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Evaluation of computer aided design (CAD) systems and their usage efficiency in Türkiye furniture industry

Türkiye mobilya endüstrisinde bilgisayar destekli tasarım (CAD) sistemleri ve kullanım etkinliğine ilişkin bir değerlendirme

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Abstract

Computer-aided design (CAD), briefly refers to the utilization of computers to ensure quality and efficiency in design. CAD systems developed in the 1960s in the United States and their consequent application in all developed countries was discussed, focusing on making these systems more effective in the industry and evaluating their implementation conditions in the Turkish furniture sector. Accordingly, the objective of this current research is to summarize the effectiveness of CAD systems in the 2000s while evaluating current applications and their future impacts. In the 2000s, CAD systems required significant labor, hardware, and software support. In the current globalized world, CAD systems have become even more user-friendly with the support of artificial intelligence (AI), alongside more effective applications. The research employed face-to-face survey methods, focusing on large-scale furniture enterprises in the Marmara region. The results were evaluated using SPSS software and reliability tests. In the 2000s, approximately 25% of Turkish furniture enterprises expected CAD systems to shorten the design process, improve product quality, and enhance demand and order fulfilment times. Evaluations of today's enterprises indicate that these expectations remain. Many furniture enterprises in Türkiye utilize integrated software with CAD systems in handling orders. Approximately 46% of Turkish furniture enterprises report efficient use of these programs, while the remaining 54% cite a lack of trained personnel as the reason for inefficient use. CAD applications have contributed to the development of Turkish furniture enterprises. With CAD applications, the order process has decreased by 57 %, and production has increased by 34%. This research aims to provide insights into the current state and future potential of CAD systems in the sector by examining the developments and transformations over the past two decades.

Özet

Bilgisayar destekli tasarım (CAD), yalın bir tanımlamayla, tasarımda kalite ve verimliliği sağlamak için bilgisayarların kullanılması anlamına gelir. Önceleri, 1960'lı yıllarda, Amerika Birleşik Devletleri'nde geliştirilen ve günümüzde tüm gelişmiş ülkelerde uygulanmaya başlayan CAD sistemlerinin endüstride daha etkin hale getirilmesi ve Türk mobilya sektöründeki uygulama koşullarının değerlendirilmesi ele alınmıştır. Bu araştırmanın amacı; mevcut uygulamaları ve bunların gelecekteki etkilerini değerlendirirken öncelikle 2000'li yıllardaki CAD sistemlerinin etkinliğini özetlemektir. Yani 2000'li yıllarda CAD sistemleri ciddi düzeyde iş gücü, donanım ve yazılım desteğine ihtiyaç duyuyordu. Günümüzde CAD sistemleri, daha etkili uygulamaların yanı sıra, yapay zekâ desteğiyle daha da kullanıcı dostu hale geliyor. Araştırmada yüz yüze anket yöntemi kullanılmıştır. Araştırma kapsamı Marmara bölgesindeki büyük ölçekli mobilya işletmeleriyle sınırlandırılmıştır. Sonuçlar SPSS ortamında değerlendirilmiş ve güvenilirlik testlerinden geçirilmiştir. Daha önceden 2000'li yıllarda Türkiye mobilya işletmelerinin ortalama %25'i CAD sistemlerinin tasarım sürecini kısaltmasını, ürün kalitesinin artmasını, talep ve sipariş süresini iyileştirmesini beklemekteydi. Bugünkü firmalarla yapılan değerlendirmeler bu beklentilerin korunduğu şeklindedir. Türkiye'deki birçok mobilya firması siparişin şekillenmesinde CAD sistemleri ile entegre yazılımları kullanmaktadır. Türkiye'deki mobilya firmalarının ortalama %46'sı bu programları verimli kullandığını belirtmektedir. Kalan %54'ü ise verimsiz kullanım sebebini eğitimli personel yetersizliği olarak belirtmektedir. Türkiye mobilya işletmelerinin gelişimine CAD uygulamalarının katkı sağladığı görülmektedir. CAD uygulamalarıyla sipariş süreci %57 azalmış, üretimde %34 artış sağlanmıştır. Bu araştırma, son yirmi yılda yaşanan gelişmeler ve dönüşümleri de gözlemleyerek sektördeki CAD sistemlerinin mevcut durumu ve gelecekteki potansiyeli hakkında değerlendirmeyi hedeflemiştir.

INTRODUCTION

The utilization of Computer-Aided Design (CAD) and its integration with Computer-Aided Manufacturing (CAM) systems has been a focal point of several studies, highlighting the significance and advantages of these technologies in various industries. For instance, Ssemakula (1986) stressed the need for the integration of CAD and CAM systems and elaborated on the role and functions of process planning in these stages. Erecek (1993) outlined the uses of CAD/CAM systems as well as the advantages that come with the use of the systems; identified the means of choosing the right programs to use and introduced a number of software packages.

Kazan (1993) provided a brief on the definitions of CAD and CAM and utilized a practical example to explain these concepts whereas Koç (1993) looked at the case of the implementation of CAD/CAM systems in Türkiye's forest products industry. His study involved a sample base of the Turkish furniture industries, thus using companies as case studies. Koç's (1993) research results showed that these enterprises should implement CAD/CAM systems with equal consideration of the costs. In the same vein, Unver (1994) proposed a new method in the optimization of part programs in turning operations with the use of CAD/CAM program written in Pascal for optimization and simulation. Wiebe and Summey (1995) reviewed the current status of CAD/CAM implementation in the furniture industry, with the focus on the analysis of surveys, factory visits, and system assessment. Arslan (1996) concentrated on the NC (Numerically Controlled) machines with CAD and stressed the importance of CNC machinery in production. Bilgin (1996) demonstrated the advantages of employing AUTOLISP in CAD and called for the need to acquire sufficient knowledge when using this tool with a focus on parametric gearbox design. Sensoy (1996) defined CAD/CAM systems and their uses in CNC turning centers and identified the economic factors and the importance of the self-sufficiency in manufacturing these systems. Wiebe et al. (1997) investigated the organizational evaluation of CAD integration and product data management tools and changes in the furniture industry.

Furthermore, Kertlioğlu (1998) proposed a programming technique based on easy manufacturing principles and data, supporting the design for manufacturing concept. Uzunalan (1998) outlined the advantages of CAD and CAM systems and concluded with industrial application of the discussed systems. Yakın (1998) discussed CAD/CAM systems and the concept of CIM and the steps and activities that the machinery industry needs to undertake for a seamless integration. Wiebe et al. (1998) extended the study on the transition of 2D to 3D CAD and information management systems in the furniture industry by evaluating the readiness of enterprises for these changes and analyzing the trends. In his study on total design which includes market research, product features, conceptual design, and manufacturing, Sevinç (1999) provided guidelines for product development success. Lastly, Celikliay (2000) conducted a study on the decision making for CAD/CAM systems in a company that supplies the automotive industry. An evaluation team consisting of department heads and users was created, and the results were analyzed using the Analytical Hierarchy Process.

CAD and CAM systems have revolutionized the manufacturing sector in the current world and have enhanced accuracy, productivity, and interconnection. CAD systems allow designers to design, edit and fine-tune their designs by using computer programs and come up with high accuracy 2D and 3D drawings. The CAD technology emerged in the 1960s and has evolved over the years from simple vector graphics to complex 3D modeling with features such as solid modeling, parametric design, and simulation (Zeid 1991). Transition from 2D to 3D CAD has been crucial in improving the design methods and increasing the accuracy of designs since they can be easily created in detail as mentioned by Farin et al. (2002). These developments have made CAD an essential tool in different sectors such as automotive, aerospace, and construction, thus playing a vital role in the product development process.

The advancement in CAD systems has been informed by the need to enhance the design effectiveness and productivity. The first CAD systems were simple and only allowed for the creation of basic shapes and drawings, while today's systems offer surface modeling tools, finite element analysis, and automated design checking (Singh, 1996). These tools have helped the designers in coming up with new design solutions, simulate design prototypes and enhance the performance of the final product before actual prototyping. This move has minimised development costs and time to market as pointed out by Groover (2015). Also, the combination of CAD with other business systems, including Product Lifecycle Management (PLM), has improved the sharing and control of information throughout the product development life cycle (Kalpakjian et al. 2013).

CAM systems, on the other hand, act as an interface between design and manufacturing by translating CAD models into detailed machine control instructions. The development of CAM technology started in the late 1970s and early 1980s due to the need for automation and increased accuracy in manufacturing (Groover 2015). CAM systems provide toolpath generation, machine setup, and process planning to increase manufacturing productivity and minimize errors that could be made by a human operator. The incorporation of CAM with CNC (Computer Numerical Control) machines has been a breakthrough that enables the mass production of intricate shapes with high accuracy and consistency (Kalpakjian et al. 2013). The developments in CAM software and its increased simulation and optimization capacities have also enhanced the manufacturing processes.

The synergistic relationship between CAD and CAM systems exemplifies the convergence of design and manufacturing, promoting innovation and efficiency in industrial applications. The adoption of CAD/CAM systems has also led to the development of new manufacturing techniques, such as additive manufacturing (3D printing), which relies heavily on CAD data for the creation of complex parts (Gibson et al. 2015). Moreover, the implementation of CAD/CAM systems has significant implications for workforce skills and training. As noted by Hassan et al. (2023), the shift towards digital manufacturing requires a workforce that is proficient in using these advanced tools, necessitating continuous education and training programs. The ability to leverage CAD/CAM technologies effectively is critical for maintaining competitiveness in the global market.

In conclusion, the integration of CAD and CAM systems has revolutionized the manufacturing industry by enhancing design precision, reducing production costs, and improving overall efficiency. The evolution of these technologies from basic drafting tools to sophisticated design and manufacturing systems underscores their importance in modern industrial applications. The continuous advancements in CAD/CAM software and hardware will likely drive further innovations in manufacturing processes, solidifying their role as essential tools in the industry.

Ashraf (2023) discusses the integration of digital design techniques, specifically generative design and parametric modelling, into traditional furniture design processes. It highlights the impact of Industry 4.0 on the furniture manufacturing industry, emphasizing the shift from manual to digital methods. According to Ashraf (2023), generative design, facilitated by tools like Rhino and Grasshopper, allows designers to create complex and customizable furniture designs more efficiently. This approach enhances accuracy, speed, and flexibility, enabling the production of multiple design iterations and ready-to-manufacture products. The study compares traditional and digital design methodologies, underscoring the advantages of digital tools in terms of creativity, processing time, and mass customization. The research also focuses on the practical application of these digital tools within the Pakistani furniture industry, aiming to bridge the gap between user demands and manufacturing capabilities. By adopting advanced digital methodologies, the furniture industry can achieve significant improvements in design innovation and production efficiency, ultimately leading to better quality products and enhanced designer capabilities (Ashraf 2023).

Ikubanni et al. (2022) explore the profound influence of CAD/CAM technologies across various industries, including architecture, manufacturing, medicine, aerospace, and education. The integration of CAD/CAM has revolutionized design and manufacturing processes, enhancing efficiency, accuracy, and creativity. In architecture, CAD software has transformed the drafting of building designs, enabling more sophisticated and creative outputs (Ikubanni et al. 2022). In manufacturing, CAD/CAM systems have significantly reduced production times and improved product quality by facilitating the creation of numerical control programs and automation strategies, such as robotic automation and additive manufacturing (3D printing) (Ikubanni et al. 2022). The use of CAD/CAM in the automobile industry has improved design accuracy, safety features, and production speed The paper also highlights the role of CAD/CAM in medicine, particularly in the fabrication of dental prostheses and complete dentures, which have seen improvements in predictability and accuracy). The future trends in CAD/CAM include advancements in 3D bioprinting for tissue engineering, integration with virtual reality for enhanced visualization, and the use of artificial intelligence to automate design tasks. Despite the limitations such as high costs and the potential for unemployment among unskilled workers, CAD/CAM technologies promise a significant positive impact on various sectors, making them integral to modern production and design processes (Ikubanni et al. 2022).

Rafsanjani and Nabizadeh (2023) discuss the application and potential benefits of human-centred AI in the AEC industry. According to Rafsanjani and Nabizadeh (2023), traditional AI applications in AEC often focus on automation and optimization without adequately integrating human input, leading to inefficiencies and underutilized human expertise. The authors argue for a shift towards human-centred AI, which incorporates natural language processing (NLP) and machine reading comprehension (MRC) to better understand and utilize human preferences, behaviours, and expertise. Human-centred AI can enhance various aspects of the AEC industry, including architectural design, engineering analysis, and construction management. In architecture, AI can assist in generating design options, optimizing spatial layouts, and ensuring compliance with building codes. For engineering, AI facilitates complex structural analyses, geotechnical assessments, and predictive maintenance. In construction, AI improves project planning, risk management, quality control, and safety through real-time data analysis and automation. The challenges of implementing human-centred AI in AEC include the need for extensive training to handle diverse human inputs, ensure data security, and develop adaptable and user-friendly interfaces. Despite these challenges, according to the authors, the integration of human-centred AI promises to enhance productivity, safety, and overall project outcomes by leveraging human expertise and improving decision-making processes (Rafsanjani and Nabizadeh 2023).

In the same vein, Rame et al. (2023) provide a comprehensive review of various digital technologies and innovations adopted in the furniture industry to enhance efficiency, sustainability, and competitiveness. The study highlights the potential of automation, robotics, augmented reality, and the IoT in improving production processes, reducing waste, and boosting profitability. These technologies enable furniture manufacturers to achieve higher precision and efficiency, facilitating mass customization and innovative design solutions (Rame et al. 2023). The authors emphasize the importance of adopting sustainable practices, such as green supply chain management and life cycle assessment, to address environmental concerns and promote social responsibility. They argue for a comprehensive digital transformation strategy that includes embracing new technologies, developing innovative business models, and upholding ethical standards (Rame et al. 2023). The paper also discusses the challenges associated with digital transformation, such as high implementation costs, resistance to change, and the need for skilled labor. Case studies of companies like Integral Surface Design (ISD) and IKEA demonstrate the economic benefits and competitive advantages of integrating digital technologies in production and customer engagement (Rame et al. 2023).

Zahra (2023) investigates how AI technologies, particularly generative design and machine learning, are revolutionizing the furniture design process. AI enables the exploration of numerous design alternatives, significantly enhancing creativity and efficiency in design. The study presents two models: one differentiating between human-led and AI-driven design processes, and the other highlighting the role of designers within AI systems. A SWOT analysis conducted in the paper reveals that 89.4% of furniture designers believe AI excels in generating initial design ideas, while 87.2% agree that AI needs human collaboration to be effective. Additionally, 72.3% view AI as a professional tool that enhances interactive and virtual design (Zahra 2023). However, designers express concerns about the loss of identity and creativity due to the standardized use of AI techniques. The research underscores the need for designers to acquire new skills to collaborate effectively with AI technologies. Despite its limitations, AI offers significant opportunities for innovation, efficiency, and sustainability in furniture design. The study concludes that integrating AI can transform the design process, but human expertise remains crucial for optimal outcomes (Zahra 2023).

Long et al. (2020) explore the implementation of an AI management system in the Chinese furniture manufacturing industry. This system aims to address prevalent issues such as low production efficiency, poor accuracy, and lack of innovation.

The AI management system integrates a data management system and an expert system. The data management system processes and analyzes big data to generate actionable insights for management, while the expert system utilizes artificial neural networks to simulate human learning and decision-making processes. This combination allows for real-time monitoring, control, and optimization of manufacturing processes, significantly enhancing efficiency and product quality (Long et al. 2020). The paper details the AI system's structure, which includes modules for big data processing, decision-making, knowledge generation, and management application innovation. These modules work together to improve data collection, transmission, storage, and processing, leading to better customer

experiences and higher management efficiency. Furthermore, the AI system facilitates scientific space management within plants, optimizing space utilization and improving work efficiency (Long et al. 2020). The study concludes that, despite the initial investment required for establishing such a system, the benefits in terms of improved production efficiency and product quality make it a worthwhile investment for furniture enterprises. The implementation of AI technology is seen as a crucial step towards the intelligent transformation of the furniture industry (Long et al. 2020).

Armağan (2019) examines the impact of AI and generative design on the furniture design process, focusing on Design and R&D Centers in the furniture industry. The study reveals that AI and generative design tools significantly enhance efficiency, creativity, and innovation in furniture design by enabling designers to explore numerous design alternatives rapidly and accurately. Armağan's (2019) research involves interviews with officials from various Design and R&D Centers, highlighting both the advantages and disadvantages of AI-supported design tools. The findings suggest that while AI can streamline the design process and foster innovation, there are concerns about the potential loss of human creativity and the over-reliance on standardized AI techniques. The study underscores the necessity for designers to adapt and acquire new skills to effectively collaborate with AI technologies Overall, the thesis concludes that AI has the potential to revolutionize the furniture design industry, improving productivity and design quality. However, it also emphasizes the importance of maintaining human input and creativity to achieve the best outcomes in design processes (Armağan 2019).

Aboushall and Jalagat (2024) explores the integration of AI in the furniture design process, highlighting significant advancements from intelligent furniture to AI furniture. The study discusses how machine learning techniques, such as expert systems, case-based reasoning, neural networks, formal grammar, and genetic algorithms, enhance the design process by automating and optimizing various stages. AI technologies enable designers to generate innovative designs, improve product quality, and increase production efficiency by simulating human decision-making and creativity. The research emphasizes the transition from intelligent furniture, which uses embedded systems and sensors, to AI furniture that leverages advanced algorithms to predict consumer preferences and create customized products at scale. AI tools like MidJourney AI and platforms like RoomsGPT facilitate creative invocations, rapid design iterations, and diverse design variations, making the design process more efficient and effective (Aboushall and Jalagat 2024). The study concludes that AI's integration into furniture design significantly benefits designers, industry executives, and stakeholders by enhancing creativity, speed, and personalization while addressing challenges such as high costs and technical complexities. The findings underscore the importance of AI in transforming the furniture industry and its potential to revolutionize design processes (Aboushall and Jalaga 2024).

MATERIAL AND METHOD

Material

Türkiye Furniture Industry

In Türkiye, the furniture industry's growth started in the 19th century at the same time as the forest products industry was being invested in, which mainly consisted of small-scale, traditional workshops. Since 1975, although the industry has experienced several significant changes, such as the introduction of NC machines and later CNC machines, it has long been dominated by small-scale enterprises utilizing traditional methods. Even though there have been many major changes in the industry since 1975 such as the introduction of NC and CNC machines, the industry is still dominated by small-scale enterprises that use traditional methods. Approximately 99.4% of furniture enterprises have 1-9 workers, and this shows that small-scale operations are not institutionalized.

Despite experiencing management challenges like financial barriers and a lack of advanced technology applications in the 2000s, the Turkish furniture sector grew dynamically. Twenty years ago, despite a significant increase in commercial volume, the sector's market remained around USD 256 million (Erdinler 2005). However, the Turkish furniture sector has swiftly implemented advanced technology applications in the last two decades, illustrating best practices in design, quality, certification, and global market orientation. At the same time, the industry continues to struggle with issues like heterogeneous appearance, economies of scale, location, and operational conditions.

Currently, the global furniture trade continues to increase rapidly. In FY2022, the world furniture export volume reached USD 317.2 billion. The top five countries leading in furniture exports are respectively China (41%), Vietnam (16%), Germany (6%), Italy (5%), and Mexico (4%). Türkiye ranks 11th with USD 5.7 billion (1.8%). World furniture imports in FY2022 totaled USD 293.2 billion. The top five importing countries are the USA (30%), Germany (8%), the UK (5%), France (5%), and Canada (4%). Türkiye is ranked 45th with USD 932.5 million. Furniture industry in Türkiye, despite the epidemic, furniture exports increased by 12% compared to the previous year (Yigit and Koc 2021). These figures show that the Turkish furniture sector is starting to secure a remarkable position in the global market.

Furthermore, it must be underlined that the furniture sector holds an important place in the Turkish manufacturing industry. According to the TOBB database, there are 5.281 registered furniture enterprises in Türkiye employing 170.901 workers. The furniture industry accounts for 5.4% of the total number of firms and 4.3% of the total number of employees in the overall manufacturing industry. With an average of 32 employees per firm, the furniture sector has scaled up from small to medium-sized enterprises compared to previous years (Koç 2023)

Industrial Application Example: Company X1 General Information

The company was established in 1959. The company's facility consists of 13.800 square meters of covered space and 41.000 square meters of open area. The workforce is composed of 68 employees with 10 in management, 55 in production, and 3 in maintenance. Design activities are managed by the administration team.

The production, PPC, procurement, maintenance, and R&D departments are under the authority of the factory manager. The quality control department is under the quality assurance manager, whereas accounting, human resources, and finance are under the financial affairs manager.

The company manufactures furniture in the form of panels such as seating groups, bedroom sets, dining rooms, youth rooms, office furniture, tables (TV, computer, multipurpose), shoe cabinets, desks, wardrobes, bookshelves, and coat stand. Mass production is based on the use of the same inputs and production tools which are arranged according to the streamlined workflow so that many units of the same product can be produced at the same time. This system is a kind of high-demand system that requires the owner to make a significant investment in specialized and expensive machinery and equipment, as any drop in demand can cause a lot of costs due to the lack of production flexibility. This technique is applicable to the production of complicated products that require advanced technology and is characterized by the uninterrupted flow of the product and the facilities that are designed around the products being made. A custom production is a production that caters to specific orders in small quantities but with a high product variety and versatile machinery that is capable of multiple operations. This adaptability implies that the workers need to be well-trained to use different machines. Although at first, the company used the mass production system, it then changed to the made-to-order model because of financial and organizational problems.

Industrial Application Example: Company X2 General Information

Company X2 started its production as a limited liability company in Bayrampasa in 1980. The company moved to its production facility in Catalca in 2004, which has 6,000 m² of indoor and 14.000 m² of outdoor space. The company employs an average of 60 people. Operating with a production system based on orders, the company manufactures TV stands and sewing machine stands for large suppliers. Designs are made according to the TV cases sent by these companies, or designs developed directly in the R&D department of the TV manufacturing company are produced. Due to the production structure of the company, the design of the stands is done first, and after a preliminary evaluation, the designed model is produced on CNC machines.

Method

To find out the overall situation of CAD system usage in Türkiye's Forest Products Industry, a data collection form was designed. This form was only for the large-scale furniture enterprises (LSEs) in the Marmara Region. The inclusion criteria for the study were based on the number of employees, following the definitions by the State Institute of Statistics (SIS): small-scaled enterprises (1-9 employees), mid-scaled enterprises (10-24 employees), and large-scaled enterprises (25 or more employees). The scope of the application is limited to large-scale furniture enterprises in the Marmara Region. The selection of enterprises is based on the number of employees, in

accordance with the definitions of the State Institute of Statistics (DIE). This classification defines small enterprises as those with 1-9 employees, medium-sized enterprises as those with 10-24 employees, and large enterprises as those with 25 or more employees.

The data collection form was made in such a way that it could record the full information of all LSEs in the Marmara Region without sampling or targeting. The materials such as research results, professional organization records, trade fair booklets, catalogs, and internet data were reviewed to find out the 98 LSEs in the region. The form, which was made of 26 questions, was methodically arranged and mainly conducted through face-to-face interviews with the production engineers, design unit staff, or company owners.

From the 98 enterprises that were targeted, 70 were interviewed on-site, and 63 of them gave complete responses. As a result, the response rate to the survey was 64%.

The overall results obtained from the two selected sample firms were evaluated through on-site observation and analysis on a firm-by-firm basis.

The data collection form consists of 26 questions divided into five main sections:

- Introduction and structural characteristics of the enterprises
- Questions about design activities within the enterprises
- Questions about the features and usage of the CAD system employed
- Questions about the contributions of the CAD program to the enterprises
- General opinions about CAD systems

The first part with six questions is designed to collect general information about the enterprises, such as their legal structure, personnel, technical staff, annual production capacity, and production methods. The second section, with three questions, is to get general information about the design activities and originality of the products designed by the enterprises. The third part, which consists of eleven questions, is aimed at obtaining more detailed information about the CAD systems, their features, the way they are used, and the encountered problems. The fourth part, which has four questions, deals with the advantages that the business gets from the use of CAD systems. The fifth and last part consists of twoquestions which are overall opinions and the perception of CAD systems.

Reliability of the Research and Statistical Evaluation

The results of the survey were processed with the help of the SPSS 12 (Statistical Package for Social Sciences), which is a widely used software for both basic and advanced statistical methods, especially for unclassified data from surveys and research forms. SPSS was decided upon because of its wide use in the Windows environment and its capacity to conduct different tests on the same data, thus, assuring the reliability and comprehensiveness of the analysis (Kinnear and Gray 2005).

The tests applied during data analysis are divided into two main groups based on whether they meet specific conditions: Parametric and Non-Parametric (Distribution-Free) tests are the two types of statistical tests. Parametric tests are built on some specific assumptions about the distribution of the population, while non-Parametric tests are not based on such assumptions, which makes them easier to use. Non-parametric tests usually deal with the ranks or signs of variables rather than the actual values.

The survey data, which was made up of 26 questions from 63 enterprises, was arranged into a 63x114 matrix (63 enterprises x 114 variables) and statistically analyzed using SPSS. The consistency of the questions (F-test), the social scale preparation of questions within each group, and the overall reliability of the survey (Reliability Analysis) were tested using the Alpha method (Cronbach's Alpha Coefficient). The mode of the results (the term that occurred most frequently) was found and graphically represented based on the obtained data.

In this manner, the study intended to cover the whole spectrum of CAD systems' utilization in Türkiye furniture industry and their effect on the companies.

RESULTS

This research is limited to three findings derived from the survey conducted on Large Scale Furniture (LSF) enterprises located in the Marmara Region. These are respectively as follows:

- Expectations of Furniture Enterprises from the CAD System
- Efficiency of CAD Systems in Furniture Enterprises
- Contribution of CAD Systems to Furniture Enterprises

Expectations of Furniture Enterprises from the CAD System

As illustrated in Table 1, 20-27% of furniture enterprises indicated that they expect the CAD systems they use to shorten the design process, improve quality, make it easier and quicker to evaluate customer demands/orders and improve design documentation. Current evaluations with companies indicate that these expectations remain unchanged. As a matter of fact, many furniture companies utilize software integrated with CAD systems in shaping orders.

Table 1. Expectations of furniture enterprises from computer-aided design (CAD) programs (Erdinler 2005)

Options	Frequency of enterprises	%
Shortening the design process	39	27.3
Improving the quality of design	39	27.3
Easier and quicker evaluation of customer demand/orders	30	21.0
Enhancing design documentation	32	22.3
Others	3	2.1
Total	143	100

Moreover, the factors influencing the selection of CAD programs by furniture enterprises in Türkiye have been identified as follows: the transition of competitor firms to these systems (1.4%), the need for flexibility in meeting customer demands (37.2%), the necessity brought by acquired CNC machines (21.4%), and the company's goals for growth and expansion (40%). Considering the current widespread use of CAD programs and CNC machines, it can be stated that the sector has made remarkable progress toward its goals.

In addition, as shown in Table 2, the reasons why enterprises prefer CAD systems are determined as their popularity (widespread use) (49.2%), CNC support (33.3%), and the availability of training support (17.5%). Currently, the widespread CNC applications have made the selection of suitable CAD systems mandatory.

Table 2. Reasons for preferring CAD Systems in LSF E-enterprises (Erdinler 2005)

Options	Frequency of enterprises	%
Popularity (widespread use)	31	49.2
CNC support	21	33.3
Availability of training support	11	17.5
Total	63	100

Efficiency of CAD Systems in Furniture Enterprises

As seen in Table 3, 46% of enterprises use the program efficiently, while 16% do not. The reasons for inefficient use of the program are identified as follows: insufficient trained personnel (55%), inadequate design demand (20%), not all modules of the program being purchased (7.5%), and insufficient compatibility of the program with other production system software (17.5%). Although these conditions have significantly changed today, the need for training persists.

Contribution of CAD Systems to Furniture Enterprises

As illustrated in Table 4, the benefits obtained by the programs utilized in enterprises include increased efficiency by shortening the design process (30.8%), enabling the pre-determination of the manufacturability of designs (21.8%), facilitating quality and waste assessments among similar raw materials (15.8%), increasing product variety (15.1%), ensuring product flexibility (13.5%), and reducing unit costs.

Furthermore, as shown in Table 5, the advantages of products manufactured using CAD systems over competitor products include: improved design quality (38.8%), creation of unique designs aligned with the company's profile (35%), and longevity of designs as brands in the market (23.7%). Under the "Others" (2.5%) option, the benefits include a more systematic structure for documentation and R&D processes, achieving a superior level as a system, and ensuring production efficiency.

Evaluation of CAD Systems in Furniture Companies with Sample Applications

Impact of CAD Application on Order Fulfillment Time

As illustrated in Figure 1, the order fulfilment time for designs previously created using traditional methods was 7 days, but after starting to design with CAD, this time was reduced to 3 days. In traditional methods, the process took 7 days due to developing a design suitable for the incoming order, producing an estimated prototype to test the design's suitability, and repeating the process several times using trial and error. With the use of CAD, the elimination of errors and working with precise measurements allows the design to be completed in one sitting, reducing the process to 3 days. The use of CAD systems in this company has resulted in a 57% reduction in order fulfilment time.

Table 3. Efficient Utilization CAD Systems in Enterprises (Erdinler 2005)

	Options	Frequency of enterprises	%
Efficient use of the CAD system	Yes	**23**	**46**
	No	**8**	**16**
	Partially	**19**	**38**
	Total	**50**	**100**
Reasons for insufficient use of the CAD system	Insufficient trained personnel	**22**	**55**
	Inadequate design demand	**8**	**20**
	Partial module purchase	**3**	**7.5**
	Insufficient compatibility with other production system software	**7**	**17.5**
	Total	**40**	**100**

Table 4. Benefits of CAD systems in LSF enterprises (Erdinler 2005)

Options	Frequency of enterprises	%
Increased product variety	20	15.1
Ensured product flexibility	18	13.5
Increased efficiency by shortening design time	41	30.8
Facilitated quality and waste assessments among similar raw materials	21	15.8
Enabled pre-determination of manufacturability of designs	9	21.8
Reduced unit costs	4	3.0
Total	133	100

Table 5. Advantages of products manufactured using CAD systems (Erdinler 2005)

Options	Frequency of enterprises	%
Improved design quality	31	38.8
Creation of unique design	28	35
Longevity of designs as brands in the market	19	23.7
Others	2	2.5
Total	80	100

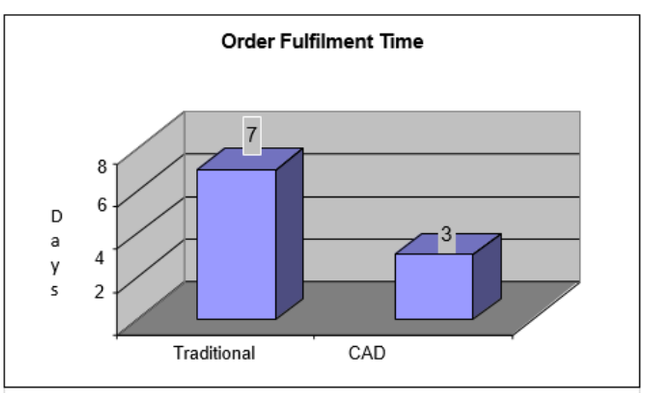

Figure 1. Order fulfilment time

Impact of CAD Application on Production Quantity

To begin with, it must be underlined that the direct impact of CAD systems on production quantity cannot be discussed unless they are integrated with CAM systems. However, the use of CAD systems indirectly affects production quantity and capacity utilization rate, especially in order-based production structures. As illustrated in Figure 2, the company that implemented the application produced 3.000 units monthly before the transition to CAD systems, but this number reached 4.000 units per month after the implementation. The designs obtained in a shorter time were directed to production, and more varieties were sent to production, leading to an increase in production quantity. This situation can also be interpreted as the more efficient operation of idle machines and better returns on capital in a shorter time. The time lost with traditional methods due to the time it takes to create designs, achieve precise measurements, and the failure of estimated moulds or prototypes to meet expected designs is no longer lost with AutoCAD, resulting in increased production quantity. The use of AutoCAD has led to a 34% increase in the monthly production quantity of tables within three months in this company.

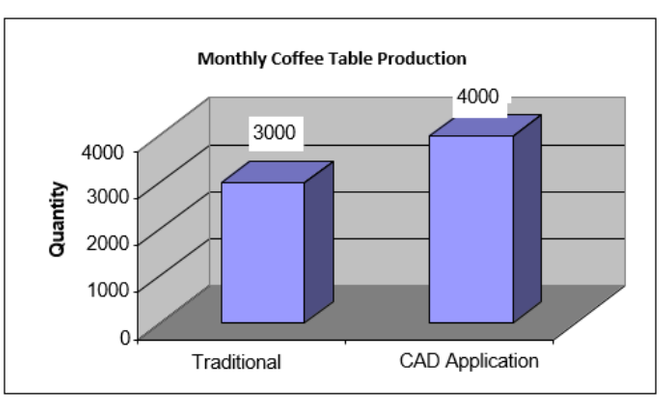

Figure 2. Impact of CAD application on production quantity

This result does not apply to the order and re-production of previously designed products. However, it can be said that the production capacity will increase to a certain level, especially with the reduction in order fulfillment time when new product demands with different designs come in. Before the CAD system, the production capacity in the company was 40.000 units/month of tables, while the actual production was 3.000 units/month. In other words, the company was operating at a 7.5% capacity utilization rate with traditional design processes. After transitioning to the CAD system, the capacity utilization rate increased to 10% with 4.000 units/month. The very low-capacity utilization rate can be explained by the variability in the order-based production structure, the lack of integration between the CAD system and the CAM system, and the company's insufficient capacity scale. It can be said that the production capacity in this company can be significantly increased depending on the conditions of CAD/CAM integration and capacity planning structure.

Impact of CAD Application on Material Supply Time

When assessing the procurement processes of primary and auxiliary materials used in the company, as shown in Figure 3, the material supply times were monthly before the use of the CAD system. With the use of AutoCAD, these times have been reduced to an average of one week, depending on the clarity and quick fulfilment of order processes. This result, like the production quantity example, is due to an indirect effect created by the CAD system in the company.

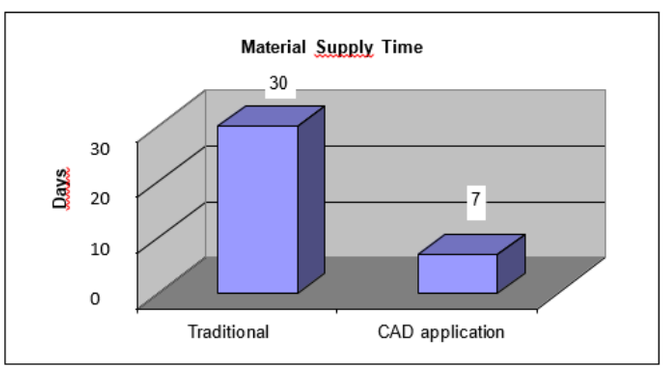

Figure 3. Impact of CAD application on material supply time

In addition, the results are consistent with Figures 1 and 2. The use of the CAD system significantly reduces the order fulfillment time directly, while indirectly increasing the production quantity and shortening the material supply time. A shortening of processes is observed in the purchasing, design, production, and sales cycle. In this company, the CAD application has reduced the material supply process by 90%. When investigating the reasons for this reduction, it is found that the time loss in receiving and processing orders using traditional methods extends the material supply process to an average of one month. However, the CAD application allows for the rapid elimination of uncertainties related to product design and production, enabling the procurement of necessary materials. These results highlight the relationship between the CAD system and material supply systems, demonstrating the critical importance of CAD/CAM integration.

CONCLUSION

Evaluation of Survey Results and Design Studies in Large-Scale Furniture Enterprises in the Marmara Region

In this section, the effectiveness of CAD systems in Türkiye furniture industry is discussed by assessing the survey results applied to large-scale furniture enterprises in the Marmara Region and the design studies observed in sample furniture enterprises. Certain recommendations are also provided.

General Overview of Furniture Enterprises

The large-scale furniture enterprises (LFB) participating in the research are domiciled in Bursa (34), Istanbul (13), Tekirdağ (4), Çanakkale (4), Kırklareli (4), Kocaeli (3), and Edirne (1). The initial establishment dates of these enterprises date back to the 1950s. These enterprises experienced a rapid development trend starting in 1981, which continued to increase in the 1990s. It was determined that 70% of the furniture enterprises were established after 1991.

A significant portion of the furniture enterprises are family-owned. Although not yet at a sufficient level, there is a tendency towards institutionalization in these enterprises. The partnership structure of joint-stock companies shows that more family members are involved. Among these enterprises, 41% are joint-stock companies, and 52% are limited liability companies.

Approximately 53% of the enterprises have open areas over 5.000 square meters, and 30% have areas over 10.000 square meters. While 48% of the enterprises carry out their production in closed areas over 5.000 square meters, it was determined that 19% do not have the necessary open area for organizing production activities.

In terms of the number of employees, there is a concentration of enterprises with 25-49 employees (33.3%). The number of enterprises with fewer than 100 employees constitute 65% of the total. The number of enterprises with 100 or more employees constitutes 35% of the total. There are no enterprises with a total of 500 or more employees.

Furniture Enterprises and CAD Systems

In 87% of enterprises, computer support is used in design. Of the 13% that do not use computer support, six stated that they do not need it, while two indicated that they do not have sufficient equipment in their enterprises.

Computer support in design activities began between 1996 and 2000 in 51% of the enterprises. Among the programs used, AutoCAD is the most preferred, with 42%. The primary factor driving the use of computer support in these enterprises is their growth and deepening objectives (40%). Additionally, the initial factor influencing their choice of program is its popularity (49%).

When examining the efficiency of program use in enterprises, 23 enterprises believe they use the program efficiently. In contrast, 19 enterprises (38%) reported that they could only partially use the program efficiently. The primary reason for this is the lack of trained personnel (55%).

The most prominent issues encountered during program use are hardware deficiencies. Enterprises often make incorrect choices based on popularity without considering their technological infrastructure.

The survey results illustrate that in Türkiye Furniture Industry, 28% of the enterprises using CAD systems reported a 71-90% increase in design quality, 15% reported a 91-100% increase in product variety, and 16% reported a 71-90% decrease in order fulfilment time. Medium and large-scale enterprises, due to their institutional nature, show a greater inclination towards CAD systems. In these enterprises, the financial structure is stronger, and the benefits of the systems are recognized, with cost considerations being secondary. Enterprises aiming to enter international markets are willing to compete with foreign firms and invest in systems without compromise. This is because the use of CAD systems reduces part costs, prevents time losses, and allows for the production of original designs.

CAD Applications in Sample Furniture Enterprises

The results obtained from two sample enterprises indicate that the use of CAD systems has led to a 57% reduction in order delivery time. When designs were created using traditional methods, the process took 7 days. However, four months after the introduction of AutoCAD, the order delivery time decreased to 3 days. Traditional design methods caused significant time losses due to the trial-and-error approach in preparing moulds according to incoming order measurements. This often resulted in repeating the processes until the appropriate design was achieved. With AutoCAD, easy dimensioning and the ability to obtain 2D and 3D images of the design before production allow for the desired designs to be achieved in a shorter time.

The enterprise's monthly production quantity of tables also increased by 34% with the use of CAD. This increase, achieved within four months, is attributed to the faster readiness of designs for production and the capability to produce more tables within the normal production time frame.

The increase in production and the reduction in order fulfilment time are in line with the reduction in material procurement times. There is a noticeable shortening of the cycle in purchasing, design, production, and sales processes. In this enterprise, the reduction in sheet order time is 90%. CAD systems shorten the duration of the purchasing, production, and sales cycle, helping ancillary industries (such as the sheet industry) to better plan and schedule their operations.

General Evaluation

The business model is defined as the factory of the future (such as Industry 5.0 applications), in other words, the optimization of all links of the value chain that defines a product with computer support and interconnectedness, remains an important goal for furniture enterprises.

The views of enterprises regarding the more widespread and effective use of CAD systems in Türkiye furniture industry can be summarized as follows:

- Educational institutions that train students for the furniture sector should place more emphasis on CAD systems, focusing on practical applications alongside fundamental knowledge.

- Enterprises should provide continuous improvement training for personnel in the design department to keep up with evolving CAD systems.
- There should be increased collaboration between educational institutions and the sector concerning CAD applications.

Currently, the integration of design-analysis-production is crucial for enterprises. These processes should be interconnected, starting from the design phase.

In conclusion, the importance of CAD systems, which has been increasingly felt since the early 2000s, continues to grow in today's furniture industry. Especially in Türkiye's furniture industry, even small and medium-sized enterprises have at least one CNC machine application, necessitating a special connection with CAD systems. For example, the use of CAD/CAM interfaces is essential for the correct management of sizing, processing, drilling, and ultimately shaping the product according to its design.

Based on the findings of this study, the implementation of CAD systems has a positive impact on both production and supply timelines. Accordingly, the following recommendations are proposed for manufacturers regarding the adoption of current and advanced CAD system features in the industry.

Considering the characteristics of the environment as product's place of use alongside its shape, model and intended purpose, throughout the design process would have a positive impact and enhancement on consumer satisfaction. In this regard, incorporating inputs such as the environment color scheme, light effects and fixed features available in advanced CAD software into the des process will add value to the product and the brand.

Currently, the combination of solid modelling and engineering analysis offered by CAD systems not only saves time in product development also mitigates potential issues during production. The integration of such technology into the design process would also provide practical benefits in optimizing design workflows.

The opportunities created by the development of artificial intelligence applications and their reflection on CAD/CAM applications are another important aspect of the furniture sector. Within the scope of this study, a survey on "CAD Systems and Artificial Intelligence Applications" conducted with selected furniture companies in Türkiye revealed that a few companies have utilized AI recommendations to overcome design process bottlenecks. Turkish furniture enterprises should focus on activating current applications like CAD, CAM, CIM, ERP, and CRM, alongside implementing big data-focused, smart systems supported by artificial intelligence more rapidly.

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