually used for bottom and back support, the remaining parts could not be used as a part of other chairs. But these remaining parts still have potential, and it is difficult to identify them as residuals. Other than bent wood residuals KYS has remaining wood pieces coming out of CNC routing of panellised wood. While identical shapes are cut from wood panels the remaining piece becomes as a pattern and it also have potential to be used as decorative purposes. Other wood residuals are tiny wood chips and sawdust which are difficult to be reused in a design scenario unless they are recycled. KYS revalued these cut residuals in some of their products as lampshades, some tabletop or hang on wall accessories which cannot be categorized as furniture. KYS is a small-scaled firm with 30 employees and it is difficult to employ a full-time designer. For this reason, the company owner is the only designer who works for creative purposes. The residuals are in many shapes and dimension which makes work with them a fatigue duty. Pieces from diverse profiles have diverse forms but also because of the low precision cut they also have variety in size. Only one piece can have many variations to check for and recutting and assembling diverse pieces makes these variations nearly infinite. This makes the design process a lot more different than the ones that the designer starts designing from scratch. The design process needs lots of trials and redoes which is like doing a jigsaw with infinite pieces. For this reason, a different design thinking is needed to increase efficiency. As mentioned before KYS is limited to one designer and because he is the owner of the firm design is not his sole occupation. A collaboration with the University would be useful for the industry because free minded approach of young people (students) could accelerate idea generation.

Both University and industry had expectations from this collaboration: From University's side to continue the class in an applied manner and use industry facilities, to have access to production knowledge from first hand, to minimize material costs for the class, to minimize production costs, to have a lower student per lecturer ratio, to have attention from public to this collaboration by an exhibition of final products and to publish the story of the collaboration were the expectations. For industry to have new ideas for added value products, to have the experience of teaching and academic environment, to promote company and its products by this collaboration and have reputation were the expectation. Set up of classroom based on these facts.

2.3. Classroom Set-up

2019-2020 first semester Furniture Design class was open in three groups for three lecturers. Two of them were full-time professors and KYS owner has conducted his own group. 62 students were enrolled to the classes. Students were free to choose their desired group. The classes are held at the same place with students all together, but every group had separate critics from their dedicated lecturers. Students made up working groups of 3-4 people and they were free to choose their group members. To introduce the production facility, production methods, existing products of the company and residual pieces, a trip to the factory was organized. In the following lesson, a selection of residual pieces was brought to class and students are asked to examine pieces and make compositions. Every group then showed their ideas. In this exercise students are not confined with restrictions of choice of pieces or to realize a function. Student groups are asked to document every phase of their form research with photos or video, they are also asked to prepare a web blog explaining everything they have done during their research. In the following weeks students are asked for more exercises to get used to with pieces and their potentials to create new forms. One of the exercises was titled as "divide-cut-multiply". In this exercise students are encouraged to cut the pieces in different shapes and combine them. It was difficult for them to imagine how they could cut pieces and attach them together. Because they could not cut the pieces in real. In another exercise students are asked to take photographs of pieces and use computer image editing software to cut the photographs and create a collage of possible compositions. In the following lessons when students familiarized with pieces function is criticized and students are asked to confine their multiple ideas. At the end of studio critics students started production at KYS facility. The wood related production has been done in KYS but for other materials if needed students used the other workshops in the periphery. For these kind of production students covered their own expenses. Also, the cost for transportation of product was covered by students. The end products are exhibited to the class. Students are asked to answer a questionnaire and prepare a report explaining each week of the class. Both are used to evaluate the class performance and collaboration. The idea to hold an exhibition open to public could not be possible because of the global pandemic.

Figure 1: Central tendency on the positive expected questions

2.4. Methodology

Collaboration is evaluated on realization of the expectations of both sides. Research is based on student reports and surveys. For surveying a questionnaire is prepared. Students are asked to answer questions. Also, at the end of the collaboration, to understand the industry's view about this collaboration a questionnaire is prepared and KYS owner is requested to answer.

The questionnaire prepared for students included 33 questions. 5 questions are about demographic data, 28 questions are about evaluation of the class, 25 of those are 5 grade likert scaled and remaining 3 are open-ended. Questions are answered individually. The questionnaire prepared for KYS includes 79 questions, 16 are open-ended and the remaining 63 questions are 5 grade likert scaled.

Student reports are constructed on qualitative data. Students are asked to prepare a report explaining their progress in class. Every group had one report and 14 class weeks are explained on 3 titles: "What we have done this week.", What we have learnt this week." and "What we felt this week."

Quantitative analysis for student questionnaires is evaluated on IBM SPSS Statistics v24 and qualitative analysis are made on Nvivo 12.

3. Results

The results section should detail the main findings and outcomes of your study. You should use tables only to improve conciseness or where the information cannot be given satisfactorily in other ways such as histograms or graphs. Tables and figures should be numbered serially and referred to in the text by number. Following figures show demographic data of the class: 54 students have answered to the questionnaire. 13 Students are male, and 41 students are female. 15 students are in the group of the associate professor. 1 of the students was took the class for the second time. The questionnaire's Cronbach's alpha score is .861>1.

3.1. Analysis on Student Surveys

It is found out that students are mostly positive about the class. They have answered 22 questions positive which are expected to be so (M=4.17 / 5). Some questions have relatively low means. The survey shows that students did not find residual materials helped in design. Also, students do not feel themselves sufficient to work at furniture industry. Students also liked to have more possibility to have hands-on experience during production. Students are not feeling confident about material knowledge.

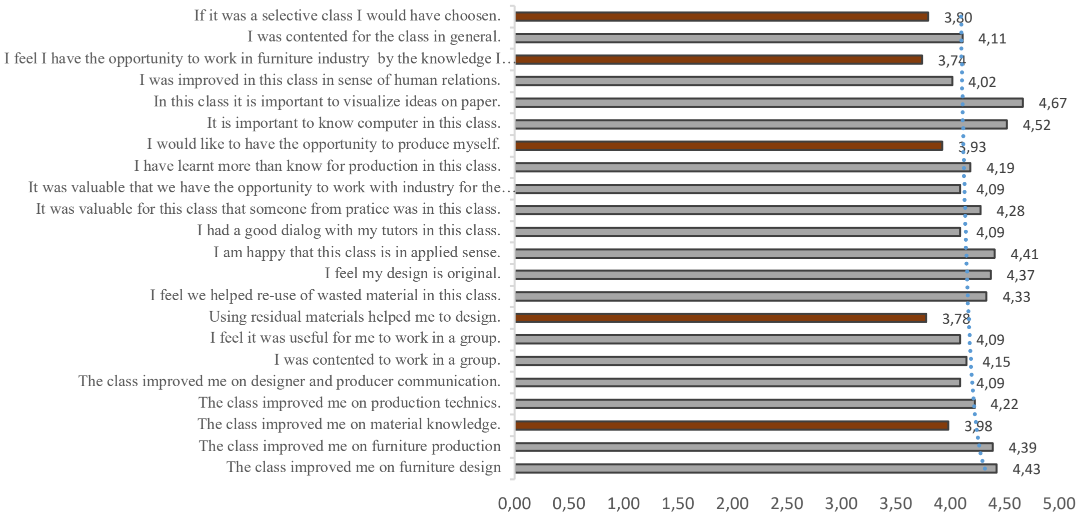

Figure 2: Central tendency on questions which were expected to be answered positive

Students answered questions which are expected to be negative: "The class was hard on budget." M = 4.19 /5 and "The class was hard on timing." M = 3.54. To understand the relations between positive and negative answers correlation analysis has been checked. (Table 1) The results have shown that the students who feel not to choose the class are upset about timing, budget, and limited opportunity for hands-on working. Working in groups and dialogues with tutors have no effect on this tendency.

Table 1: Correlations

		This class was hard on timing.	**This class was hard on budget.**	**I was contented to work in a group.**	**I am happy that this class is in applied sense.**	**I had a good dialog with my tutors in this class.**	**If it were a selective class I would have chosen.**	**I feel it was useful for me to work in a group.**	**I would like to have the opportunity to produce myself.**
This class was hard on timing.	Pearson Correlation	1	,308*	-0,263	**-,414****	-0,202	**-,535****	-0,206	-0,250
	Sig. (2-tailed)		0,023	0,054	0,002	0,143	0,000	0,135	0,068
This class was hard on budget.	Pearson Correlation	,308*	1	-0,054	**-,316***	-0,195	-,269*	-0,178	**-,394****
	Sig. (2-tailed)	0,023		0,697	0,020	0,158	0,049	0,198	0,003
I was contented to work in a group.	Pearson Correlation	-0,263	-0,054	1	0,115	0,124	,285*	**,735****	**,372****
	Sig. (2-tailed)	0,054	0,697		0,406	0,373	0,036	0,000	0,006
I am happy that this class is in applied sense.	Pearson Correlation	- **,414****	-,316*	0,115	1	,451**	,602**	0,224	0,263
	Sig. (2-tailed)	0,002	0,020	0,406		0,001	0,000	0,103	0,054
I had a good dialog with my tutors in this class.	Pearson Correlation	-0,202	-0,195	0,124	,451**	1	,499**	0,094	**,355****
	Sig. (2-tailed)	0,143	0,158	0,373	0,001		0,000	0,500	0,008
If it weree a selective class, I would have chosen.	Pearson Correlation	- **,535****	**-,269***	**,285***	**,602****	**,499****	1	0,225	**,369****
	Sig. (2-tailed)	0,000	0,049	0,036	0,000	0,000		0,103	0,006
I feel it was useful for me to work in a group.	Pearson Correlation	-0,206	-0,178	,735**	0,224	0,094	0,225	1	0,265
	Sig. (2-tailed)	0,135	0,198	0,000	0,103	0,500	0,103		0,053
I would like to have the opportunity to produce myself.	Pearson Correlation	-0,250	**-,394****	**,372****	0,263	**,355****	**,369****	0,265	1
	Sig. (2-tailed)	0,068	0,003	0,006	0,054	0,008	0,006	0,053	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The question "I had a good dialog with my tutors." was checked for positive answers for each tutor and students of the associate professor answered M =4.13 / 5 positively. Full time professor A's students answered M = 4.3 / 5, B's M = 3.8 / 5. The figures show that there were no problems about dialog with associate professor.

For a qualitative analysis 3 open ended question which are mostly focused on suggestions for the class are coded. When they are asked for suggestions instead of giving new suggestions most of the students criticized the existing class. From the answer following codes and frequencies are acquired:

- It was hard on budget (n=20).
- It was good to work with industry (n=12).
- I would like to have hands-on experience (n=9).
- I have not got enough materials for production (n=9).
- It was hard on timing (n=9).
- Organization was not good enough (n=9).
- It was hard to go to the factory (n=8).

The highest frequency was on the budget. Most of the students mentioned that they are contented to work with industry and a lot of them also mentioned that how they liked to have hands-on experience. A surprising fact came out of answers was that there was a shortage on material supply. Students who have mentioned "working with industry was good" also mentioned "it was instructive" (n=5).

Some of the student comments are:

"It is possible to learn a joinery detail that I would never imagine from an ordinary craftsman on site. Craftsmen are sage of the work so they have enormous experience. It is impossible not learn something from them."

"To be honest, I finally have learnt and had the opportunity to practice the technics properly which I have learnt in class or read…"

One report from every lecturer's group has been selected randomly and they are evaluated in NVivo 12. Reports are mainly coded for the titles "things that have been done, things that have been learnt and things that have been felt". Randomly selected groups were consisted of 3,4,4 students 11 students in total. It was assumed that all the students have collaborated for preparing the report. Coding has been done on text and images. (Table 2).

Table 2: Codes and frequencies

			A	B	C	Sum
Things that have been done						**203**
	Computer visualization		0	4	0	4
	Material tryout		2	0	3	5
	Finding a function		10	15	1	26
	Trials with scaled models		0	1	1	2
	Relating with space		0	0	0	0
	Modular design trials		6	0	1	7
	Experiments for joinery		22	16	4	42
	Presentation		1	4	1	6
	Design research on computer		12	16	5	33
	Design research on paper		13	6	4	23
	Design decision		2	0	2	4
	Dialog with craftsmen		0	3	4	7
	Production					
		Finishing	0	1	3	4
		Assembly	0	1	2	3
		Parts forming	0	1	1	2
		Production documentation	0	0	4	4
	Production research					
		Joinery trials on computer	8	8	0	16
		Physical joinery trials	0	6	1	7
		Joinery trials on paper	6	0	2	8
Things that have been learnt						**66**
	Familiarizing with pieces		5	5	0	10
	Design with limits		0	0	0	0
	Design					0
		Importance of working with actual materials.	1	0	0	1
		Form-Function relation	3	1	0	4
	Production details					0
		Power tools	4	6	9	19
		Production Planning	0	0	0	0
	Material knowledge		2	2	6	10
	KYS and wood lamination		5	1	2	8
	Dimensioning		1	0	1	2
	Reuse- Recycle		0	2	0	2
	Computer visualization		3	1	0	4
	Cost analysis		0	3	0	3
	Ergonomics		0	3	0	3
	User in design		0	0	0	0
	Teamwork		0	0	0	0
Things that have been felt						**47**
	Positive					39
		Fun	0	0	2	2
		Pride	0	0	0	0
		Trust	1	0	0	1
		Excitement	3	2	2	7
		Pleasure	0	1	1	2
		Contented	2	1	3	6
		Motivated	2	3	2	7
		Happy	1	4	6	11
		Relaxed	0	1	0	1
		Appropriation	0	0	1	1
		Novelty	1	0	0	1
	Negative					8
		Lack	0	0	0	0
		Disappointment	0	1	0	1
		Fear	1	5	1	7
		Unmotivated	0	0	0	0
		Upset	0	0	0	0
		Tired	0	0	0	0
		Strain	0	0	0	0

As seen from figures students mentioned more of that have done over that they have learnt and felt. There was no restriction for this to happen, but it supposed to be occurred because students believed the report will have effect on their marks. Under the title "things that we have done" the most mentioned subject is the experiments for joinery (n=42), design research on computer (n=33) and paper (n=23) are also mentioned more than other subjects. Especially design research on computer was coded mostly for pictures of examples of desired design. Mentions for finding a function (n=26) is also remarkably high. These mentions mostly included explanations and hand drawings of different design scenarios. It can be seen from figures that students mentioned joinery (total n=31) also in production research. This can be evaluated as they had difficulty in joinery, or it was more interesting for them because it is the first time they have an experience with them.

Some of the students' mentions:

"We decided to focus on the lighting function but at the same time we were dealing with the separator idea."

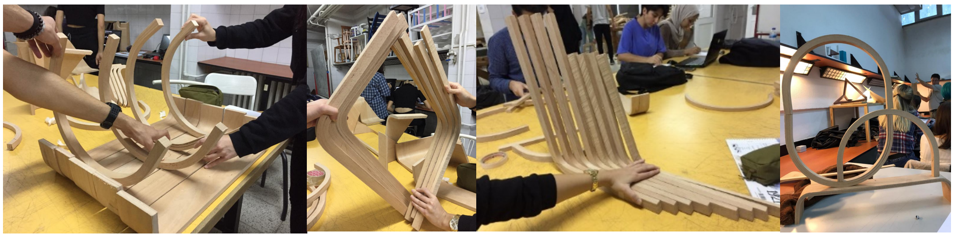

Figure 3: Students' mentions coded as "experiments for joinery"

The mentions (n=66) under title "Things that we have learnt" surprisingly have more mentions (n=19) than expected for power tools. Students mentioned power tools names and their specifications and explained how they work. Material knowledge is mentioned (n=10) as expected. Students also mentioned how they get familiarized (n=10) with residual pieces.

Some of the students' mentions are:

"We have seen how the CNC works and realized that how the sanding we have done was not enough."

"We have learnt that while choosing materials esthetics is not the only criteria we also must think about the cost. So, we can reduce cost just by changing the materials and we will still have the same appearance."

The title "Things that we have felt" is more positive than expected, students mentioned positively (n=39) nearly five times greater than negative (n=8). The most remarkable figure in negative mentions is the fear (n=7) that it is dominating the negative mentions. Because only one group have 5 mentions about fear it is evaluated as a bias.

Some of the students' mentions are:

"It was very exciting and pleasing to see our deign in production."

"We were faced with reality that because of the cost not every design can be realized so it made a group like us full of enthusiasm disappointed."

3.2. Analysis on Industry Survey

The questionnaire answered by KYS owner includes open ended and 5 grade likert scaled questions. Open ended questions were mostly about the unseen facts. The questions are answered honestly by respondent. The open-ended question about the time spent weekly for this collaboration was answered as 3 hours for the class and 1 hour for preparation to the class and for the production period 2 full days from morning till the afternoon. Respondent also mentioned that he has paid extra wage to workers for out of work hours. It was also mentioned that material supplies did not cost much to the company thanks to the use of residual material. But when residual pieces were not enough it was needed to prepare new pieces from production pieces. It was also mentioned that some disruption was occurred in ongoing production because of unprogrammed visits by students. At least 2 or 3 workers were reserved for students' productions.

The respondent answered questions about the reuse or recycle policy of the company. Company has already a vision about reuse of residual material in new products and it is said that these products are more profitable than their other products. But at the other hand these products are mostly one-off productions and need more workmanship. Other than reusing the cut residuals of wood profiles, polyurethane sponge and upholstery fabric residuals are reused. But the company does not have a vision for recycling for other residuals as sawdust and wood chips. It was told that they are used as fuel for winter and burnt in stoves.

KYS owner has been requested to answer questions in four diverse groups titled as University-industry collaboration, thoughts on students, personal thoughts, and thoughts on end-product design. From answers to questions about University-industry collaboration shows the respondent believes that this collaboration will continue and improve in the future and the identity of the University and being a tutor in the class is important for this collaboration but not more than personal relations with colleagues. From answers to questions about the students, it was understood that the respondent believes, students learnt a lot in this collaboration and they were motivated both in design and production phase, working in groups was useful in production phase. The respondent did not have a clear opinion about the cost of production for students and if working groups was efficient. He also was indecisive if the students are sufficient at design, but he believes that they are not sufficient at production. Answers for personal questions show that the class has confronted respondent's expectations. He believes that he has done a valuable work in this class. He mentioned he was contented in this class. He also believes that his vision to design improved but to production it cannot be said. The class was not difficult for him on timing or budget. Finally, he mentioned that in consideration of the end-products, students' designs are better than he expected, and he found them original. But when it is asked if they are sufficient to be used in his company, he was indecisive

4. Discussion

Analysis made on student surveys, reports and industry survey indicate that expectations of University and Industry are mostly fulfilled. From student surveys it could be understood that students are happy with this collaboration. They mentioned in their reports that they have learnt more than they expected. The collaboration helped them to fill the gap between theoretical and practical knowledge. For this reason, it could be said that one of the expectations of University has been fulfilled. Students realized their ideas at the factory, but it was difficult for them to try out every idea they created because of logistics and ongoing work at the factory. For this reason, it could be said that the expectation of having the opportunity to use the workshop has been partially fulfilled. Students mentioned that they could not have enough material during production phase. But at the end all of them have realized their projects. It was assumed that it was a temporary lack of desired materials, because also KYS told they had to prepare new pieces from non-residual parts. Therefore, the expectation of lowering material cost has been fulfilled. At the other hand students mentioned the cost was too high for production and it was difficult to hold their budget. Some groups needed other materials like steel construction. This kind of production could not be done in KYS therefore students needed to make these in separate workshops in the periphery. That is why they needed to cover those expenses. Also, transportation of goods from KYS to the University was a mess and students needed cover expenses on their own. For this reason, it could be said that expectations of lowering costs was not fulfilled. Students are mostly happy with the associate professor. It could be understood from the higher ratios on likert scale and students' sayings in report. the expectation of employing a professional as an associate professor is fulfilled successfully.

From industry side expectations are mostly fulfilled as KYS liked the end-product designs and was happy with the collaboration. The owner was keen to continue the collaboration. Two students started their internship at KYS and after finishing the internship they started to work part-time.

More than the expectations of both sides the collaboration paved the way for students to think about reuse and recycle. A remarkable situation about the end-products is that most student groups found ideas about lighting. This finding could be helpful for KYS to which function they should focus on to reuse residual material in new design.

5. Conclusion

The collaboration was started for the needs of both sides and improved to an ongoing system where the industry representative became a part-time associate professor in University. Most of the expectations from this collaboration are fulfilled but some lessons are taken also. Some of these are evident but some are hidden in the process. To find out these hidden problems and find solution for them both sides of the collaboration must have passion to continue. Industry must think that University is not just the other side of the collaboration. University side is consisted of students and academics and both have different expectations. The combination of their expectations makes the expectations of the University. For this reason, it is important to improve contact with students as done with academics. Academics have the role of being a bridge between industry, students, and University administration. University – industry collaboration is a demanding act. If only one side is demanding the collaboration will be ineffective for both sides.

The collaboration which has been done in 2019 was focused on education and University is the most demanding side. Industry's demands were more abstract. This collaboration will continue to deal with Industry's more substantial needs but the collaboration on education will be continued.

6. Acknowledgments

This study was presented in IFC 2020 - 6st International Furniture and Decoration Congress held by Karadeniz Technical University, Trabzon.

References

Ankrah S. and Al-Tabbaa O. (2015). Universities—industry collaboration: A systematic review, Scandinavian Journal of Management, 31, 387-408.

Odabasi A., Helvacioglu S., Insel M. and Helvacioglu I.H. (2010) A Model for University-Industry Collaboration, Naval Architecture and Marine Technology, 18, 20-25.

Alfonso A., Ramirez J. J. and Diaz-Puente J. M. (2012). University- industry cooperation in the education domain to foster competitiveness and employment, Procedia - Social and Behavioral Sciences, 46, 3947-3953

Altın M. A. (2016) Learning to design for production: Industry and Academia Collaboration, Mugla Journal of Science and Technology, 2,2, 193-198.

Yetis Ü. B. (2016). Sectoral Waste Guidelines: Wood, Wood Products and Furniture Manufacturing, Ministry of Environment and Urbanization, Ankara, 21.

Wood Industry and Engineering
ISSN: 2687-6043 e-ISSN: 2687-6035
https://dergipark.org.tr/en/pub/wie
Year: 2020
Volume: 02 Number: 02
Pages: 61 - 69
Paper Type: Research Article
Received: 28/11/2020
Accepted: 10/12/2020

PROBLEMS AND SOLUTION SUGGESTIONS OF ENTERPRISES PRODUCING FURNITURE AND WOODEN YACHTS/BOATS (EXAMPLE OF BARTIN-KURUCASILE)

Göksel Ulay
g.ulay@yyu.edu.tr
(ORC-ID: 0000-0003-4080-8816)

Van Yuzuncu Yil University, Van Vocational School, Department of Furniture and Decoration, Van, Turkey

Abstract

This study aims to identify the problems of the wooden boats and the furniture used in these boats in Bartin-Kurucasile district center and to develop solutions. These boatbuilding enterprises use local chestnut woods obtained from the forests of the Black Sea Region. It is noteworthy that the number of enterprises that have been producing boats with their unique characteristics with traditional methods for many years in the district has decreased in recent years. In this study, in order to reveal the current situation of wooden yacht / boat and furniture manufacturers with Kurucasile and the changes between in 2012-2020, face-to-face interview method was used with boatbuilding owners. As a result, the current statuses of the manufacturers who continue their existence in the district were determined and solution suggestions for the problems were discussed and solution suggestions for the development of these enterprises were included.

Keywords: Boatbuilding, enterprise, furniture, Kurucasile, wooden boat

1. Introduction

The coasts of Turkey is a traditional wooden boat manufacturing techniques and methods vividly one of the last centers of the region is carried out using the wood materials in Bartin (Davulcu, 2013). Kurucasile district, which is connected to Bartın province, has managed to preserve its feature of being one of the important wooden boatbuilding centers in the Black Sea Region for the navy requirement of the state during the Ottoman Empire period (Web-1, 2020). For many years, it has maintained its existence as a maritime district where valuable masters have been raised using chestnut wood and solid construction (Kaygin and Aytekin, 2005). It has maintained its existence as a maritime district where wooden boats are produced and valuable craftsmen are trained. Throughout history, masters who grew up in this region and went to other regions have carried their crafts to new places and made significant contributions to the development of the boatbuilding industry in Turkey (Web-2, 2020). It can be said that the place where wooden boatbuilding is the most active in our country is Kurucasile. In the past, rowing and sailing freighters called pulling are replaced by wooden fishing boats, boats and wooden yachts of various types today (Ozdemir, 2006). The fact that it was reported that some projects were planned to be carried out by the district municipality to encourage this area (Yildiz and Cekic, 2015), since the wooden boat construction, which is very important for Kurucasile, has been reported by the local administrators. Today, after centuries of history, wooden boat construction of international scale and quality continues in Kurucasile and boats that can sail to the world's seas are being built (Ozdemir, 2006).

However, in recent years, the number of boat manufacturers in Kurucasile has been gradually decreasing due to the lack of infrastructure in both the region and the boat production areas. Producers active in the region, while working with a small number of people, are trying to fulfil many orders and also have a problem of not being able to register the boats they produce because their workshops cannot meet the standards set by the undersecretaries of maritime affairs (Ceyhan, 2015).

The companies that came to the present day by passing from father to son cannot be supported from below, as the new generation's interest in boat construction has decreased or migrated to big cities such as Istanbul (Web-1, 2020).

In the context of the study, which deals with the influence factors in the urban identity and historiography process, the study deals with the historical impact of Bartın province and wooden shipbuilding; he reported that small-large models of pullers are used as symbol objects in many parts of the city today (Isik and Gezgin, 2019). In the SWOT analysis made for Bartın province, the biggest opportunity regarding the economic structure of the province; Re-strengthening and building activities of ship and yacht, which have become widespread especially in Kurucasile and its surroundings and the Central district, are reported to be exhibited in international fairs (Celik and Murat, 2009). In addition to being a business line of wooden shipbuilding, which is continued only in a few places in our country, it is also important in terms of maintaining a traditional production and more attention should be paid to wooden boat manufacturing with Kurucasile (Ozdemir, 2006). In the scientific literature, the importance of boat manufacturing (Kaygin and Aytekin, 2005), (Kaygin, 2002) using the chestnut tree in the region (Yazici, 1998) is emphasized, but many studies have been the subject of many studies from the past to the present (Ozdemir, 2006; Kaygin, 2002; Ulay, 2011).

Turkey's relatively ships have a voice abroad, except for some small number of other sectors and preparation of the annual report or the construction sector is important in terms of providing guidance to investors in this area. Yacht furniture manufacturing (Ulay, 2011), yacht industry wood material usage (Yazici, 1998; Kaygin, 2002) yacht industry varnish and paint usage (Ulay, 2018; Altiparmak, 2017; Ulay and Cakicier, 2017), yacht electrical/electronic installations, or decoration, such as the status of employment of the subtitles Turkey yacht / boat building industry for the power supply industry and to carry out studies that reveal the current situation has been proposed (Ulay et al., 2016).

A comprehensive report was prepared by the West Black Sea Development Agency (BAKKA) in 2013 for the establishment of Kurucasile Wooden Boat and Yacht Manufacturers Small Industrial Site on a specific area in Kurucasile district, and to determine the strategic road map for wooden boat manufacturers (BAKKA, 2013). The result of the research commissioned by BAKKA in 2013 was presented as a paper in the 1st Bartın sectoral development symposium in 2015 and was published as a paper (Alkan and Altin, 2015). The purpose of this report is stated as "To contribute to the sustainability of wooden boat production activities in the district by supporting the clustering activities of Kurucasile Wooden Boat and Yacht Manufacturers Building Cooperative" (BAKKA, 2013). According to Yildiz and Kaygin (2020), it was emphasized that the results of research studies and official reports made for the manufacturing sector in Bartin province should not remain on the shelves and that the results and effects should be re-evaluated over time (Yildiz and Kaygin, 2020). Yildiz (2016), in the study performed as an example to the recommendations part; Bartın province included the results and recommendations of the master's thesis made in 2015 for the forest products industry (Yildiz, 2016). In the next study, the current situation in the last 5 years (2020) was analyzed comparatively on a qualitative scale and they reported that progress was made in 85% of the recommendations (Yildiz and Kaygin, 2020).

Yıldız and Kaygın (2020) stated that the results of previous studies in any field should be evaluated with new studies. From this point of view, the results of the feasibility and research report (BAKKA, 2013) made for wooden boat manufacturers in Bartın-Kurucasile district in 2013 were compared with the current situation and suggestions for a solution were presented (Ulay, 2020).

Today's wooden boat and yacht manufacturing in Aegean coast in Turkey and the Black Sea coast continues in lower level than the one in the past. The domain of this study using traditional methods and techniques with different types of wood raw material in Turkey are businesses engaged in manufacturing of wooden yachts and boats. The sample of the study, on the other hand, consists of the enterprises that manufacture wooden yachts/boats located in the district center of Bartın Province Kurucasile (Web-3, 2020).

The aim of this study is to examine the current situation and problems of the enterprises producing wooden yachts / boats and furniture in Kurucasile district center, which is emphasized in many studies in the literature. For Bartin-Kurucasile district, it is important for the preservation of cultural and sectoral heritage as well as employment and economic incomes, ensuring sustainability and transferring it to future generations. By revealing the change and development of wooden boat manufacturers in the period between in 2012-2020, it determines the situation and develops solutions for the problems.

2. Materials and Methods

2.1. Material

The sample of the study consists of 10 enterprises manufacturing boats, yachts and different fishing boats using chestnut trees obtained from the forests of the Black Sea Region and located in Kurucasile District Center, which is 52 km from Bartin province and located on the Black Sea coast.

2.2. Method

It has been determined that there are a total of 10 micro-scale enterprises producing wooden yachts / boats and furniture for boats. In order to reveal the current situation of the enterprises, the development and changes in the production areas between in 2012-2020, the workshops of the enterprises were visited, face-to-face meetings/interviews were made with the employees and information on the current situation of the enterprises was collected. Business visits were conducted between July 2018 - August 2019. Frequency analysis was made by evaluating the information obtained during business visits in MS Excel program. The information collected by the interview method was compiled and given in the findings section of the study.

3. Results

The data obtained from the enterprises manufacturing wooden yachts and boats in Kurucasile district center are given below.

3.1. Wooden Boat Builders Information in Kurucasile Center

In this section, the number of enterprises currently operating in the district center in 2020 and information about the wooden boat builder enterprises included in the 2013 report are included.

Table 1: Wooden boat builder enterprises names in Kurucasile center in 2013 (BAKKA, 2013).

Number	Enterprises Name	Owner
1	HERBOT BOATING	Kemal AYTAN
2	HALK PAZARI BOATING	Hasan BUYUKBOCEK
3	SOYTÜRK BOATING	Halil SOYTURK
4	YILMAZ BOATING	Yılmaz CANBAZ
5	HASAN FAYIZ	Hasan FAYIZ
6	DOGAR BOATING	Arif DOĞAR
7	YASA BOATING	Soner YASA
8	SOYTURK MARINE	Hayri SOYTURK
9	FAIZLER WOOD BOATING	İbrahim FAIZ
10	TOMRUK BOATING	Mehmet TOMRUK
11	UNSAL SARIŞAN	Unsal SARISAN
12	NIGMET INCE	Nigmet INCE
13	SIYA MARIN	Sinan OZTEKIN

According to BAKKA (2013), it has been determined that the enterprises numbered 11, 12 and 13 in Table 1 do not operate in the district center of Kurucasile as of 2020. It was determined that the number of enterprises decreased by 23% compared to 2013.

3.2. Information on The Activity Periods of Businesses

Information on the activity periods of the enterprises is given in Figure 1. The business with the longest period of activity has been operating for 69 years, while the shortest operating company has been manufacturing for 31 years.

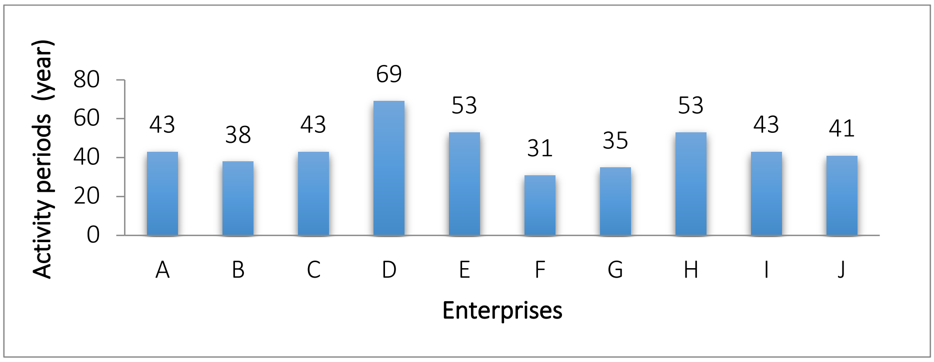

Figure 1: Activity duration of enterprises as of 2020.

Considering that the enterprises are family businesses within the master apprentice system, it has been determined that the activity periods in Figure 1 are quite long and the average approximate operating activity period (ages) is 45 years.

3.3. Number of Employees Working in Boat Builder Enterprises

When the number of employees in enterprises is examined, as seen in Figure 2, the number of employee is very low. For an establishment producing wooden boats, the average number of employee found to be 1.7.

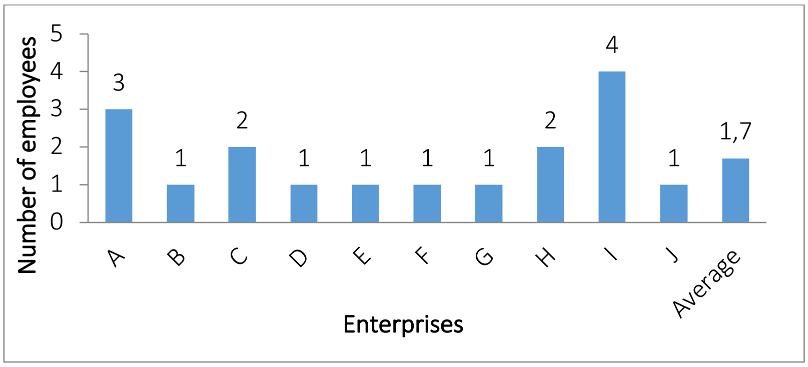

Figure 2: Number of employees employed by enterprises as of 2020.

According to the SME classification, the enterprises that manufacture wooden boats in Kurucasile can be considered as micro enterprises.

3.4. The Current Status of The Physical Infrastructure of Wooden Boat Builder

In this section, the physical conditions of the workshops of the enterprises are examined and the current situation between 2013 and 2020 has been compared.

3.4.1. Workshop of Herbot Boating

Figure 3 below shows the physical condition of the Herbot Denizcilik workshop belong to in 2013 and 2020. The workshop location and infrastructure of the business have not been changed in the last 7 years. Manufacturing continues in the ground floor and gardens of the houses located on the roadside in Kargacak neighborhood. It has been reported that Herbot Boating manufactures yachts and boats have CE certificate in accordance with Turkish and Italian Lord standards (Web-4, 2020).

3.4.2. Workshop of Faizler Wooden Boating

Figure 4 below shows the physical condition of the Faizler boat workshop, belong to 2013 and 2020. It has been determined that the workshop location and infrastructure of the enterprise have not changed in the last 7 years. Manufacturing continues in the workshop located on the ground floor of the house on the roadside in Kargacak neighborhood. It has been reported on the business website that it produces wooden boats that comply with the standards of their boats and have CE certification (Web-5, 2020).


Figure 4a: Faizler boating workshop in 2013(BAKKA, 2013). Figure 4b: Faizler boating workshop in 2020.

3.4.3. Workshop of Yilmaz Boating

Figure 5 shows the physical condition of Yılmaz boat and yacht atelier belong to 2013 and 2020. Yılmaz yacht and boat manufacturing workshop was revised in the workshop in Figure 5 next to the PTT institution building in 2012 and it was used for cafe purposes. It continues on the ground floor of the building, which is used as a residence, 150 meters from the beach, as a boat building workshop.


Figure 5a:Yılmaz Boat workshop in 2013 (BAKKA, 2013).Figure 5b:Yilmaz Boat workshop old place in 2020.

3.4.4. Workshop of Soyturk Boating

Figure 6 shows the physical condition of the Soyturk boat and yacht builder workshop below belongs to in 2013 and in 2020. The workshop location and infrastructure of the enterprise has changed in the last 7 years. While the location of the workshop in Figure 6a is 15 meters from the coastline, in Figure 6b it was moved to the new workshop 350 meters from the coastline in 2020.


Figure 6a: Soyturk Boat workshop in 2013 (BAKKA, 2013). Figure 6b: Soyturk Boat workshop in 2020.

3.4.5. Workshop of Dogar Wood Boating

Figure 7 shows the physical condition of the Dogar wooden boat and yacht builder workshop below belongs to in 2013 and in 2020. When Figure 7a and b are examined, it has been determined that there has been no change in the workshop location and infrastructure of Dogar Boat enterprise in the last 7 years. Children's playground on the coastline continues its activities next to it.

Figure 7a: Dogar Boat workshop in 2013 (BAKKA, 2013). Figure 7b: Dogar Boat workshop in 2020.

3.4.6. Workshop of Hasan Fayiz Wood Boating

Figure 8 shows the current situation of the boat manufacturing workshops in the Liman District. There has been no change last seven years. The activity continues in the workshop, which has insufficient space. When Figures 8a and 8b are examined, it has been determined that Hasan Fayiz Boat operation has not experienced any changes or developments in its workshop location and infrastructure in the last 7 years. It continues its activities in the workshop next to the PTT building in the Liman neighbourhood.

Figure 8a: Hasan Fayiz Boat workshop in 2013(BAKKA, 2013). Figure 8b: Hasan Fayiz Boat workshop in 2020.

3.4.7. Small Industrial Site and Workshops and Boatyard Project Planned for Kurucasile

Kurucasile Wooden Boat and Yacht Manufacturers Small Industrial Site (SIS) Boat Production and Slipway Settlement Plan, whose plan was drawn in the strategic road map and feasibility report prepared by BAKKA in 2013 (BAKKA, 2013), is given in Figure 9a. It has been determined that the planned SIS and boat building workshops and boatyard project could not be realized as of 2020. It has been determined that the area in Figure 9b is currently used as a municipal vehicle garage and warehouse on the planned area.

Figure 9a: SIS floor plan for 2013 (BAKKA, 2013). Figure 9b: Current status of the relevant area in 2020.

Since the Kurucasile SIS plan layout in Figure 9a. is a project that has not been realized yet, the area indicated in Figure 9b. is used as a warehouse for tools and equipment belonging to the district municipality. The completion of this project in order to improve the physical infrastructure needed by wooden boat manufacturing workshops and to present it for the use of businesses that manufacture boats are among the expectations of the enterprises.

3.5. Problems of Businesses Producing Wooden Yachts and Boats

The data collected as a result of interviews with the enterprises operating in the production of wooden yachts and boats in the district center of Kurucasile are summarized in this section. The following issues have been reported, in particular the lack of cooperation skills among cooperative members.

• Improving the physical infrastructure facilities of the workshops,
• Insufficient access to the district,
• Insufficiency of advertising and promotional activities,
• Failure to deliver boats on time,
• Not balanced quality-price relationship,
• New boat types specific to Kurucasile should be designed and design support not provided,
• Lack of training qualified personnel and not encouraging wooden boating,
• Inadequacy in producing project-oriented boats and certification,
• High raw material prices,
• The price range for wooden boats produced in Kurucasile has not been determined,
• The problems experienced in the registration of the boats produced in accordance with the regulation by the undersecretaries of Maritime Affairs.

4. Discussion

As of 2020, it has been determined that Kurucasile and wooden yacht and boat manufacturers have not been able to produce a solution in the last 8 years for the problems identified in 2012. Although the number of wooden boat manufacturers, which is 10, continues their activities, it is thought that many of them may close and stop production in the long term. There are many studies in the literature that emphasize the importance of this issue (Alkan and Altin, 2015; Web-1, 2020; Ozdemir, 2006; Ceyhan, 2015; Cekil and Murat, 2009; Ulay, 2020).

It has been determined that the physical facilities and infrastructures of the workshops are not sufficient. This situation may negatively affect the low capacity and efficiency of the enterprises, as well as the job satisfaction and motivation levels of the personnel. The infrastructure and physical facilities of the enterprises producing wooden boats should be improved as soon as possible.

It has been reported that one of the major problems according to wooden boat manufacturers is the lack of advertising and publicity. A common website showing boat pictures and information of all businesses can be established with the support of staff from the vocational school or university. Consultancy services can be obtained from institutional supports such as TSO (chamber of commerce and industry) and BAKKA (West Black Sea Development Agency) in advertising and promotion.

It has been determined that the enterprises are not sufficient for project-oriented boat production and certification. It may be possible with the employment of qualified engineers, technicians and technicians to make progress in this field. In addition, trainings on project and certification can be taken.

Producing unique boats with characteristic features using their own unique methods, using chestnut trees, not training young personnel and not transfer their production technique and skills to new generations by enterprises are considered as great loss.

It has been determined that young people, especially vocational high school and vocational school students and graduates do not show enough interest to work in the field of wooden boat manufacturing, therefore no enough new personnel is available. Thus, there is a shortage of qualified personnel and the average number of business employees is 1.7 person. In the literature, between these results and parallel determinations; According to the study of Yildiz and Cekic (2015), it has been reported that the young people do not prefer to work in the wooden yacht and boat manufacturing sector due to the lack of social security, institutional structure and migration to metropolitan cities (Ceyhan, 2015).

It has emerged that the lack of new boat designs specific to the founder is among the problems faced by the enterprises. The fact that businesses feel the need for innovation and originality in products shows that they understand the importance of design. It also suggests that they are open to improvement.

The average operating time of the enterprises within the scope of the research was determined as 45 years. In the literature; In Kurucasile, it has been reported that teaching boat building from father to son with the master-apprentice system and production activities have continued for three generations in some enterprises (Web-1, 2018). The ability of businesses with such long years of activity to survive different economic crises and other negative conditions shows their flexibility and resilience characteristics like other SMEs.

5. Conclusion

As a result, almost all of the problems identified by the BAKKA report in 2013 belonging to the wooden boat manufacturers with Kurucasile still remain as unsolved problems in 2020. In order to solve these problems, solutions for similar sectors should be examined and new researches are recommended.

Kurucasile Small Industrial Site, Completion of Shipyard for Boat Building; A joint project can be organized by gathering institutions such as BAKKA, TSO, KOSGEB, University, Vocational Education Institutions and Kurucasile Wooden Boat and Yacht Manufacturers Building Cooperative.

In addition, the traditional methods and techniques specific to watchmaking Kurucasile used wooden boats, vocational summer courses organized for 1-3 months in Kurucasile for wood technicians who come from different regions of Turkey can be arranged.

Wooden yacht and boat manufacturing, which is considered to be a sector that should be evaluated within the scope of regional development plans, should be supported within the framework of public-private cooperation and have a sustainable structure.

6. Acknowledgments

This study was presented in IFC 2020 - 6st International Furniture Congress held by Karadeniz Technical University, Trabzon, Turkey.

References

Altiparmak M. (2017). Comparison of the Performance of Various Varnishes Used in Wooden Yachts on Different Wooden Materials. Master Thesis, Mugla Sitki Kocman University, Institute of Science, Woodworking Industrial Engineering, Mugla.

Alkan S. and Altin S. (2015). The Development of the Wooden Boat Production Activities in Kurucasile. *1st* Bartin Sectoral Development Symposium, 8-10 April 2015, Bartin, Turkey, 19-28.

BAKKA (2013). Western Anatolia Development Agency, Kurucasile Wooden Boat and Yacht Manufacturers Strategic Road Map Report, Bartın.

Celik N. and Murat G. (2009). Evaluating the Economic Structure of Bartın Province with Digitized SWOT Analysis, Dokuz Eylul University Faculty of Economics and Administrative Sciences Journal, 24 (1), 199-212.

Ceyhan I. (2015). Kurucasile Boat Builders, Turkey Boat Builder Magazine, (50), 14-24.

Davulcu M. (2013). Wooden Boat Building in Bartın Region, Dokuz Eylul University Maritime Faculty Journal, 5 (1),23-52.

Isik S. and Gezgin U. (2019). Social Memory and Historiography in the Context of the Construction of Urban Identity: The Case of Bartın. Journal of Anthropology, (37),35-49.

Kaygin B. and Aytekin A. (2005). Wooden Boat Construction, Journal of ZKÜ Bartın Forestry Faculty, 7(7),14-23.

Kaygin B. (2002). Comparison of the Adhesion Strength of Sapwood and Sapwood of Tree Species Used in Wooden Boat Construction, PhD Thesis, ZKU Institute of Science, Forest Industry Engineering Department, Bartın.

Ozdemir U. (2006). Traditional Wooden Boat Building in Kurucasile District, Eastern Geography Magazine, 11 (16), 193-210.

Ulay G. and Çakıcıer N. (2017). The Effect of Accelerated Aging (QUV) on the Protective Layer Applied to Tree Species Used in Yacht and Boat Production, Journal of Advanced Technology Sciences, 6 (3), 212-218.

Ulay G. (2011). Comparison of Traditional Production System and Computer Aided Manufaction (CAM) System in a Yacht's Furniture Factory, Master Thesis, Institute of Science, Duzce University, Duzce.

Ulay G., Çakicier N., and Koc K. H. (2016). Importance of Yacht Furniture and Construction Needs, Journal of Selcuk-Technical, Special issue, 1055-1075.

Ulay G. (2018). Determination of the Effect of Thermal Modification and UV Aging Processes Applied to Some Wood Types Used in Yacht and Boat Furniture on Varnish Layer Performance, PhD Thesis, Duzce University, Institute of Science, Duzce.

Ulay G. (2020). Problems and solution suggestions of enterprises producing furniture and wooden yachts/boats (example of Bartin-Kurucasile). *IV. International Furniture Congress,* 2-5 November 2020, Trabzon, Turkey, Abstract book pp:84.

Yazici H. (1998). Some physical and mechanical properties of chestnut trees used in wooden boat construction and naturally grown crooked, Master Thesis, Zonguldak Karaelmas University, Bartın.
Yildiz Z. and Cekic S. (2015). The Role of Local Governments in Sectoral Development: Bartın Province Tourism Sector Case, I. Bartın Sectoral Development Symp. 8-10 April 2015 Bartın, pp: 283-293.
Yildiz Ö. and Kaygin B. (2020). University-Industry Cooperation in Forest Products Sector in Bartin Province: 2015-2020 Qualitative Process Analysis. Bartın Forestry Faculty Journal, 22 (3), 1-13.
Yildiz Ö. (2016). Evaluation of University-Industry Cooperation in terms of Regional Development Problem in Bartın Province (Applied Survey Study for Forest Products Sector). Master Thesis, Bartın University Institute of Science, Forest Industry Engineering Department.

Web sites:
Web-1:"Wooden Boat Building in Kurucasile", http://www.kurucasile.gen.tr/, consulted 18 Nov. 2020.
Web-2:"Kurucasile Boat Builders" http://www.boatbuilderturkiye.com/, consulted 15 November 2020.
Web-3:“ Boat Builders in Kurucasile” http://www.kurucasile.info/,consulted 10 November 2020.
Web-4:“About the Company” http://www.herbotdenizcilik.com/tr/ , consulted 18 November 2020.
Web-5:“İEM 790 Boat” http://www.faizlertekne.com/ , consulted 18 November. 2020.

Wood Industry and Engineering
ISSN: 2687-6043 e-ISSN: 2687-6035
https://dergipark.org.tr/en/pub/wie
Year: 2020 Volume: 02 Number: 02 Pages: 70 - 79
Paper Type: Research Article
Received: 06/12/2020
Accepted: 15/12/2020

THE EFFECT OF ACCELERATED WEATHERING ON COLOR AND SURFACE ROUGHNESS IN THERMOWOOD WILD CHERRY WOOD

Ayhan Aytin[1,a]
ayhanaytin@duzce.edu.tr
(ORC-ID: 0000-0002-7938-1111)

Süleyman Korkut[2]
suleymankorkut@duzce.edu.tr
(ORC-ID: 0000-0002-4871-354X)

Nevzat Çakıcıer[2]
nevzatcakicier@duzce.edu.tr
(ORC-ID: 0000-0001-6566-7541)

[1]*Duzce University, Duzce Vocation School, Design of Department, Duzce, Turkey*
[2]*Duzce University, Faculty of Forestry, Forest Industrial Engineering, Duzce, Turkey*

Abstract

In this study, changes in some physical properties after accelerated weathering of Thermowood Wild Cherry (*Cerasus avium* (L.) Monench) wood were investigated. Firstly, Wild Cherry (*Cerasus avium* (L.) Monench) planks were heat treated by Thermowood method and Thermowood Wild Cherry was obtained. Afterwards, the trial samples prepared were periodically accelerated with 144, 248, 576 and 864 hours of UVB lamps, and color values (L, a, b and ΔE) and average surface roughness (Ra) values were determined at the end of each period. The results were analyzed by multiple comparison techniques with SPSS and Duncan test was applied to see if there were $p < 0.05$ statistical differences. The results of the study showed that the average surface roughness values were better in Thermowood samples than the control samples. On the other hand, it was determined that the samples got darker with heat treatment, started to gray on the surfaces with aging, and the degree of graying increased due to the prolongation of the aging period.

Keywords: Wild cherry, thermowood, accelerated weathering, color, surface roughness

1. Introduction

Wood material is a renewable natural raw material that people have used for centuries to meet various needs (Bozkurt and Erdin, 1997). The wood material, which has a very wide usage area, has some undesirable properties; depending on the usage conditions, its service life decreases and its value decreases due to features such as dimensional change, biological degradation and color change.

Heat treatment is one of the studies aimed at extending the service life of the wood material by removing the unwanted properties (Anonymous, 2003). The basic idea in the practice, which is a physical process resulting in permanent changes in the chemical composition of cell wall polymer compounds, is based on heat treatment of wood material at temperatures above 150 °C, where chemical reactions accelerate (Johansson 2005, TS CEN/TS 15679, 2010).

Since the application of heat treatment causes the molecular structure of the wood to be modified, it increases its performance. Potential qualities increased with heat treatment application; biological resistance against fungi and insects, low equilibrium moisture content, increased dimensional stability due to the reduction in contraction and expansion, increased thermal isolation capability, paint adhesion, increased resistance to weather conditions, decorative color variety and prolonged use (Wikberg, 2004; Enjily and Jones, 2006).

Heat treatment methods are divided into two as old methods and new methods. Old methods; Staybwood (providing the dimensional stability of the wood by heat alone by not being compressed) and Staypak (wood stabilized by compression with severe heating) (Korkut and Kocaefe, 2009).

New methods; ThermoWood (Finland), PlatoWood-Lignius-Lambowood (Netherlands), Retification process (Retiwood) -New Option wood-Le Bois Perdure (France), Hot Oil treatment (OHT) -Menz Holz (Germany), Calignum (Sweden), Thermabolite (Russia), Huber Holz (Austria), Wood treatment technology (WTT) (Denmark), Westwood (America, Canada, Russia) (Sundqvist, 2004; Tjeerdsma, 2006).

[a] *Corresponding Author*

Various research groups in Europe have developed heat treatment methods based only on heat, hot oil, hygrothermal (the condition in which steam, moisture and heat act simultaneously) and hydrothermal (use of heat energy obtained with hot water). The basic characteristics of these methods are given in Table 1 (Aytin, 2013).

Table 1: Basic characteristics of some heat treatment methods.

Method	Environment	Moisture	Tem.(ºC)	Phases	Country
Thermo Wood	Steam	Fresh or air-dried tree	150-240	1.Temperature increase 2.Heat treatment 3.Cooling and conditioning	Finland
Plato Wood	Steam and air	Fresh or air-dried tree	170-190	1.Pre drying 2.Hydrothermolysis process 3.Drying 4.Heat treatment 5.Equalization and cooling	Netherlands
Oil Heat treatment	Hot oil	Air dried tree or about % 6	180-220	1.Heating and drying 2.Heat treatment 3.Cooling	Germany
Retification	N_2	Air dried tree	200-240	A step	France
Bois Perdure	Steam	Fresh tree	200-240	A step	France

The heat treatment methods that have become commercial among these methods today is the "ThermoWood" method. Thermowood method consist of three basic phases;

•The first phase, in which the oven temperature is increased to 100°C rapidly using heat and steam, then up to 130°C with a slower increase to achieve high temperature drying; At this stage, which varies between approximately 14-30 hours, the moisture of the wood material is reduced to approximately zero.

•At the end of the high temperature phase, the heat treatment application phase in which the temperature in the furnace is raised up to 185 °C and 215 °C, which is the target heat treatment temperature, in approximately 6-8 hours; depending on the purpose of application, the heat treatment is continued for 0.4 hours to 4 hours at the heat treatment temperature reached. Steam is sent into the furnace in order to prevent the wood material from being damaged at high temperatures.

•The cooling and conditioning phase in which the temperature of the wood material is reduced from 50 °C to 60 °C by using the water spray system; This process is continued until the moisture content of the wood material reaches 4-6%. The cooling and conditioning phase varies between approximately 24 hours and 30 hours depending on the thickness and width of the heat-treated wood material.

ThermoWood is classified in two different ways as Thermo S and Thermo D. The average shrinkage and swelling of the wood material treated in Thermo S class due to moisture is 6-8%. Thermo S is classified as relatively durable according to EN 113 standards. Its natural resistance to rot meets the requirements of "CLASS 3". The letter "D" in Thermo D means durability. The average shrinkage and expansion of the wood material treated in Thermo D class due to moisture is 5-6%. Thermo D is classified as durable according to EN 113 standards. Its natural resistance to decay meets the requirements of "CLASS 1". Thermo S end use areas are given in Table 2a and Thermo D class end use areas are given in Table 2 b (Aytin, 2013).

Table 2a: Thermo S use areas. Table 2b: Thermo D use areas.

Thermo S Softwoods	Thermo S Hardwoods	Thermo D Softwoods	Thermo D Hardwoods
Building materials	Upholstery	Exterior cladding	Exterior cladding
Upholstery	Furniture	Interior and exterior door	Outdoor flooring
Furniture	Flooring	Door Window case	Garden furniture
Garden furniture	Sauna banks	Blinds	Parquet
Sauna banks	Garden furniture	Environmental structures	
Door and Window materials		Sauna and bathroom furniture	
Exterior cladding		Flooring	

The properties of wood material in heat treatment classes in ThermoWood method are given in Table 3 (Aytin, 2013).

Table 3: Properties of wood material in heat treatment classes in ThermoWood method

	Pine and Spruce		**Iroko, Ash, Oak, Beech**	
Properties / Class	Thermo S	Thermo D	Thermo S	Thermo D
Process Temperature	190 ºC	212 ºC	180 ºC	200 ºC
Durability	+	++	-	+
Dimensional stability	+	++	+	+
Bending resistance	-	-	-	-
Color darkening	+	++	+	++

Accelerated weathering tests are performed with lamps emitting UV rays in test cabinets where the effects of moisture condensing on the surface are applied in successive periods. The wavelengths of fluorescent lamps used and emitting UV rays contain higher energy than sunlight. Therefore, it may be possible for the test to cause damages in the natural external environment that will never come to the fore (Cakicier, 2007).

Color and surface roughness are very important physical properties in the use of wood. In this respect, even though it has been modified, the condition of the surface properties of heat-treated materials from wood based products should be carefully monitored.

Wild Cherry (*Cerasus avium* (L.) Monench) is a tree species whose wood, which is very valuable in the forest products industry, is mostly used in coating, cabinet making and turning. Due to the fact that the demand for wood in the market is above the supply, it is ready for the use of the industry for a short operating period and the gene resources are depleted, it is the subject of remarkable studies in both Europe and our country. There are very few researches and information in Turkish forestry sources on the ecology, biology and genetics of the Wild Cherry (Cerasus avium (L.) Monench) tree. Efforts are encouraged to increase its productivity and economic input as a rapidly growing species with a valuable wood and fruit, high wildlife function (Eşen et al., 2005).

Having an idea about the surface roughness and color changes of Wild Cherry (*Cerasus avium* (L.) Monench) wood, which grows naturally in our country and has the potential to create great economic value, after being subjected to heat treatment and accelerated aging and to work on increasing its potential benefit value aims to contribute.

2. Materials and Methods

Wild Cherry (*Cerasus avium* (L.)) Monench trees were taken from Düzce Forestry Directorate of Odayeri Operation Department. Trees were selected according to TS 4176(1984). Selected trees were divided into 2 m body parts after 1.30 m height from the bottom and necessary markings were made on each part (Figure 1) (Aytin, 2013).

Figure 1: Wild Cherry (Cerasus avium (L.) Monench

The 2 m body parts obtained were cut planks of 60 mm thickness according to TS 2470(1976) with the sharp cutting method. The planks were kept in the air conditioning room which can be adjusted to 20 ±

2 ° C and 65 ± 5% relative humidity until the heat treatment is done in the classical drying oven which is controlled fully automatically. The air-dried planks were exposed to heat treatment.

In the heat treatment application with the ThermoWood method, 4 different variations were created by heat treatment at 190 ° C and 212 ° C for 1 and 2 hours in accordance with the production schedule of the enterprise. Production schedules in which heat treatment variations are applied are shown in Table 4.

Table 4: Heat treatment variations

Temperature (°C)	Time (min)	Heat treatment variations
190	60	**TW1**
190	120	**TW2**
212	60	**TW3**
212	120	**TW4**

Heat treated test samples were prepared from the planks whose heat treatment application was completed (4 pieces for each of the control and heat treatment variations, 10x75x300 mm in total, 100 pieces together with the control group). Then, color and surface roughness values were measured before weathering to be used for control purposes from 5 points of each test sample in order to compare with the values to be determined after aging. The weathering process is carried out by Nova Forest Products San. Tic. In the R&D laboratory of the 0 factory of Bolu Province Gerede; The QUV Accelerated Weathering Tester-Model QUV / Spray was performed in 144, 288, 576 and 864 hours on the QUV device manufactured by Q-LAB. Aging process in ASTM G154 (2006) with standard principles to be taken by Q-Lab company in Turkey distributor Feza Kimya AS A modified program was used for the QUV accelerated aging device. Modified program stages consisting of 3 consecutive sections are given in Table 5. This section should provide sufficient details of the experiment, simulation, statistical test or analysis carried out to generate the results such that the method can be repeated by another researcher and the results reproduced.

Table 5: Accelerated weathering program.

Operation	Time (Min)	Temperature (°C)	Light intensity (W/m²)	Wavelength (nm)
UV	60	60	0.67	310
Sprinkler	10			
Conditioning	240	50		

After weathering, experimental studies were started after waiting for 2 months until it reached the constant weight in the conditioning room with 20% ± 2 ° C temperature and 65 ± 5% relative humidity.

2.1. Determination of Surface Roughness

Average surface roughness (Ra) is determined according to ISO 4287(1997) and DIN 4768(1990) standards. Mitutoyo Surftest SJ-301 test device was used in the measurements. The measuring process of the device was made with a 4 (μm) needle diameter and a measuring angle of 90° with the longitudinal fiber direction with a measuring speed of 10 mm / minute (Figure 2) (Aytin, 2013).

Figure 2: Determination of Surface Roughness.

2.2. Determining Color Difference

Color difference compared to white color a = 4.91; b = 3.45; It was examined according to the ISO 7724-2 (1984) standard with the Elrepho 071 spectrometer instrument, which can be calibrated to c = 6.00, L = 324.9. In order to determine which tone of the color difference is effective, the red hue (a *), yellow hue (b *) and color angle (L*) values were examined independently (Figure 3) (Aytin, 2013).

Figure 3: Determining color difference.

The color values (L *, a * and b *) of the test samples were determined first, and then the color values of the samples after aging were determined following each aging phase. The total color difference (E *) from the determined color values was calculated with the following formula according to ISO 7724-3 / 1984. In the formula, Δ denotes the difference and the letter E is the initial of the German word Empfindung, which means feeling (Yeşil, 2010).

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

Equally; ΔE* : Total color difference occurring in samples after heat treatment, ΔL*: Black-white color change, Δa*: Red-green color change, Δb*: Yellow-blue color change.

3. Results

3.1. Average Surface Roughness (Ra)

Simple analysis of variance (BVA), statistics and Duncan test (HG) results for the average surface roughness values of test samples after accelerated aging are given in Table 6.

Table 6: Related to average surface roughness BVA, statistics and HG results.

	BVA						Statistics and HG			
		Sum of squares	df	Squares	F	P	Variation(V)	Ra	Standard	HG
144 hours accelerated weathering	WG*	61.566	4	15.391	7.47		C	**10.37**	2.273	a
	BG	195.662	95	2.060			TW1	**8.154**	0.731	c
	T	257.222	99				TW2	8.352	1.308	bc
							TW3	8.987	1.520	bc
							TW4	9.257	0.755	b
288 hours accelerated weathering	WG	514.537	4	126.634	19.37	0.000	C	**15.48**	4.515	a
	BG	630.651	95	6.638			TW1	10.74	2.178	b
	T	1145.188	99				TW2	**9.31**	1.336	b
							TW3	9.40	1.631	b
							TW4	11.13	3.473	b
576 hours accelerated weathering	WG	573.006	4	143.251	38.93	0.000	C	**16.69**	3.015	a
	BG	349.496	95	3.679			TW1	10.490	1.491	c
	T	922.502	99				TW2	11.848	1.783	b
							TW3	10.911	1.543	bc
							TW4	**10.23**	1.228	c
864 hours accelerated weathering	WG	794.656	4	198.664	75.96	0.000	C	**17.61**	1.505	c
	BG	248.448	95	2.615			TW1	10.226	2.309	ab
	T	1043.103	99				TW2	11.249	1.537	b
							TW3	11.166	1.405	b
							TW4	**10.03**	1.065	a

*WG: Within groups; BG: Between groups; T: Total; df: Degrees of freedom

3.2. Color Values and Total Color Change

Results of L*, a*, b* and ΔE Values after 144 hours weathering: Simple analysis of variance (BVA), statistics and HG results related to L *, a *, b * and ΔE values of test samples after 144 hours weathering are given in Table 7.

Table 7: BVA, statistics and HG test results after accelerated weathering first period (after 144 hours).

BVA							Statistics and HG					
		SUM	df	SQA	F	P	V	Control Value (CV)	Last Value (LV)	Change (CH)	SS	HG
L*	WG	10292.9	4	2573.23	178.50	0.000	C	72.66	48.57	24.09	6.75	**b**
	BG	1369.50	95	14.416			TW1	53.10	54.52	-1.42	2.19	**a**
	T	11662.4	99				TW2	52.30	51.40	0.89	1.78	**a**
							TW3	42.10	43.30	-1.2	3.50	**a**
							TW4	40.99	43.71	-2.7	2.48	**a**
a*	WG	2971.83	4	742.959	209.0	0.000	C	5.40	16.6	-11.2	4.09	**a**
	BG	337.549	95	3.553			TW1	9.50	7.48	2.02	0.44	**b**
	T	3309.38	99				TW2	10.10	8.13	1.93	0.27	**b**
							TW3	9.35	6.57	2.79	0.62	**b**
							TW4	9.03	6.34	2.69	0.55	**b**
b*	WG	2730.74	4	682.685	138.8	0.000	C	24.10	32.1	-8.06	3.55	**a**
	BG	467.032	95	4.916			TW1	24.40	18.12	6.28	1.45	**d**
	T	3197.77	99				TW2	23.7	18.5	5.22	0.69	**cd**
							TW3	18.5	14.1	4.37	2.80	**bc**
							TW4	17.3	14.2	3.1	1.22	**b**
ΔE*	WG	7458.92	4	1864.73	117.3	0.000	C	-	-	27.8	8.46	**b**
	BG	1509.86	95	15.893			TW1	-	-	7.08	1.50	**a**
	T	8968.78	99				TW2	-	-	5.91	0.57	**a**
							TW3	-	-	6.67	1.84	**a**
							TW4	-	-	5.48	1.37	**a**

Results of L *, a *, b * and ΔE Values after 288 hours weathering: Simple analysis of variance (BVA), statistics and Duncan test (HG) results related to L*, a*, b* and ΔE values of test samples after 288 hours weathering are given in Table 8.

Table 8: BVA, statistics and HG test results after accelerated weathering first period (after 288 hours).

BVA							Statistics and HG					
		SUM	df	SQA	F	P	V	CV	LV	CH	SS	HG
L*	WG	17913.	4	4478.45	344.5	0.000	C	72.23	43.55	28.68	6.55	**c**
	BG	1234.7	95	12.998			TW1	54.70	57.74	-3.03	3.44	**b**
	T	19148.	99				TW2	49.04	53.79	-4.74	1.67	**b**
							TW3	40.13	47.47	-7.33	2.62	**a**
							TW4	38.88	41.47	-2.58	0.68	**b**
a*	WG	2940.8	4	735.21	706.2	0.000	C	5.64	15.43	-9.78	2.09	**a**
	BG	98.89	95	1.041			TW1	9.41	5.96	3.45	0.57	**b**
	T	3039.7	99				TW2	9.81	5.51	4.30	0.34	**c**
							TW3	8.26	4.85	3.40	0.55	**b**
							TW4	8.13	4.32	3.81	0.28	**bc**
b*	WG	3076.7	4	769.191	33.90	0.000	C	24.04	27.46	-3.42	1.54	**a**
	BG0	219.50	95	2.311			TW1	25.42	13.58	11.84	1.58	**d**
	T	3296.2	99				TW2	23.51	12.01	11.49	1.05	**d**
							TW3	16.35	9.94	6.40	2.02	**b**
							TW4	16.02	7.94	8.08	1.21	**c**
ΔE*	WG	5998.9	4	1499.74	150.2	0.000	C	-	-	30.64	6.76	**c**
	BG	948.34	95	9.983			TW1	-	-	13.22	0.83	**b**
	T	6947.3	99				TW2	-	-	13.28	0.70	**b**
							TW3	-	-	10.75	1.25	**a**
							TW4	-	-	9.33	1.18	**a**

Results of L *, a *, b * and ΔE Values after 576 hours weathering: Simple analysis of variance (BVA), statistics and Duncan test (HG) results related to L*, a*, b* and ΔE values of test samples after 576 hours weathering are given in Table 9.

Table 9: BVA, statistics and HG test results after accelerated weathering first period (after 576 hours).

BVA							Statistics and HG					
		SUM	df	SQA	F	P	V	CV	LV	CH	SS	HG
L*	WG	10337.	4	2584.30	455	0.000	C	72.76	60.12	12.6	3.40	d
	BG	538.45	95	5.668			TW1	55.77	61.27	-	2.56	c
	T	10875.	99				TW2	49.65	60.93	-	2.14	b
							TW3	42.86	56.91	-	1.75	a
							TW4	39.66	54.53	-	1.57	a
a*	WG	971.10	4	242.77	524	0.000	C	5.70	7.52	-	1.29	a
	BG	43.994	95	0.463			TW1	8.32	4.31	4.00	0.35	b
	T	1015.0	99				TW2	9.64	3.92	5.72	0.38	c
							TW3	9.75	3.03	6.72	0.43	d
							TW4	8.89	2.76	6.12	0.39	c
b*	WG	593.41	4	148.353	95	0.000	C	23.85	14.41	9.43	1.37	a
	BG	147.26	95	1.550			TW1	24.8	9.08	15.7	0.88	d
	T	740.68	99				TW2	23.23	7.55	15.6	0.86	d
							TW3	18.55	5.57	12.9	1.01	c
							TW4	16.81	5.35	11.4	1.82	b
ΔE*	WG	300.16	4	75.041	25.42	0.000	C	-	-	16.1	2.53	a
	BG	280.37	95	2.951			TW1	-	-	17.2	1.64	b
	T	580.53	99				TW2	-	-	20.2	1.46	c
							TW3	-	-	20.3	1.30	c
							TW4	-	-	19.8	1.32	c

Results of L *, a *, b * and ΔE Values after 864 hours weathering: Simple analysis of variance (BVA), statistics and Duncan test (HG) results related to L*, a*, b* and ΔE values of test samples after 864 hours weathering are given in Table 10.

Table 10: BVA, statistics and HG test results after accelerated weathering first period (after 864 hours).

BVA							Statistics and HG					
		SUM	df	SQA	F	P	V	CV	LM	CH	SS	HG
L*	WG	17675.4	4	4418.86	1244.0	0.000	C	74.17	61.62	12.55	3.6	e
	BG	337.42	95	3.552			TW1	55.46	65.92	-10.46	0.7	d
	T	18012.8	99				TW2	50.83	68.20	-17.36	1.1	c
							TW3	39.27	63.90	-24.62	1.1	b
							TW4	36.99	58.52	-21.52	1.0	a
a*	WG	1059.68	4	264.92	791.82	0.000	C	4.70	6.40	-1.70	1.1	a
	BG	31.78	95	0.335			TW1	8.24	2.91	9.05	0.2	b
	T	1091.46	99				TW2	9.50	2.39	7.10	0.3	d
							TW3	8.86	2.01	6.84	0.1	d
							TW4	7.51	1.72	5.79	0.3	c
b*	WG	1035.06	4	258.76	354.04	0.000	C	25.02	12.34	12.68	1.5	b
	BG	69.43	95	0.731			TW1	24.72	7.28	17.43	0.5	c
	T	1104.49	99				TW2	24.24	6.13	18.11	0.7	d
							TW3	16.34	4.10	12.24	0.3	b
							TW4	13.31	3.57	9.73	0.5	a
ΔE*	WG	1280.47	4	320.11	233.34	0.000	C	-	-	18.29	1.7	a
	BG	130.32	95	1.372			TW1	-	-	21.03	0.7	b
	T	1410.80	99				TW2	-	-	26.08	1.3	d
							TW3	-	-	28.34	1.0	e
							TW4	-	-	24.34	0.6	c

4. Discussion

As can be understood from the Ra values determined after each weathering period, the surface has undergone less deformation in heat treated samples (Figure 4). According to Figure 4, it is seen that the difference of Ra between the C and heat-treated samples increases as the weathering time increases.

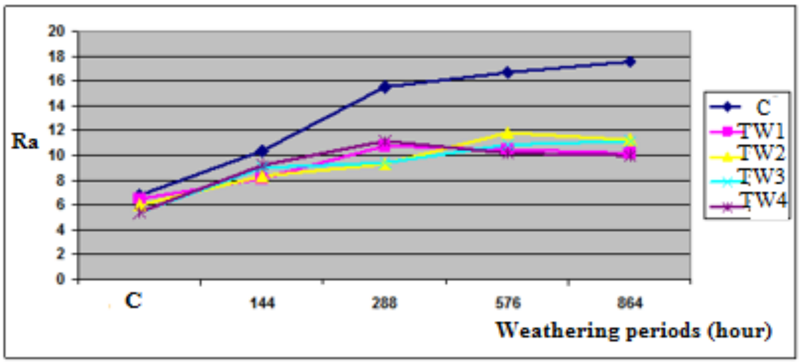

Figure 4: Change of Ra after accelerated weathering.

Huang et al. (2012), it has been stated that after 1500 hours of aging in heat-treated Jack pine (*Pinus banksiana*), the radial surfaces in IR and IIGTÖ are smoother and without cracks, and small cracks begin to form on the tangent surface after 672 hours of weathering.

The views of the trial samples used in the study after the accelerated weathering periods are given in Figure 5 a, b, c and d.

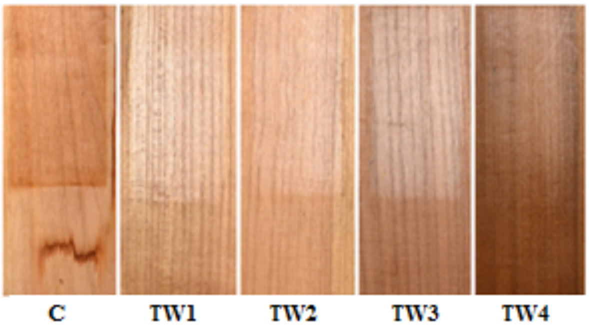

Figure 5a: Appearances after 144 hours

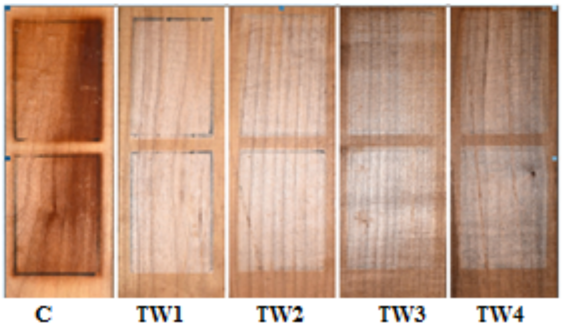

Figure 5b: Appearances after 288 hours

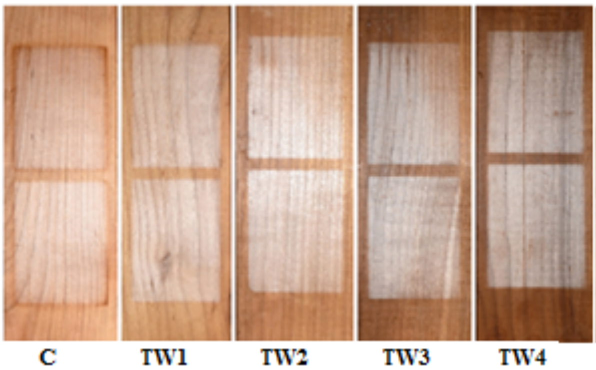

Figure 5c: Appearances after 576 hours

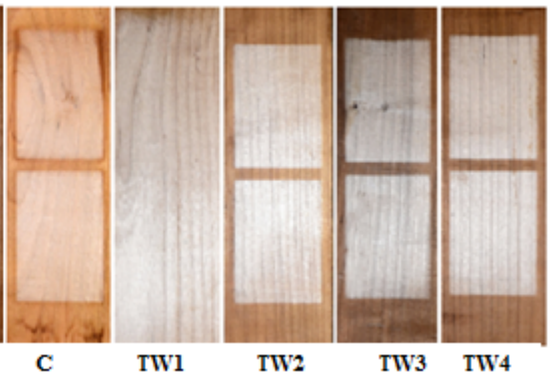

Figure 5d: Appearances after 864 hours

As can be seen in Figure 5a, it is seen that graying started in ThermoWood samples with 144 hours of accelerated aging. On the other hand, graying did not start in the control samples yet. Similarly, as seen in 5 b, it was understood that while graying continued in ThermoWood samples, it did not start in the control samples yet. In the third (576 hours) and fourth (864 hours) periods of accelerated weathering, graying was observed in both ThermoWood and control samples, and it was more noticeable in samples with higher heat treatment temperature and time.

It is seen that the total color difference starts to increase with weathering in all ThermoWood samples (Figure 6a). In the control samples, the high ΔE, which was considerably higher than the ThermoWood samples at the beginning, decreased as the aging periods increased and lower values were obtained. Figure 6 shows the E change.

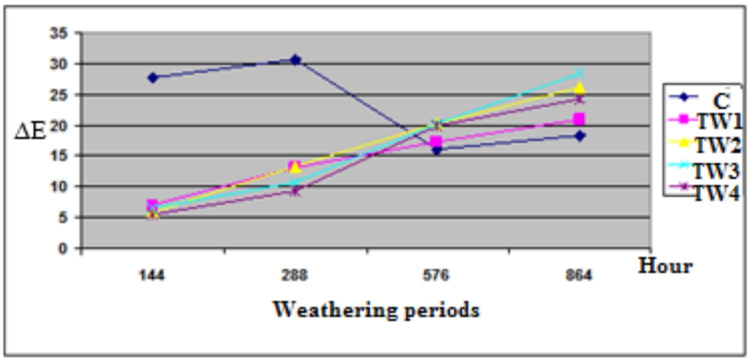

Figure 6: Total color change

When the literature is examined, it is seen that different results are revealed regarding the changes in color with aging in heat treated modified wood material.

As stated in Thermowood Handbook (2003), heat-treated wood materials that are not surface treated but are affected by UV rays similar to untreated wood materials, UV rays cause the surfaces to appear gray and gain an antique appearance over time. It is reported that surface treatment should be applied in order to preserve the natural appearance of the material. Similarly, Huang et al. (2012) reported that they obtained similar color values (L*, a*, b*) in İİGTÖ with IR at the end of 1500 hours of aging in heat treated Jack pine (*Pinus banksiana*). They stated that the color was obtained. On the other hand, Dubey et al. (2010) in their study examining the color change after 2100 hours of accelerated weathering in heat treated wood material, determined that more changes occurred in the control samples compared to the color of the heat-treated ones. They stated that although the color of the samples where heat treatment was applied at 160 and 180 °C temperatures did not fade after accelerated aging, it produced a small amount of fading in the heat-treated wood at 210 °C, and the color stability was better in the heat-treated wood. Ayadi et al. (2003), stated that the color stability of heat-treated test samples at the end of 835 hours was better than those that were not heat-treated in their accelerated weathering study. They stated that this is due to the changes in the structure of heat-treated wood (lignin modification and monomers of phenolic compounds) becoming more resistant to UV rays.

5. Conclusion

There is a significant difference in Ra values determined in ThermoWood Wild cherry wood with accelerated weathering compared to C samples. Ra results were lower in ThermoWood Wild cherry wood. This gives a clue that the surface smoothness of the heat treated ThermoWood Wild cherry wood samples may remain more stable under the influence of climatic conditions. This difference can be explained by the fact that the sprinkling and conditioning conditions are more effective on the control samples during the aging period. In ThermoWood samples, the deformations on the surface will be less since the wood-water relations will be restricted due to the degradation of hemicellulose and its decrease in quantity. On the other hand, due to the abundance and accessibility of free hydroxyl groups in the control samples, it is in an intense relationship with water and water vapor in the air, as a result, more degradation can be seen in the surface layers.

In the observations made in the samples that were aged in the wild cherry wood samples, it was determined that the surface layers except the control samples started to turn gray after the 144 hours aging application, and with 576 hours aging, a significant graying occurred. Considering that the amount of lignin decreased significantly in the aged samples and it was thought that it degraded hemicelluloses significantly in the heat treatment, it can be said that the presence of cellulose was responsible for the gray layer seen on the surfaces after aging. According to these data, when ThermoWood Wild cherry wood is desired to be evaluated under different atmospheric conditions, appropriate processes should be applied to the material in order to maintain the color values obtained after heat treatment.

6. Acknowledgments

This study is derived from the doctoral thesis "The Effect of High Temperature Application on Physical, Mechanical and Technological Properties of Wild Cherry (*Cerasus Avium* (L.) Monench) Wood" and presented as an oral presentation at the 6th International Furniture Congress.

References

ASTM G154 (2006). Standard practice for operating fluorescent light apparatus for UV exposure of nonmetallic materials, American Society for Testing and Materials International, Philadelphia.

Ayadi N., Lejeune F., Charrier F., Charrier B. and Merlin A. (2003). Color stability of heat-treated wood during artificial weathering, Holz als Roh- und Werkstoff, 61, 221–226.

Aytin A. (2013). Effect of High Temperature Treatment on Physical, Mechanic and Technologic Properties of Wild Cherry (*Cerasus Avium* (L.) Monench) Wood. Doctoral Thesis, Düzce University, Turkey.

Boonstra M.J. (2008). A two-stage thermal modification of wood, Ph.D. dissertation in cosupervision, Ghent University and Université Henry Poincaré, Nancy-Fransa.

Bozkurt Y. and Erdin N. Wood Technology, İ.Ü. Printing House and Film center, (1997), ISBN 975-404-449-X.

Çakıcıer N. (1990). Changes Due to Weathering of Surface Finishing Layers of Wood, Doctoral Thesis, Natural Sciences, İstanbul.

DIN 4768 (1990). Determination of values of surface roughness parameters Ra, Rz, Rmax using electrical contact (stylus) instruments, concepts and measuring conditions.

Dubey MK., Pang S. and Walker J. (2010). Color and dimensional stability of oil heat-treated radiata pinewood after accelerated UV weathering, Forest Products Journal.

Enjily V. and Jones D. The potential for modified materials in the panel products industry, Wood Resources and Panel Properties Conference, Valencia-Spain, (2006) E44/E49.

Eşen D., Yıldız O., Kulaç Ş. and Sargıncı M. Neglected Precious Leaved Species of Turkey Forests: Wild Cherry (*Cerasus Avium* (L.) Monench) Wood, TBMMO Magazine of Forestry Engineers Chamber, 42 (4-5-6) (2005) 18-22.

Huang X., Kocaefe D., Kocaefe Y., Boluk Y. and Pichette A. (2012). A Spectro colorimetric and chemical study on color modification of heat-treated wood during artificial weathering, Applied Surface Science, 258(14), 5360–5369.

http://www.thermowood.fi (Accessed on 28 June 2010).

ISO 4287 (1997). Geometrical product specifications surface texture profile method terms, definitions and surface texture parameters, International Standard Organization.

ISO 7724-2 (1984). Paints and varnishes-colorimetry-part 2: colour measurement, ISO standard.

ISO 7724-3 (1984). Paints and varnishes-colorimetry-part 3: Calculation of colour differences", ISO standard.

Johansson D. (2005). Strength and colour response of solid wood to heat treatment, Licentiate Thesis, Luleå Technology University, Department of Skellefteå Campus, Sweden,

Korkut S. and Kocaefe D. (2009). Effect of heat treatment on wood properties. Düzce University Journal of Forestry, 5 (2), 11-34.

Sundqvist B. (2004). Colour changes and acid formation in wood during heating. Doctoral Thesis, Lulea Technology University, Skellefteå-Sweden.

Tjeerdsma B. F. (2006). Heat treatment of wood-thermal modification. SHR Timber Research, Wageningen, The Netherlands.

TS 2470 (1976). Wood - Sampling Methods and General Requirements for Physical and Mechanical Tests, Turkish Standardization Institute, Ankara,

TS 4176 (1984). Wood - Sampling Sample Trees and Long for Determination of Physical and Mechanical Properties of Wood in Homogeneous Stands., Ankara

TS CEN/TS 15679 (2010). Heat treated timber-terms and characteristics, Turkish Standards Institute, Ankara.

Wikberg H. (2004). Advanced solid state NMR spectroscopic techniques in the study of thermally modified wood, Academic Dissertation, Helsinki University, Helsinki- Finland.

Yeşil Y. (2010). The Prediction of The Color Values in The Mélange Fibre Blends by A Newly Developed Algorithm, Doctoral Thesis, Çukurova University Adana.

Wood Industry and Engineering
ISSN: 2687-6043 e-ISSN: 2687-6035
https://dergipark.org.tr/en/pub/wie
Year: 2020 Volume: 02 Number: 02 Pages: 80 - 90
Paper Type: Review Article
Received: 02/12/2020
Accepted: 18/12/2020

COLLABORATION AND SCOPE AREAS OF CHANGING CO-DESIGN APPROACHES IN THE FORMATION OF DESIGN CRITERIA

Esin Fakıbaba Dedeoğlu[a]
e.dedeoglu@etu.edu.tr
(ORC-ID: 0000-0001-6831-7168)

Meryem Yalçın
myalcin@etu.edu.tr
(ORC-ID: 0000-0003-1836-4243)

TOBB University of Economics & Technology, Department of Interior Architecture, Ankara, Turkey

Abstract

Nowadays, new trends see design education not as a discipline shaped by a perfectionist form approach; but as a collaborative holistic, sharing, and exploratory approach. The aim of this study is to develop a perspective on Furniture development and formation in today's world within the innovative, collaborative holistic, ever-evolving process design approaches that have been developing and diversifying since the 90s (Burnett, 2009; Rylander, 2009; Sanders and Stappers, 2008). It is not possible for a single design discipline to answer the scale or complexity of the design problems we face today and seek to provide solutions. Considering that experimental, virtual and real mixed areas will be designed in the future; it is not possible to ignore the fact that areas that work in collaboration with integrated disciplines in the field of design and work with an understanding of common gain will spread. Co-Design expertise/disciplines are involved in the design and production of furniture; many design disciplines such as *Communication design, interface design, brand design, graphic design, digital design, system design, transformation design, organizational design and space design* require simultaneous/joint/integrated work because of the effort to create the holistic values of design. By proposing a roadmap for the development of design-based professions, these forms of expansion create new areas of design activity where designers facilitate creative collaborations. The research method in the study in which qualitative research method is used can be defined as "explanatory case study". In line with the purpose of the study, one of the qualitative data collection tools, "document analysis" technique was used.

Keywords: Co-design, innovative furniture, multiple design collaboration, design criteria

1. Introduction

According to the functionalist understanding, "Furniture-Item" is a means of action. It is used to perform a service and/or job. It is an action that determines, conducts, and directs things. Every item is for an action (Bilgin, 1991). According to Asatekin; "It is a phenomenon of product design that human beings begin to consciously shape objects that they use for a certain purpose and to meet a certain need, and that they develop this form with possible feedback by observing the usage process over time" (Asatekin, 1997).

Accordingly, the designer is in an effort to present an integrated design process by evaluating the values that the user wants to have, show and/or exhibit on the furniture within the framework of both the user and his/her own design understanding and vision. In the furniture design process, the designer must consider certain stages and criteria. Koberg and Bagnall summarized the design process that starts with the determination of a problem and need in seven steps. The process that begins with the determination of needs is detailed with analysis, and the main issues and goals are clarified. Ideas are developed to diversify the options and the most suitable one is chosen among these designs. The next step is to take action to make the abstract idea concrete. Finally, the concrete product is evaluated in every aspect. There are some criteria that the designer should consider while designing the product to be produced. These are handled in two aspects, human-based and technical criteria. While human-based criteria address the ergonomic, psychological, aesthetic, and functional dimensions of the design, both the material and the production phase are evaluated with its technical dimension.

[a] *Corresponding Author*

In the period that started with modernism, while the disconnection of disciplinary information was experienced in the design processes, the efforts to re-establish these ties in the last 15 years have gained importance and new collaborative relationships that define these ties with different frameworks have been presented.

These new collaborative approaches are described as "Integrated Design". Sanders and Stappers (2008) defines Integrated Design as "Collective Creativity" applied throughout the entire design process. With this "Collective Creativity", the importance of collaboration between different disciplines for the richness of processes and products is increasing day by day. Since a linear and hierarchical path is followed in the traditional design process, different disciplines are included in the process independently when their time comes. For this reason, in order to make the processes stronger and based on the idea that integrated strategies should be carried out not only in the design process, but also in the production and use process, while the integrated design process is followed from the very beginning in the designer-manufacturer and user chain in the furniture sector, it is aimed to integrate information, to provide discipline based integration and visual integration by considering all multi-disciplinary data components that can be involved in the process.

2. Furniture Design Process and Its Criteria

2.1. Furniture Design Process

Koberg and Bagnall (1974) stated that the furniture design process takes place in certain stages as seen in Figure 1.

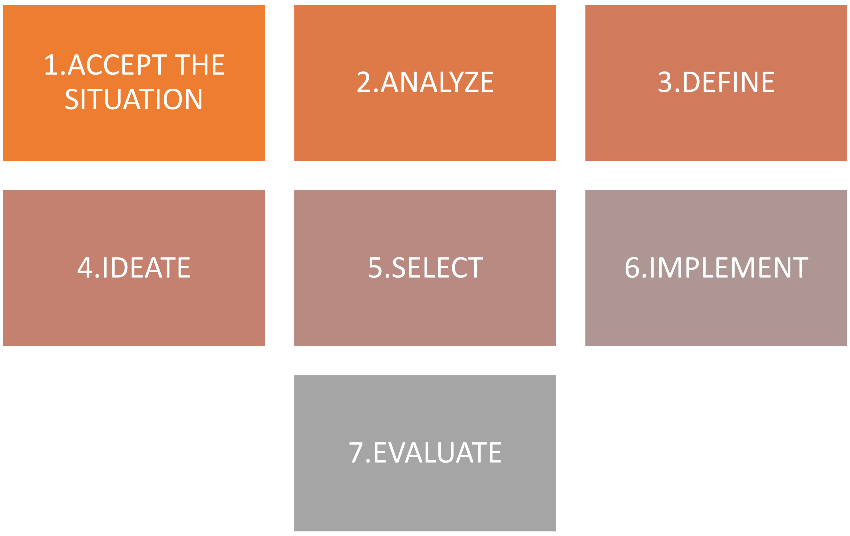

Figure 1: Furniture design process (Koberg and Bagnall, 1974)

2.1.1 At the situation determination stage, the solution of an existing or newly formed problem or need is handled. Why this problem or need has arisen and thoughts about the ways to solve it are examined. This process involves revealing the thoughts and experiences of the designer or the design team, and the search for solutions by considering the opinions and evaluations of the user group regarding the solution.

2.1.2 In the analysis stage, if there is another furniture designed for the same problem or need, the deficiencies related to it, the opinions and suggestions of the relevant experts are examined. Researches are made on the selection of the materials to be used, how they will be used, the methods of the construction of the furniture, and the technological developments that can be utilized during construction.

2.1.3 With the identification stage, everything that is examined, determined, and predicted during the preparation and research stages is handled. In the light of these data, technical issues such as the functions for the purpose of the furniture to be designed, the technology to be produced, the materials to be used, and how these materials will be used are enlightened and a final decision is made. In other words, the results of all processes that the furniture will undergo in the process from the emergence of the need to the production are evaluated at this stage.

2.1.4 In the intellectualization- ideate stage, the designer makes different designs using his/her own skills and creativity in the light of all the data collected and decided in the previous stages. All these designs are designed to be made with the material, construction, function, and production method determined in the other stages.

2.1.5 Screening- Selection stage can be defined as choosing the most suitable design according to certain criteria among different designs with the same technical features. If necessary, some changes can be made on the choice made for improvement. Since more than one design is chosen, sometimes a product can be created by combining designs.

2.1.6 With the implementation stage, the design that was mentioned, solved, researched, and decided in the previous stages is put into practice. Design, which is an abstract idea, becomes concrete.

2.1.7 At the end of the design process completed with the last stage, whether the desired result has been achieved regarding the product, the point reached, and the observed effects are evaluated.

2.2. Furniture Design Criteria

On the other hand, there are some criteria that a designer should consider while designing a furniture (Figure 2). The first goal to start off in furniture design is to meet certain physical needs of the designed product. "Every furniture is in a one-to-one relationship with the human body, in forms suitable for use. Therefore, human measurements, body shapes for the purpose of use, psycho-social and socio-cultural structure of the user, as well as aesthetic understanding are variable factors that closely affect furniture design." (Altınok, 1987).

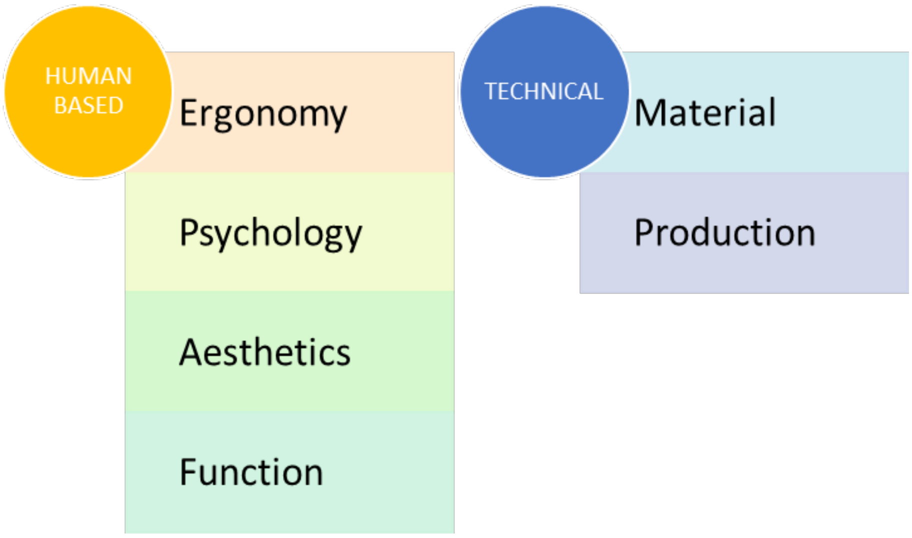

Figure 2: Furniture design criteria (Meru, 1986).

2.2.1 Functionality: In shaping the furniture, for what requirement it was produced, is the first question to be answered. Furniture can be designed in a variety of ways according to the intended use. It is the main requirement and constant function expected of a furniture. Each design should be suitable for what needs to be met and what action is considered as a priority, but it is possible to produce multi-functional furniture by considering its main purpose.

2.2.2 Ergonomics: "Ergonomics is the science of personal work. By researching the characteristics and abilities of the human organism, it provides the necessary conditions for the adaptation of the work to the human and the human to the work. By enabling people to realize their talents and to use them effectively, it prevents people from being worn out due to excessive strain while working and increases work efficiency thanks to this harmony" (Milliyet Economy Encyclopedia, 1994). The necessity to arrange the conditions in the human-vehicle relationship more favorably for the user by handling the problems arousing from people's working and using tools in terms of their features has created ergonomics. The designer must be limited in certain measures while designing the furniture. At this point, human measures come into play. "Anthropometry is defined as the measurements of the human body resulting from the anatomical (skeleton, muscular system) structure within the scope of action science" (İzgi, 1999). A designer should improve the harmony between the furniture he/she designs and the user and analyze it well.

2.2.3 Psychology: A person establishes a connection with his/her environment and the things around him/her through senses. Especially the visual relation is the most prominent among these senses. For this reason, the designer should take these senses into account to ensure that the furniture he/she designs and produces is perceived by its users. "Like every formation, the qualities of being understood through seeing can also be based on certain foundations. In many studies on this subject, the nature and logical qualities of understanding, the types and causes of errors have been examined. Based on these, it is possible to interpret how the furniture fits its functional structure with the emotions it arouses in the user" (Arnheim, 1966). While creating a product, designer must meet the psychological needs of people. Some of these requirements are as follows; **Security requirement:** When buying a piece of furniture, the user must first and foremost feel that the furniture is safe and reliable for him/her. Therefore, although the designer thinks that he/she creates a durable and reliable product, it should be ensured that the furniture evokes the same feeling in user. **Comfort requirement:** Another requirement that the user should feel while buying the product is comfort. The shape, form and material of the furniture should give the user a sense of comfort. **Peace requirement:** The color, texture, form, and material used are related to the peace of the furniture. Sometimes a furniture may not be preferred just because of its color, although all other design factors are considered properly. Colors have a significant impact on human psychology. In some cases, although the color is soothing, the complexity, density and irregularity of the material used can have a negative effect on the person. **Prestige requirement:** This requirement is the desire of the person to want the product he/she bought to be different and to be liked by others. While producing a furniture, designer should pay attention that it is developed and different from previous examples.

2.2.4 Aesthetics: When people buy a product, they want their needs to be met, as well as the product being visually appealing to their taste. In this respect, aesthetic factors directly interact with human psychology.

2.2.5 Material Factor: Material is a criterion that should be considered in detail during and after the design process. The material to be used should be suitable for the physical properties of the furniture designed. The design of the furniture and the material is a process that should be considered simultaneously. Each material has different strength, flexibility, texture, and workmanship. The ability of the furniture, each designed to meet a certain need, to fulfill its function and at the same time to comply with the environment and conditions of use is closely related to the material used.

2.2.6 Production Method: All designers should benefit from all the innovations brought by technology as much as possible. The materials, manpower, energy, etc. used in production are an important part of the production line. Decisions made during the design process are important at this point. Problems that may occur due to design decisions can endanger all these production inputs. For this reason, the designer's appropriate furniture design is important in terms of both consumer satisfaction and the expansion of the manufacturer market.

In order to better understand and interpret integrated design processes, it becomes important to define the environments where the processes take place and the relationship patterns established on different information areas. It is necessary to explain the concepts of 'inter-disciplinary', 'multi-disciplinary', 'trans-disciplinary', and 'cross-disciplinary' at this point, and to analyze the relationships formed within the integrated design processes. It is also gaining importance for understanding and developing the collaborative environments that occur in these processes (Figure 3).

Figure 3: Design for Future requires 'inter-disciplinary', 'multi-disciplinary', 'trans-disciplinary', and 'cross-disciplinary' understandings (Web- 1)

Inter-disciplinary: The term inter-disciplinary is defined as revealing new disciplinary knowledge by combining multiple disciplines. With the use of more than one disciplinary knowledge in inter-disciplinary studies, new emerging disciplines and thus the existence of a disciplinary knowledge in different aspects are mentioned (Klein, 2005). In such work environments, different disciplinary knowledge and methods are integrated into the work environment and a real synthesis approach is used to solve problems or generate new disciplinary knowledge (Stember, 1991).

Multi-disciplinary: The term multi-disciplinary refers to areas where more than one academic discipline or professional knowledge is used. A multi-disciplinary project describes a group from different disciplines with equal rights and a common goal. In this group, partners who have different disciplinary knowledge try to reflect their disciplinary knowledge to the project. It is characteristic of the multi-disciplinary structure that different disciplinary knowledge is integrated into the work in the context of the common goal.

The common goal in multi-disciplinary work environments is divided into certain sub-parts and distribution is made according to the disciplinary knowledge of the participants. It is possible to talk about distributed information and distributed control in such environments. In other words, each participant deals with it by undertaking his/her duty. There is also a decentralized situation here (İpek, 2014).

Trans-disciplinary: Trans-disciplinary working environments can be defined as areas where subjects are studied where disciplines are not sufficient and where holistic research processes are not required. In these working environments, the aim is to go beyond the disciplinary perspectives by combining the intellectual frameworks of different disciplines (İpek, 2014).

Cross-disciplinary: In cross-disciplinary work environments, the process takes place by explaining one disciplinary knowledge from the perspective of another discipline. Although explaining one discipline from the perspective of another discipline is far from holistic approaches, it contains an analogical approach. In such processes, two disciplinary areas are communicating and therefore cross-disciplinary processes have moved away from holistic approaches (İpek, 2014).

3. Changing Design Approaches

One of the main points where the integrated design process differs from the traditional design process is the order in which data information is included in the design process. In the integrated design process, data are collected at the beginning of the process, and are controlled in an integrated way simultaneously throughout the process. In the traditional design process, the data are included in the process when their time comes.

The traditional design approach is a process that is based on linear and causal systems, with each discipline that follows and controls each other in a hierarchical order, separated from each other with clear boundaries, and plays a role in design included in the design process independently of other disciplines and in order (Turan and Bayazıt, 2010) (Figure 4).

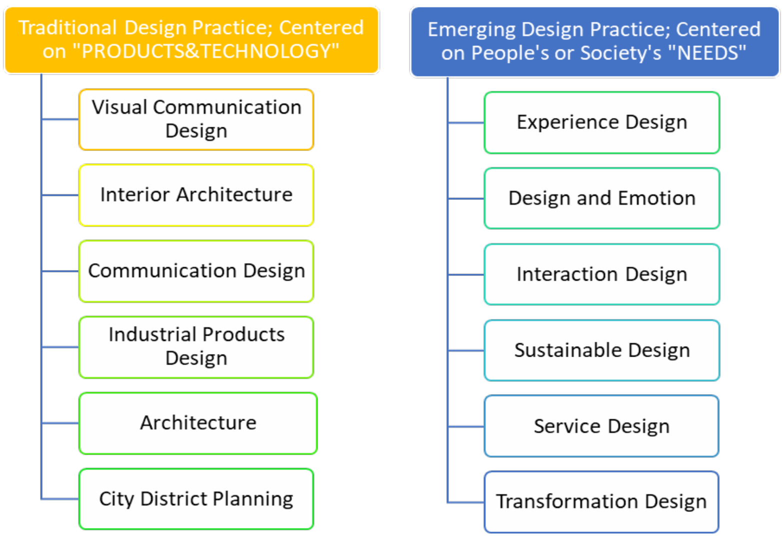

Figure 4: Traditional design versus emerging design practice (Sanders and Stappers, 2008).

A multi-disciplinary approach requires the presence of different types of information adapted to meet common ground for clarifying design decisions. Adapting different types of information from different disciplines to meet a common ground while supporting the decision-making process will prevent project development from being slowed down at the early design stage. At the same time, the multi-disciplinary approach must have the ability to overcome the challenge of transferring and coordinating knowledge across disciplines. The adaptation of 'input information' from different disciplines requires the use of a multi-disciplinary approach that can address the complexity of the process, being multidimensional, and uncertainty. The expected process in this approach is shared decisions, compromises, preference rankings and an open decision-making process as a role for all disciplines. (Fregonara et al., 2016) (Figure 5).

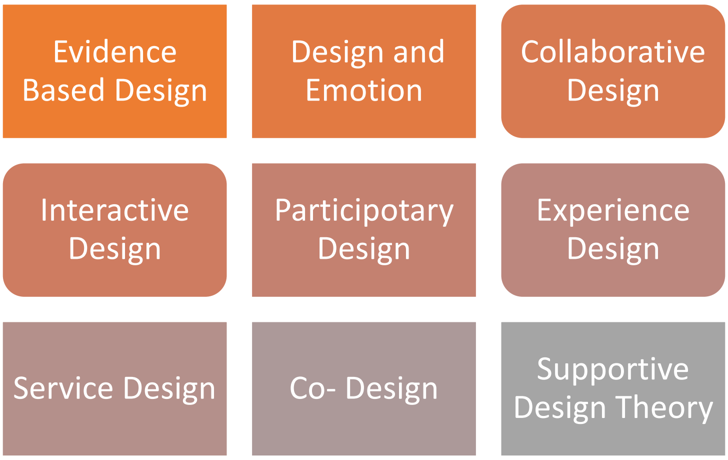

Figure 5: Multi- disciplinary design approach

3.1. Collaborative Design

Collaborative design is often defined as an approach that aims to design with users rather than design for users. Muller (2002) discussed various participatory design methods and practices and expressed a number of benefits as follows; developing mutual learning and understanding, combining and integrating the ideas of different people, improving communication and collaboration between different people and ensuring the creation of new common ideas form the basis of the collaborative design approach (Schuler and Namioka, 1993) (Figure 6).

Figure 6: Collaborative design approach - design with users (Kymalainen, 2013).

It is aimed to involve the target user in the design process and thus increase the success of the service. Collaborative design is the process in which actors from different disciplines share their knowledge about both the design process and the design content. They do that in order to create shared understanding on both aspects, to be able to integrate and explore their knowledge and to achieve the larger common objective: the new product to be designed. Actors share design knowledge through design communication, which means communication about the design content (Chui, 2002; Valkenburg, 2000). From literature on success and failure in product design projects, we can learn that collaboration is an important factor for success (Cooper, 1999; McDonough III, 2000). Effective collaboration also influences the quality of the product designed (Valkenburg, 2000).

3.2. Evidence Based Design

The evidence-based practice, which started with Archie Cochrane's evidence-based research methods in the 1960s, was followed by studies revealing the relationship between staff productivity and hospital organization in the United States and England in the following years (Malone et al., 2007)

In the 1990s, studies on orientation (Carpman and Grant, 1993) were conducted, and in the 2000s (Baird et al., 1996), how the "Post-Use Evaluation" (POE) system can be used to improve the design and building quality was revealed. (Zimring et al., 2008). Today, evidence-based design, which has been prominently highlighted by the American Institute of Architects, is supported by the organization "The Center for Health Design".

With evidence-based design, the understanding of architects' relying and adhering to evidence within their own fields such as engineering science, statics, geometry, physics, and construction law has been replaced by an inter-disciplinary understanding. The usual answers to the complex problems that arise in design and implementation have been replaced by new responses that the designer puts forward with the user (Hamilton and Watkins, 2009) (Figure 7).

Figure 7: Evidence based design approach - designing furniture with users (Web- 2).

In evidence-based design, the collaboration of the designer with the user is seen as the main condition. The important thing here, as perceived by many architects; the user is not considered as a barrier to design decisions and project control, but rather as a key to solving many crucial points.

3.3. Experience Design

In order to define the experience design, the concept of "experience" must first be understood. In terms of furniture design, experience is the mental and cognitive consequences arising from user and product interaction. It is not correct to define interaction as an experience alone. Knowledge gained as a result of interaction, perceptions and emotions formed constitute the whole of the experience (Martin and Guerin, 2006). According to Forlizzi and Ford (2000), the concept of experience expresses the continuous flow in the human mind. People accept experience by talking to themselves or by expressing themselves. The experience in question refers to a situation where the user is constantly and completely experiences it subconsciously.

The effect of furniture design features on the psychological state of the individual has been revealed, and the method of experience design is used according to the type of structure. According to Hamilton, in the simplest terms, experience design is a holistic process that guides design decisions by combining research data and user experiences (Hamilton 2003) (Figure 8).

Figure 8: Experience design approach - focus on furniture design (Web- 3).

Furniture design works as a whole in order to convey the desired perception and message to the user. The prominent approach in furniture designs is on the requirement that the product meet the psychological needs of the users. For this reason, designers need experiential user data. The concept of experience design can be explained using experiential data. The concepts of user, design, interaction, and context are mentioned in experience design (Andarood, 2014). Furniture can be defined as a form of non-verbal communication using materials, colors, textures, and forms.

3.4. Service Design

Service design is a very new field that designs ideas through consumer experiences, using both tangible and intangible environments. This area provides many benefits for the end consumer experience, especially in industries such as retail, banking, transportation, and healthcare. The service design process as an application often results in the design of systems and processes that aim to provide a holistic service to the consumer. Service design is an inter-disciplinary approach that brings together various methods and tools from different disciplines. This inter-disciplinary application combines design, management, and developmental engineering skills. It also improves factors such as ease of use, satisfaction, and efficiency, without ignoring the environment, communication and products used (Stickdorn and Schneider, 2011).

Service design is a method used for both consumers and service providers to improve service quality. It brings together various disciplines such as service design, ethnography, system design, interaction design, product design, industrial design, graphic design, service marketing, innovation management and social psychology (İlisulu, 2015).

Service design refer to the process of planning and organizing people, infrastructure, communication and material components of a service, with the goal of improving the service's quality, the interactions between a provider and its customers, and the customers' experiences (Mager, 2008) (Figure 9).

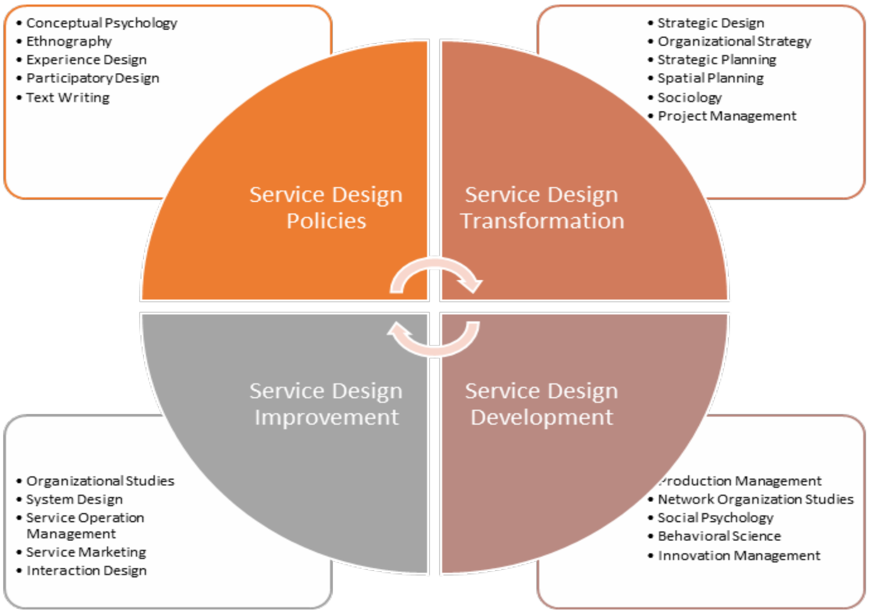

Figure 9: Service design - human oriented aproach (Mager, 2008)

Service design is a completely consumer-oriented design and management of the entire "process" through visualization of elements such as infrastructure, communication, technology and materials, with the aim of maximizing consumer satisfaction, creating awareness by adding value to the brand or service (İlisulu, 2015). It can be said that this discipline constitutes its own principles in its development process as a result of handling service design from all aspects. Although it overlaps with other design areas as a design concept, it shows that the service design methodology is a concept that is open to innovation thanks to its own design criteria. The fact that service design elements are rich and developable supports the inter-disciplinary integrity of this design concept (Moritz, 2005).

3.5. Supportive Design Theory

When Ulrich's supportive design theory is examined, it is seen that the physical environment designed, the furniture and accessories used especially in healthcare spaces have a physical content that reduces the stress caused by being sick, accelerates the healing process and provides psychological support. Humans cannot be considered separate from space throughout life. In this process, it is inevitable for individuals to be affected by the social and physical environment of the space. The reflection of the emerging effects on the life process of people increases the importance of the space perception in users (Ulrich, 1991). Another factor affecting the design of healthcare spaces is the transformations in space/design-patient/healthcare personnel approaches. In healthcare spaces where the concepts of patient-oriented approach, healing environments and therapeutic architecture are at the forefront, the necessity of designing environments that support the users in a psychosocial way emerges. For this purpose, using the space experience data of the users in order to determine the patient/healthcare personnel needs in the most accurate way has become an important requirement in the design processes. Environmental graphic design elements, which are an important part of the physical environment of the hospital space, should be handled with a team of various design groups, considering the user needs and requirements in the light of these data (Ulrich, 2003).

4. Conclusion

"Design" with all its aspects should be handled with a holistic perspective. This fact should be adopted by all design disciplines, not just furniture. In this sense, many design disciplines require simultaneous/joint/integrated work. Well-performed integrated product design processes may result in higher speed to the market, higher quality products that fit the market needs and the possibility of developing products with different functionalities (McDonough III, 1993; Cooper and Kleinschmidt, 1994; Langerak, et al., 2005). This approach is also important for the success of the final product. The margin of error of the product, of which every detail has been studied with relevant disciplines from the very beginning, will be reduced to almost zero. Integrated design understanding focuses on needs, while traditional design adopts an understanding that focuses only on the product itself. Instead of focusing on project typology, Co-Design focuses on design for experience, design for interaction, design for culture, and sustainability (Sanders and Stappers, 2008).

We are in an age where spaces are perceived as real by deceiving the senses. Considering that virtual and mixed spaces, furniture, and equipment will be designed in the future, "collective creativity" will be highly needed. Due to their different disciplines, all actors in the multi-disciplinary design team have a different view of the new product to be developed and they each address their own interests during negotiation (Bucciarelli, 1996). Thus, the product is handled in every aspect and the margin of error is minimized.

The furniture industry transforms and develops with the interaction of all design disciplines. Research areas are expanding, so spaces, accessories and furniture are designed with Holistic/Participatory/Collaborative approaches. However, in order to keep up with changing conditions and to realize the right designs, the fact that the factors affecting the productivity of the furniture sector such as Branding, Standardization, Technology, Capital, Technical Information, Trained Personnel, Design and Designers deficiency should be improved in order to increase efficiency in the furniture sector.

5. Acknowledgments

This study was presented as a paper at the 6th International Furniture Congress.

References

Altınok M. (1987). Industrial Design in Furniture Production. Master Thesis. Ankara: Gazi University, Natural Sciences, Ankara, Turkey.

Andarood H. G. (2014). In the field of interior design, the analysis of visual communication based on graphic design. Master Thesis. Ankara: Hacettepe University, Ankara, Turkey.

Arnheim R. (1966). Dynamics of Shape: Design Quarterly. Berkeley: Uni. California Press.

Asatekin M. (1997). Product-User Relations in Industrial Design. ODTÜ Faculty of Architecture Editorial Board, Ankara.

Baird F., Moore C.J. and Jagodzinski A.P. (2000). An ethnographic study of engineering design teams at Rolls-Royce Aerospace. Design Studies, 21, 333-355.

Bilgin N. (1991). Goods and People, Gündoğan Publications, Ankara.

Bucciarelli L.L. (1996). Designing Engineers. The MIT Press, Cambridge, Massachusetts, London, England.

Burnett B. (2009). Building New Knowledge and the Role of Synthesis in Innovation. International Journal of Innovation Science, 1(1), 13-27.

Carpman J. R. and Grant M. A. (1993). Design That Cares: Planning Health Facilities for Patients and Visitors, American Hospital Publishing, Chicago.

Chiu M.L. (2002). An organizational view of design communication in design collaboration. Design Studies, 23(2), 187-210.

Cooper R.G. and Kleinschmidt E.J. (1994). Determinants of Timeliness in Product Development. Journal of Product Innovation Management, 11, 381- 396.

Cooper R.G. (1999). The invisible Success Factors in Product Innovation. Journal of Product Innovation Management, 16, 115-133.

Forlizzi J. and Ford S. (2000). The Building Blocks of Experience: An Early Framework for Interaction Designers. In Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, 419–423.

Fregonara E., Giordano R., Rolando D. and Tullian J.M. (2016). Integrating Environmental and Economic Sustainability in New Building Construction and Retrofits, Journal of Urban Technology, 23(4), 3-28.

Hamilton D. K. (2003). The four levels of evidence based design practice. Healthcare Design, 3, 18-29.

Hamilton D.K. and Watkins D.H. (2009). Evidence-Based Design for Multiple Building Types, John Wiley, Hoboken, New Jersey.

İlisulu T. İ. (2015). A New Dimension in Design: Service Design. The Turkish Online Journal of Design, Art and Communication, 5(4), 98-111.

İpek Y. (2014). Computational Design Approaches: An Integrated Design Proposal. Master Thesis. İstanbul: İTÜ, Natural Sciences, İstanbul, Turkey.

İzgi U. (1999). Process, Concepts and Relations in Architecture. İstanbul: Building Information Center Publications.

Klein J. T. (2005). Humanities, culture, and interdisciplinary: the changing American academy. Albany, State University of New York Press.
Koberg D. and Bagnall J. (1974). The Universal Traveler. Los Altos.
Kymalainen T. (2013). Dreamnesting – Co-created future vision of an intelligent interior design experience. Futures, 50, 74-85.
Langerak F., Hultink J.J. and Robben H.S.J. (2005). The Impact of Market Orientation, Product Advantage, and Launch Proficiency on New Product Performance and Organizational Performance Journal of Product Innovation Management, 21(2), 79-94
Mager B. (2008). Service Design Definition. (PDF) Service Design Definition | Birgit Mager - Academia.edu Consulted: 17.11.2020.
Malone E., Mann-Dooks J.R. and Strauss J. (2007). Evidence-Based Design: Application in the MHS, http://www.noblis.org/MissionAreas/HI/public/Documents/EBDInMH S.pdf, Consulted: 15.11.2020.
Martin C. S. and Guerin D. A. (2006). The Interior Design Profession's Body of Knowledge, University of Minnesota.
McDonough III, E.F. (1993). Faster New Product Development: Investigating the Effects of Technology and Characteristics of the Project Leader and Team. Journal of Product Innovation Management, 10, 241-250.
Meru H. (1986). İndustrial Design, Ecohachule Für Künstlerische Und İndustrielle Gestaltung İn Linz. Austria.
Moritz S. (2005). Service Design - A Practical Guide to an Evolving Field. 244.
Rylander A. (2009). Design Thinking as Knowledge Work: Epistemological Foundations and Practical Implications. Journal of Design Management, 1-20.
Sanders E. and Stappers P. (2008). Co-creation and the new landscapes of design. CoDesign: International Journal of CoCreation in Design and the Arts, 4(1), 5–18
Schuler D. and Namioka A. (Eds.). (1993). *Participatory design: Principles and practices.* Lawrence Erlbaum Associates, Inc.
Stember M. (1991). Advancing the social sciences through the interdisciplinary enterprise. The Social Science Journal 28(1), 1-14.
Stickdorn M. and Schneider J. (2011). This is Service Design Thinking. Amsterdam: Building Het Sieraad Publishers.
Milliyet Economy Encyclopedia. (1991). İstanbul: Milliyet Publisher.
Turan A.Z. and Bayazıt N. (2010). A holistic model on the first concepts in design. İTÜ Architecture-Planning- Design Journal, 9(1), 3-14.
Ulrich R. S. (1991). Effects of interior design on wellness: Theory and recent scientific research. Journal of Health Care Interior Design, 3(1), 97-109.
Ulrich R. S. (2003). October 10. Creating a healing environment with evidence-based design. Paper presented at the American Institute of Architects, Academy of Architecture for Health Virtual Seminar-Healing Environments, Denver.
Valkenburg R. (2000). The Reflective Practice in product design teams. PhD thesis, Delft University of Technology.
Zimring C.M., Augenbroe G.L., Malone E.B. and Sadler B.L. (2008). Implementing healthcare excellence: the vital role of the CEO in evidence-based design, WHITE PAPER SERIES 3/5, Evidence-Based Design Resources for Healthcare Executives, The Center for Health Design.

Web sites:
Web-1: https://www.wonderlandmagazine.com/2017/11/16/bottletop-hits-regent-street/, consulted 18.11.2020.
Web-2: http://archive.missionbayhospitals.ucsf.edu/our-facilities/cancer-hospital/acute-care-patient-room, consulted 19.11.2020.
Web-3: http://www-murayama.sakura.ne.jp/service/museum/tsukuba_expocenter.html, consulted 19.11.2020.

Wood Industry and Engineering
ISSN: 2687-6043 e-ISSN: 2687-6035
Year: 2020 Paper Type: Review Article
Volume: 02 Number: 02 Received: 03/12/2020
Pages: 91 - 97 Accepted: 09/12/2020
https://dergipark.org.tr/en/pub/wie

EVALUATION OF CARBON FOOTPRINT AND ENVIRONMENTAL IMPACT IN WOOD BASED PRODUCT

Uğur Aras[1,a]
uaras@ktu.edu.tr
(ORC-ID: 0000-0002-1572-0727)

Hülya Kalaycıoğlu[2]
khulya@ktu.edu.tr
(ORC-ID: 0000-0002-1807-4353)

[1] Karadeniz Technical University, Arsin Vocational School, Department of Materials and Materials Processing Technologies, Trabzon, Turkey.
[2] Karadeniz Technical University, Department of Forest Industry Engineering, Karadeniz Technical University, Trabzon, Turkey

Abstract

The climate change is becoming an increasingly important problem for life. It is now recognized that greenhouse gas emissions caused by humans have a negative impact on the environment. The total greenhouse gas emission caused directly and indirectly by an individual and an organization is generally called a carbon footprint. Determining an organization's carbon footprint is an important step in reducing emissions generated during its activities. Wood-based products have many advantages in terms of environmental impact compared to their alternatives. Documentation of these advantages and detection of environmental impacts will contribute significantly to the competitiveness of wood materials in future building materials. Moreover, thanks to the detection and control of the emission outputs from the production of wood-based products, it will be possible to realize a more environmentally friendly production. In this study, the concept of carbon footprint in wood-based products and their effects on the environment will be emphasized.

Keywords: Carbon footprint, wood based products, greenhouse gas emissions, CO_2

1. Introduction

Climate change is defined as changes in the state or variability of climate over a long period. Today, when it comes to global climate change, it is meant the changes caused by human activities in addition to the natural variability of the climate throughout the long geological history of the earth. The heat energy held in the earth and the atmosphere is dissipated in the earth by the circulation of the atmosphere and the ocean and is released back into the atmosphere as long wave ground radiation. Clouds and greenhouse gases cool some of this. Then it is released back from the atmosphere. In this way, the earth's surface and the lower atmosphere are heated. This process, which allows the earth to warm more than expected and regulates the heat balance, is called the natural greenhouse effect. However, human activities based on fossil fuels after the industrial revolution disrupted this balance (Türkeş, 2008, MGM, 2015).

Humanity leaves its mark on the nature with the activities it performs while continuing its life. The most important activity of humanity, which causes the earth to be negatively affected because of its traces in nature, is fossil fuel consumption. While humanity wants to sustain its life on earth, it ignores the fact that it is a part of that environment, just as it never thinks about the natural environment. For this reason, it is destroying the environment and consuming especially non-renewable resources irresponsibly. Fossil fuels are the leading non-renewable resources. Excess consumption of fossil fuels used in obtaining energy causes global warming. Global warming brings along changes and degradation in the climate (Hua et al., 2011; Üreden and Özden, 2018; Muthu, 2014).

[a] *Corresponding Author*

Human consumption activities create permanent effects on nature. Carbon footprint is also a way of expressing these long lasting effects. Carbon footprint; It can be defined as the sum of carbon gas released into the atmosphere in different processes for each product purchased or each activity performed. In other words, it is the amount of greenhouse gas emissions resulting from the activities of the organization or individuals, measured in unit carbon dioxide such as transportation, heating, electricity consumption, etc.

Some greenhouse gases are occur naturally (biological activities, volcanic activities, forest fires, etc.). As a result of human activities (consumption of fossil fuels, agriculture, etc.), their formation rates and concentrations in the atmosphere increase even more. These types of greenhouse gases; water vapor, carbon dioxide, ozone, methane and nitrous oxides (Houghton at al., 2001, Franchetti and Apul, 2012).

The world population increasing uncontrollably and the growing industrialization activities cause an increase for gas released into the world atmosphere. As a result of statistical data and scientific studies, issues of global warming and climate change occupy an important place in the world agenda and studies on this subject are increasing day by day. With the Kyoto Protocol in 1997, it was aimed to reduce carbon dioxide and gases that cause greenhouse effect (Mgbemene at al., 2016). The greenhouse gases that are formed only because of human activities; such as chloro fluoro carbons (CFCs), hydrochloro fluoro carbons (HCFCs), hydro fluoro carbons (HFCs) and sulfur hexafluoride (SF_6) (Gillenwater at al. 2002).

Carbon footprint is divided into two categories as primary and secondary carbon footprint. The primary carbon footprint refers to carbon dioxide emissions resulting from the acquisition of energy used in housing and transportation. The secondary carbon footprint refers to the emissions caused by each element that comes into our lives throughout the life cycle. It is possible to say that the secondary carbon footprint contains the primary carbon footprint. It is ensured that food or products imported from abroad are transported by air, land, sea and rail until they reach the consumer. Considering that the wastes caused by the spoilage or consumption of these products are taken to the storage and disposal areas, the secondary carbon footprint is very important. A person's secondary carbon footprint is known to equal 54% of the total carbon footprint (IPCC, 2014, Argun at al., 2019).

CO_2 emissions reached a record 35.9 GtCO2 in 2014. These high values have forced governments to implement strategies to reduce CO_2 emissions. The European Union has set a long-term goal to reduce greenhouse gas emissions by 80-95 % by 2050 compared to 1990 levels (Debek, 2016). Emissions from fossil fuel and industry (FF&I) are expected to reach 36.81 billion tonnes of CO_2 ($GtCO_2$) in 2019, according to the latest estimates from the Global Carbon Project (GCP). Overall, human-induced CO_2 emissions, including those from the fossil fuel industry, are expected to increase 1.3 % in 2019. This is due to a 0.29 GtCO2 (5 %) increase in land use emissions, including deforestation. This situation represents the fastest increase value in the last five years. Land use represents only about 14 % of total emissions up to 2019, while contributing more than half of the emissions increase in 2019. The historical annual CO_2 emissions for the first six countries and confederations are given in figure 1 (EDGAR, 2019).

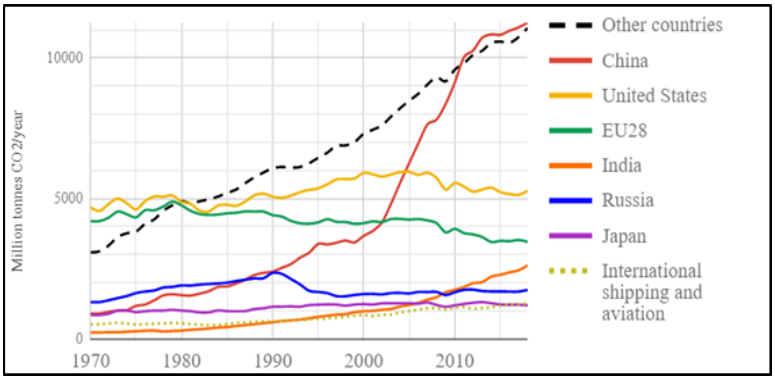

Figure 1: List of countries by carbon dioxide emissions 1970-2018

Due to the increasing emissions of various pollutants, rapidly increasing energy demands and possible global warming, renewable and environmentally friendly building materials are gaining importance. In addition, buildings consume a lot of material and energy during their lifetime and also generate waste. For this reason, the use of bio products (mainly wood) and clean energy as source (such as wind power, solar power) material for construction has become important. Wood and forest-based bio products and their structures in built homes are ideal for storing CO_2 for long periods, decades and even centuries. Also, wood can be reused after its life cycle or eventually used for energy recovery (Kunič, 2007; Košir at al., 2010).

In this study, the effects of wood and wood-based products on carbon dioxide emissions will be examined. In addition, carbon emissions and environmental impacts with equivalent materials used in the building sector will be compared.

In this study, radial stick sawing optimization from logs was aimed. Otherwise quantity and quality (tangential or radial) yield change were evaluated with different sawing pattern.

2. Environmental Effects on Wood Based Products

2.1. CO_2 Emission and Environmental Impacts of Forests

Recently, the role of the forest has been neglected in increasing environmental and health research to counter air pollution and environmental degradation. The conversion of CO_2 in the atmosphere to oxygen through the photosynthesis process helps to reduce the amount of emissions with the planting of new forests (Palmer, 2012). It has been stated that stopping deforestation in the world can reduce 7 billion CO_2 dioxide emissions annually and 42 % of the total emission reduction can be achieved by reforestation of all grazing lands in forest areas. Additionally, forests are carbon sinks, so afforestation and forest restoration (ARR) activities can effectively remove carbon emissions from the atmosphere (Minnemeyer, 2017; Ahmad, 2017).

It has been determined that significant health problems have increased in countries with rapid increase in greenhouse gas emissions (especially CO_2) (Chaabouni, 2016). The impact of air pollution on people also lead to decrease in labor productivity. It has been suggested that health problems can also be minimized if air pollution can be controlled by planting more forests through CO_2 emissions. The CO_2 levels in the atmosphere can be lowered, which can help minimize health problems when afforestation and forest investments are encouraged (Yazdi and Khanalizadeh, 2017).

World forests store enormous amounts of carbon. They only store 283 gigatons (Gt) of carbon in their biomass. In addition, it is estimated that the carbon stored in dried wood, garbage and soil is more than the carbon in the atmosphere (IPCC, 2007). Total annual carbon turnover among global forests ranges from 55 to 85 Gt per year (Zhang, 2009). The amount of atmospheric carbon converted into forest biomass is estimated at 25 to 30 Gt per year (Sabine at al., 2004).

Forests around the world have significant effects on CO_2 levels in the atmosphere. Forest area losses, mostly due to deforestation in tropical regions, cause 0.5 to 2.7 Gt of carbon emissions into the atmosphere each year. The amounts extracted from industrial roundwood are relatively small compared to the amounts of carbon converted into forest biomass annually (Miner, 2009).

Young, vigorous growing trees absorb higher rates of CO_2 than mature trees. Trees grow as defined as the sigmoid curve. While the growth rate is the highest in the early and middle years, it decreases as it matures. This decline ranges from 60 to 150 years old, depending on the species and environmental factors. When a tree is harvested, about half of the carbon remains in the tree. When forest soil degrades during harvest, some carbon is released and carbon releases as the remaining roots, branches and leaves rot. However, once the harvested area is revitalized by planting seedlings, the forest once again begins to absorb and store carbon. Thanks to photosynthesis, trees in the forest hold 0.9 t CO_2 per cubic meter. The total carbon stored in European forests is estimated at to be 9,552 million tons C per year. Managed forests have a higher carbon sequestration effect than forests left in their natural state. Tree planting is the easiest and most effective method to reduce carbon emissions according to these data (SFI, 2003; BSL Council, 2009).

2.2. CO_2 Emissions in Wood Based Products

Forests play an important role in reducing carbon emissions in terms of separating carbon from the atmosphere and storing them in their bodies (Kayo et al., 2015). Harvested forest products have the ability to store carbon emissions in the atmosphere for a certain period. In this way, wood-based materials gain an important environmentally friendly alternative, especially for concrete and steel as building materials, petroleum-derived products and coal fuels. In recent years, the use of wood-based building materials has been encouraged to reduce carbon emissions (Lun et al., 2016). According to "Architecture 2030" established within the scope of combating climate change, buildings are a major problem in terms of carbon emissions. The construction industry consumes almost half of all energy produced in the USA and 75 percent of the electricity produced is used to power buildings. In 2010, the construction industry was responsible for almost half of the USA CO_2 emissions. However, 75% of the buildings are planned to be renewed until 2035 in order to reduce the carbon footprint (Rethink, 2015). On the other hand, some environmental problems caused by harvesting forest resources and carbon emissions may occur due to material consumption. In this respect, studies focus on the environmental impacts of harvested forest products on energy consumption and carbon emissions (Eshun et al., 2010; Wilson, 2010; Heath et al., 2010). Figure 2 shows a carbon cycle of forest products (Rethink, 2005).

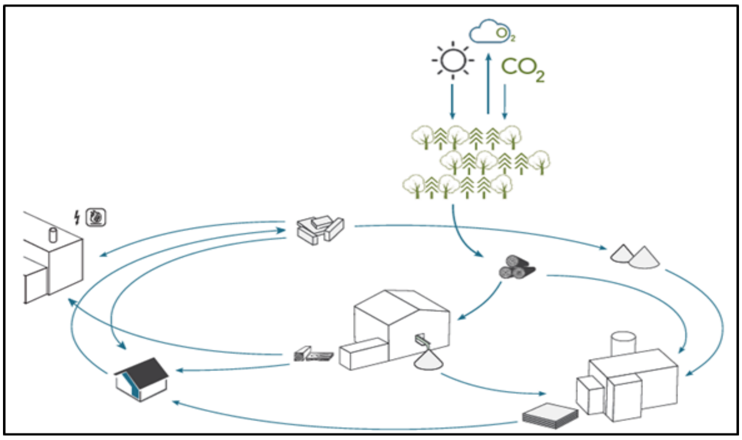

Figure 2: Sustainable forestry carbon cycle

Wood-based products have many features that will give priority to selection when it comes to combating climate change. About 50% of the carbon absorbed by growing trees is stored in products such as timber and furniture. Increased use of wood-based products also causes a decrease in fossil fuel consumption. Wood is a renewable resource produced by natural energy from the sun. Life cycle assessment (LCA) studies show that it requires much less energy to manufacture, transport, build and maintain than materials such as steel and concrete. Wood-based products can be easily applied and reused in buildings and continue to store carbon throughout their lifecycle (BSL Council, 2009).

It is very important to follow the life cycle in the cutting and production of wood-based products. Life cycle assessment determines the environmental impacts of processes, services or products, through production, usage, and disposal. Due to the ever-changing regulations, it has become important to determine in advance, where the material comes from, how it is used or how it is transformed into a product and its environmental impacts (Hauschild, 2018). An example of environmental performance for 1 m^3 of softwood dry timber is given in Table 1 (Puettmann et al., 2013).

Table 1: Environmental performance of 1 m^3 dry softwood lumber

Impact category	**Unit**	**Total**	**Forestry Operations**	**Wood Production**
Global warming potential (GWP)	kg CO2 equiv	92.89	14.52	78.38
Acidification Potential	H+ moles equiv	49.90	11.34	38.56
Eutrophication Potential	kg N equiv	0.0371	0.0120	0.0251
Ozone depletion Potential	kg CFC-11 equiv	0.0000	0.0000	0.0000
Smog Potential	kg O3 equiv	21.66	6.37	15.29
Total Primary Energy Consumption	**Unit**	**Total**	**Forestry Operations**	**Wood Production**
Non-renewable fossil	MJ	1342.09	212.57	1130.54
Non-renewable nuclear	MJ	182.35	2.10	180.25
Renewable (solar, wind, hydroelectric, and geothermal)	MJ	25.31	0.23	25.08
Renewable, biomass	MJ	2586.16	0.00	2586.16
Material resources consumption (Non-fuel resources)	**Unit**	**Total**	**Forestry Operations**	**Wood Production**
Non-renewable materials	kg	0.0853	0.00	0.0853
Renewable materials	kg	403.17	0.00	403.17
Fresh water	L	179.38	0.00	179.38
Waste generated	**Unit**	**Total**	**Forestry Operations**	**Wood Production**
Solid waste	kg	13.22	0.22	13.00

Life cycle information is needed to guide material selection decisions by building designers and earn credit for green certification of buildings under standards such as the Leadership in Energy and Environmental Design (LEED), the National Green Building Standard (NGBS), the International Green Construction Code (IGCC) and Building Standards Code (CalGreen). Wood product manufacturers take care to publish Environmental Product Declarations (EPDs) containing life cycle environmental impact data for their products (Atanda et al., 2019).

The carbon storage effect of wood products plays an important role in reducing greenhouse gases with an estimated European wood product stock of around 60 million tons. Wood products store carbon instead of carbon absorption, as they cannot hold CO_2 in the atmosphere. However, they extend the time that CO_2 held by forests is kept out of the atmosphere. In addition, the recyclability of wood-based products reduces the carbon footprint. According to the latest researches, the usage period of wood-based products varies from 2 months (newspapers) to 75 years (building elements). The longer this period is the more beneficial it is for the environment. The amount of CO_2 stored will increase and energy savings will be achieved with the use of wood-based materials (Beyer at al., 2006).

The cellular structure of wood with many small air pockets increases its thermal efficiency, providing 400 times better thermal insulation than steel and 10 times better than concrete. Steel and concrete structures need more insulation to achieve the same thermal performance as wood materials. In addition, longer-lasting structures are obtained with the use of wood-based materials in buildings. The use of wood as a building material is becoming advantageous because of less energy is required for their changes (Zhen and Zhang, 2018). The possibility of using agricultural wastes and used wood products in reproduction also provides an environmental advantage.

2.3. The Effect of Wood as Building Materials on CO_2 Emission

Energy used in construction, including the manufacture and construction of buildings, is significantly lower for wood-based products and systems than for other building materials (Gustavsson and Sathre, 2011). The wood based composites have a negative effect in terms of CO_2 emission when used in building materials. It seems that wood composites do not emit carbon, but also have carbon storage properties. Figure 3 shows the CO_2 emissions of some wood-based building materials and their comparison with the common construction materials.

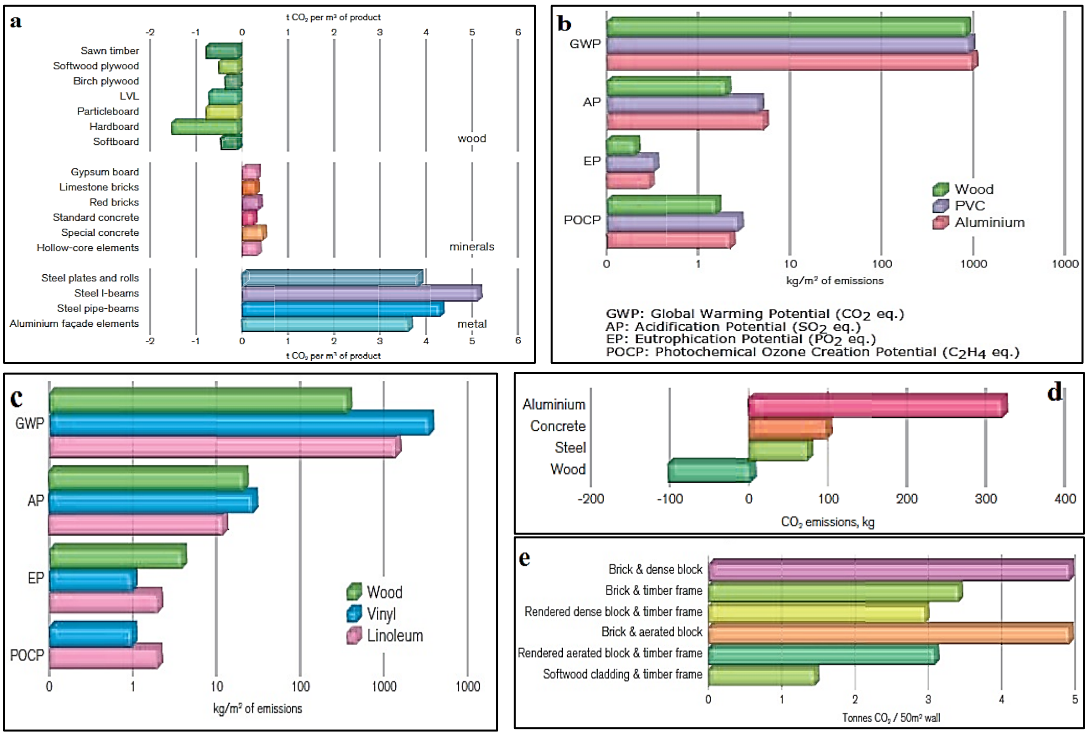

Figure 3: CO_2 emission of building materials (a: building materials, b: window elements, c: flooring materials, d: beams elements, e: wall elements

It is seen in the figures that steel and aluminium materials emit very high CO_2 emissions. When the materials used in window production are examined, it is seen that the use of wood-based materials causes less carbon emission than PVC and aluminium materials. As flooring material, wood-based materials show low polluting effect compared to vinyl and linoleum materials. When using wood as beams material, it realizes very low carbon emission compared to aluminium materials thanks to its carbon storage feature. In addition, when used with other construction materials as wall material, timber reduces CO_2 emission significantly.

3. Conclusion

Trees capture CO_2 in the atmosphere and store it as carbon. Solid wood and wood-based products used in buildings are also a carbon absorber. The use of wood-based products instead of other construction materials will both reduce the use of high CO_2-containing materials and carbon dioxide emissions thanks to their carbon retention feature. The easiest way to reduce carbon emission from materials is to increase the use of wood materials in buildings. The use of wood in buildings is a very economical method of reducing CO_2 emission. In addition, the use of wood in buildings is a very economical method of reducing CO2 emission in terms of cost. The carbon absorbing effect of forests and carbon sink of wood based product make wood a very advantageous material today where the amount of carbon emission is constantly increasing. Especially, LCA of wood-based composites used in buildings will be important in terms of increasing the use of wood materials.

4. Acknowledgments

This study was presented as an oral presentation at the VI. International Furniture Congress, 02-05 November 2020, Trabzon, Turkey.

References

Ahmad O. (2017). How forests help tackle carbon emissions: lessons from India, China and South Korea. https://www.thethirdpole.net/en/2017/11/16/forests-tackle-carbonemissions-india-china-south-korea/, consulted 16 September 2020.

Argun M.E., Ergüç R. and Yunus S. (2019). Carbon Footprint Investigation of Konya/Selçuklu District. Selcuk Univ. J. Eng. Sci. Tech., 7(2), 287-297.

Atanda J.O. and Olukoya O.A. (2019). Green building standards: Opportunities for Nigeria, Journal of Cleaner Production, 227, 366-377.

Beyer G., Defays M., Fischer M., Fletcher J. and Munck E.D. (2006). Tackle climate change: use wood. Wood Fiber Science, 42, 107–124.

Chaabouni S., Zghidi N., and Mbarek M. (2016). On the causal dynamics between CO_2 emissions, health expendituresand economic growth, Sustainable Cities and Society, 22, 184–191.

Council, B.S.L. (2009). Tackle Climate Change-Use Wood. Minneapolis: North American forest products industry by the BC Forestry Climate Change Working Group, Consulted 25 September 2020. https://www.anthonyforest.com/assets/pdf/tackle-climate-change-wood.pdf

Debek R. (2016). Novel catalysts for chemical CO2 utilization, Doctoral dissertation, AGH University of Science and Technology, Kraków 2016.

EDGAR (2019) Fossil CO_2 and GHG emissions of all world countries, 2019 report, Emissions database for global atmospheric research, European Union, https://edgar.jrc.ec.europa.eu/booklet2019/Fossil_CO2andGHG_emissions_of_all_world_countries_booklet_2019report.pdf, consulted 10 October 2020

Eshun J.F., Potting J. and Leemans R. (2010). Inventory analysis of the timber industry in Ghana. The International Journal of Life Cycle Assessment, 15, 715–725.

Franchetti M.J. and Apul D. (2012). Carbon footprint analysis: concepts, methods, implementation, and case studies. CRC Press, United States.

GCP (2019). Global Carbon Budget 2019, https://essd.copernicus.org/articles/11/1783/2019/ Consulted 10 November 2020.

Gillenwater M., Van Pelt M.M. and Peterson K. (2002). Greenhouse gases and global warming potential values, exerpt from the inventory of us greenhouse emission sand sinks: 1990-2000, pages:, US Environmental Protection Agency, 4-9.

Gustavsson L. and Sathre R. (2011). Energy and CO_2 analysis of wood substitution in construction, Climatic Change, 105(1-2), 129-153.

Hauschild M. Z. (2018). Introduction to LCA methodology. In life cycle assessment, Springer, Germany.

Heath L.S., Meltby V., Miner R., Skog K.E., Smith J.E., Unwin J. and Upton B. (2010). Greenhouse gas and carbon profile of the US forest products industry value chain. Environmental science and technology, 44(10), 3999-4005.

Hua G., Chenga T.C.E. and Wang S. (2011). Managing carbon footprints in inventory management. International Journal of Production Economics, 132(2), 178-185.

IPCC (2007) Forestry, in climate change 2007: mitigation, contribution of working group iii to the fourth assessment report of the intergovernmental panel on climate change, Cambridge University Press, Cambridge.

IPCC (2014) Contribution of working group III to the fifth assessment report of the intergovernmental panel on climate change, Cambridge University Press, Cambridge.

Kayo C., Noda R., Sasaki T. and Takaoku S. (2015). Carbon balance in the life cycle of wood: targeting a timber check dam, Journal of Wood Science, 2015, 61, 70–80.

Košir M., Krainer A., Dovjak M., Perdan R. and Kristl Ž. (2010). Alternative to the conventional heating and cooling systems in public buildings, Journal of Mechanical Engineering, 56(9), 575–583.

Kunič R. (2007). Planning an assessment of the impact of accelerated ageing of bituminous sheets on constructional complexes, doctoral dissertation, University of Ljubljana, Faculty of Civil and Geodetic Engineering, Ljubljana.

Lun F., Liu, M., Zhang, D., Li, W. and Liu, J. (2016). Life cycle analysis of carbon flow and carbon footprint of harvested wood products of larix principis-rupprechtii in China, Sustainability, 8(3), 247.

Mgbemene C.A., Nnaji C.C. and Nwozor C. (2016). Industrialization and its backlash: focus on climate change and its consequences, Journal of Environmental Science and Technology, 9(4), 301-316.

MGM (2015). Turkey projections of climate and climate change, with new scenarios, Head of research department climatology branch directorate, https://mgm.gov.tr/FILES/iklim/iklim-degisikligi-projeksiyon2015.pdf, consulted 10 November 2020.

Miner R. (2010). Impact of the global forest industry on atmospheric greenhouse gases (No. 159), Food and Agriculture Organization of the United Nations (FAO).

Minnemeyer S., Harris N. and Payne O. (2017). Conserving forests could cut carbon emissions as much as getting rid of every car on earth, consulted 7 November 2020,
http://www.wri.org/blog/2017/11/conserving-forests-could-cut-carbon-emissions-much-getting ridevery-car-earth, consulted 27 October 2020.

Muthu S.S. (2014). Assessment of Carbon Footprint in Different Industrial Sectors (Vol. 2). Springer Science and Business, Germany.

Palmer D. (2012). To what extent could planting trees help solve climate change, https://www.theguardian.com/environment/2012/nov/29/planting-trees-climate-change, consulted 8 June 2018.

Puettmann M., Oneil E. and Bergman R. (2013). Cradle to gate life cycle assessment of softwood lumber production from the Northeast-North Central. Consortium for Research on Renewable Industrial Materials. University of Washington. Seattle, WA. 1-33.

Rethink W. (2015). Evaluating the Carbon Footprint of Wood Buildings, Reducing greenhouse gases with high-performance structures, https://www.awc.org/pdf/education/gb/ReThinkMag-GB500A-EvaluatingCarbonFootprint-1810.pdf , consulted 20 November 2020.

Sabine C.L., Heimann M., Artaxo P., Bakker D.C.E., Chen C.T.A., Field C.B., Gruber N., Le Quéré C., Prinn R., Richey J.E., Lankao P.R., Sathaye J.A. and Valentini R. (2004). Current status and past trends of the carbon cycle. In C.B. Field & M.R. Raupach, The global carbon cycle: integrating humans, climate, and the natural world, Island Press, United States.

SFI (2003). Forests and Climate Swedish Forest Industries Federation (Skogsindustrierna), https://www.forestindustries.se, consulted 27 October 2020.

Türkeş M. (2008). What is Climate Change? Basic Definition, Causes, Observed and Predicted Results of Climate Change. Climate Change and Environment, 1(1), 26-37.

Üreden A. and Özden S. (2018). How to Calculate Institutional Carbon Footprint: A Theoretical Study. Anatolian Journal of Forest Research, 4(2), 10-20.

Wilson J.B. (2010). Life-cycle inventory of medium density fiberboard in terms of resources, emissions, energy and carbon, Wood and Fiber Science, 42, 107-124.

Yazdi S.K. and Khanalizadeh B. (2017). Air pollution, economic growth and health care expenditure, Economic Research-Ekonomska Istraživanja, 30(1),1181–1190.

Zhang Y.M. (2009). Global pattern of NPP to GPP ratio derived from MODIS data: effects of ecysystem type, geographical location and climate, Global Ecology Biogeography, 18, 280–290.

Zhen M. and Zhang B. (2018). Energy performance of a light wood-timber structured house in the severely cold region of China, Sustainability, 10(5), 1501.

INDUSTRY
WOOD
ENGINEERING