Transforming The Furniture Industry in The Digital Age

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ARTICLE INFO	ABSTRACT
	The furniture industry is experiencing a significant transition driven by digital technologies. This article comprehensively reviews various technologies, techniques, and innovations the furniture industry adopts to enhance efficiency, sustainability, and competitiveness. The analysis draws on a systematic literature review of recent publications in ScienceDirect and Scopus databases. The study highlights the potential of automation, robots, augmented reality, and the Internet of Things to improve the furniture production process, reduce waste, and boost profitability. Additionally, the article examines technologies and approaches that can help the furniture industry become more sustainable and socially responsible, such as green supply chain management, life cycle assessment, and ergonomic treatments. The paper concludes by advocating for a comprehensive digital transformation strategy that includes embracing new technologies, developing innovative business models, and promoting sustainability and ethical standards.

1. INTRODUCTION

The furniture industry has undergone considerable changes, including technological breakthroughs, globalization, and shifting consumer preferences. The sector has recently encountered problems such as environmental concerns (Teng et al., 2023), supply chain interruptions (Caridi et al., 2012; Hisjam et al., 2015; Susanty et al., 2016), and increased competition (Carpano et al., 2006), necessitating reform to maintain long-term survival.

The need for greater sustainability is a significant challenge for the furniture sector, including lowering environmental effects, encouraging social responsibility, and guaranteeing economic viability (Feil et al., 2015). Furthermore, the industry must handle worker safety, supply chain management, and product quality concerns

(Hisjam et al., 2015). To achieve these objectives, embracing technological breakthroughs, applying new initiatives, and executing best practices are necessary.

This review article aims to look into several technical breakthroughs, tactics, and best practices that can be used to alter the furniture sector in the digital age. The article will discuss many techniques for addressing industrial difficulties, such as enhancing sustainability, worker safety, supply chain management, and product quality. The paper will also discuss the benefits and drawbacks of different approaches and recommendations for their implementation.

Product modularity and innovation are critical strategies for improving supply chain performance (Caridi et al., 2012). This method enables businesses to design

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products with modular components that can be easily adjusted to match the needs of specific customers. This method can lower production costs, increase efficiency, and boost customer satisfaction. Therefore, significant investments in research and development are required (Michalski, 2015).

Global value chains have been demonstrated to promote competitiveness and upgrading in the furniture business (Epede & Wang, 2022). This strategy entails integrating various value chain stages across many geographies, allowing enterprises to enter new markets, cut costs, and boost competitiveness. However, to guarantee efficient adoption, extensive coordination and administration are required (Colak et al., 2015).

Automatic control is another strategy that has been found to improve precision and efficiency in the furniture sector (Teng et al., 2023). It entails using automated technology to control manufacturing, decrease human error, and enhance efficiency. This strategy can potentially increase quality while lowering manufacturing costs, but it necessitates significant investments in technology and infrastructure.

Ergonomics in analyzing work stress and its effects on workers has been identified as critical in guaranteeing worker safety in the furniture business. This method can assist in identifying potential risks and providing remedies to lessen the chance of injury. Nonetheless, significant investments in training and equipment are required. The furniture sector faces several issues requiring reform to assure long-term viability. Implementing technological advances, new techniques, and best practices can assist in addressing these issues.

In recent years, the furniture industry has witnessed a significant transformation, predominantly driven by the adoption of digital technologies. Central to this revolution has been the integration of Computer Numerical Control (CNC) machinery in production, which has enabled unprecedented precision and efficiency (Koc et al., 2017; Rabiei & Yaghoubi, 2023). CNC machines have allowed complex designs to be executed precisely, minimizing human error and reducing waste materials (Kaba et al.,

2023). It has led to cost savings and expanded the possibilities for custom furniture design, catering to a market that increasingly values uniqueness and personalization.

Alongside production enhancements, 3D modelling software has redefined the design process within the furniture industry (Caeiro et al., 2022; Falheiro et al., 2022; Tikul et al., 2022). Designers are now equipped to create and modify intricate product models digitally, which can be visualized in virtual environments, allowing for rapid prototyping and iteration (Andrikos et al., 2023; Nijdam et al., 2022; Werner et al., 2021). This shift has significantly reduced the time from concept to market, fostering a culture of innovation and agile response to consumer trends.

Furthermore, Enterprise Resource Planning (ERP) systems have brought about a new era of supply chain management (Chopra et al., 2022; Lengnick-Hall et al., 2004). By integrating all facets of operations, from inventory management to customer relations, ERP systems provide a transparent view of the supply chain, enabling companies to anticipate demand, optimize stock levels, and respond swiftly to supply chain disruptions. This comprehensive oversight has been pivotal in enhancing furniture companies' responsiveness to volatile market dynamics.

The cumulative impact of these digital technologies is profound. Production lines are not only more efficient but also more adaptable to changing consumer preferences. Design capabilities have expanded, allowing for a broader range of products to be offered. The supply chain has become more transparent and responsive, improving customer experience. As such, the digital age has not only reshaped the operations of the furniture industry but also set a new standard for what is possible within this traditional sector.

2. METHODS

The research is a literature review utilizing publications from ScienceDirect and Scopus databases. It focuses on the furniture industry: digital technologies like automation, robots, augmented reality, and IoT impact industry efficiency, sustainability, and profitability. The

study will evaluate the contribution of these technologies to production processes, waste reduction, and profitability, alongside their role in sustainability and social responsibility. It will integrate case studies of furniture companies that have adopted these technologies, providing a practical perspective and, where possible, a comparative analysis of their implementation. The methodology will also suggest future research directions, particularly in emerging technologies and their long-term industry impact.

3. RESULT AND DISCUSSION

3.1. Furniture Industry

The furniture industry is a dynamic and highly competitive sector that has undergone significant changes in recent years. The emergence of global value chains and increased competition has resulted in the need for furniture manufacturers to adopt innovative practices to stay ahead. One approach to maintaining a competitive edge is continually improving product quality, which can be achieved by developing flexible and creative goods, collaborating with relevant stakeholders, and implementing advanced technologies such as automatic control systems and electrostatic powder coating. Despite the challenges, the furniture industry presents many opportunities for growth and innovation, making it an exciting and ever-evolving field.

3.1.1. Overview and Historical Context of the Furniture Industry

The furniture industry is diverse and dynamic, facing several problems and roadblocks in its operations. Caridi et al. (2012) found that the main challenge in aligning supply chain decisions is the level of complexity and creativity involved in the product. Specifically, they identified product modularity and innovativeness as essential factors contributing to this difficulty. Furthermore, Abu et al. (2019) identify technical knowledge, training, and financial resources as major hurdles when implementing lean manufacturing in furniture. As a result, to achieve sustainable growth, organizations in the furniture sector must address these problems by improving their technical competence, supply chain efficiency, and resource allocation.

In the furniture industry, global value chains are critical. According to Epede & Wang (2022), whereas African countries have remained at a comparative disadvantage, Asian countries of various economic levels have emerged as practical instances of sector upgrading. Even with their substantial competitive advantages, European and American countries face decreasing tendencies. Navas-Alemá (2011) also shows that upgrading is limited for developing-country enterprises that export through global value chains. As a result, the furniture industry must assess its position in global value chains and look for ways to improve its competitiveness in the worldwide market.

Technology integration in the furniture sector brings both benefits and obstacles. Firms confront considerable hurdles, such as the high cost of deploying automatic control technology and the necessity for specialized people to operate and maintain machinery. Likewise, optimizing pyrolysis parameters in Auger Reactor Pyrolysis can be difficult, and the qualities of the produced bio-oil may differ depending on the feedstock (Ahmed et al., 2020). As a result, businesses must assess the cost-benefit of integrating new technologies and devise methods to overcome the hurdles of technology adoption.

The furniture industry has been linked to some health risks, emphasizes the health risks associated with wood dust, and recognizes mechanical injuries resulting from unsafe working conditions and risky activities in the wood-bamboo furniture manufacturing business. Additionally, upholsterers, sanders, and sprayers are more likely to become ill than furniture workers (Vaajasaari et al., 2004). As a result, businesses must emphasize employee health and safety by implementing relevant measures such as ergonomic interventions and safe woodworking machinery.

3.1.2. Furniture Industry Structure

The furniture industry is complicated, with a supply chain that includes many stakeholders, such as suppliers, manufacturers, distributors, and retailers. Epede & Wang (2022) underline the necessity of integrating

global value chains to promote industry competitiveness and upgrading. Furthermore, according to Abu et al. (2019), lean manufacturing can improve productivity, workplace organization, and space use. Azizi et al. (2016) recommend using a multi-criteria decision-making method to assess the sustainable growth of wooden furniture businesses since this method can identify and prioritize indices influencing the industry's sustainability.

The sector also faces worker health and safety issues. Woodworkers, for example, are at risk of nasal cancer. As a result, risk assessment and ergonomic evaluations are critical to treating pain-related and ergonomic concerns. To reduce the risk of musculoskeletal problems, Mirk (2005) suggests using safe woodworking machinery and ergonomic recommendations for the furniture manufacturing business.

Regarding innovation, according to Oliveira et al. (2016), information systems can reduce waste, optimize purchase and consumption, and increase profitability and sustainability. Furthermore, Jácome et al. (2021) propose a strategy that fosters innovation as a dynamic competence in the furniture sector, concentrating on business-led, collective innovation that prioritizes suppliers, consumers, competitors, and retailers.

Environmental sustainability is another critical part of the furniture industry (Farooq et al., 2022). Green value chain techniques can improve environmental performance by incorporating environmentally friendly practices into all value chain phases. Iritani et al. (2015) underline the importance of life cycle assessments in establishing more energy and resource-efficient manufacturing processes, which contribute to overall improvements in product environmental performance. Furthermore, Kremensas et al. (2021) emphasize the potential benefits of employing hemp shivs and corn-starch-based biocomposite boards, which offer more excellent water resistance and fire reactivity, to promote environmental sustainability.

Finally, the furniture sector has worker health and safety issues and environmental sustainability. Integrating global value chains and using lean manufacturing can boost competitiveness. The development of innovation as a dynamic competence in the industry can contribute to its

progress. The industry should prioritize worker health and safety, develop sustainable practices, and employ life cycle evaluations.

3.2. Transforming The Furniture Industry

The furniture industry is in the midst of a digital transformation, with the increasing adoption of advanced technologies such as artificial intelligence, automation, and the Internet of Things. These innovations can revolutionize how furniture is designed, produced, and distributed, resulting in increased efficiency, improved sustainability, and enhanced customer experiences. The implementation of digital technology also offers the opportunity for greater customization, with consumers able to create bespoke designs and products tailored to their needs. However, the industry faces challenges such as high implementation costs, resistance to change, and the need for skilled labour to operate and maintain machines. Despite these obstacles, the transformative power of digital technology is evident, and the furniture industry that embraces these changes will likely enjoy a significant competitive advantage in the years ahead.

The integration of digital technology in the furniture industry has catalyzed a paradigm shift with profound economic implications. The advent of automated production lines and precision machinery has significantly reduced labour costs and minimized errors, leading to a leaner production model with enhanced profitability (Falheiro et al., 2022; Long et al., 2020). Digital inventory systems have streamlined supply chain management, preventing overproduction and excess stock and optimizing capital expenditure. Moreover, online sales platforms and digital marketing strategies have broadened market reach, allowing even small-scale manufacturers to access global markets, thus democratizing the competitive landscape.

However, the journey towards digital transformation has its challenges. Resistance to change is a significant hurdle, with a portion of the workforce often wary of new technologies perceived as threats to job security. Moreover, a gap in digital literacy can stymie the adoption of advanced technologies, necessitating investment in

education and training. Companies must navigate these human factors with sensitivity and foresight, fostering an inclusive culture where technology is seen as an enabler rather than a disruptor.

Crystal Doors has digitalized its operations to remain competitive and achieve net-zero emissions. They established a network of sensors connecting their machines through the cloud to a dashboard, which has led to operational efficiencies and reduced emissions. Their digital transformation included workshops and workforce development to integrate emerging technologies and manage cultural change.

3.2.1. The Role of Digital Technology in the Furniture Industry

The furniture sector is undergoing substantial changes in the digital age, and integrating digital technologies has become critical. According to Carpano et al. (2006), international rivalry and a resource-based conception of the company drive changes in mature localized sectors. The sector must adapt to new business settings to stay competitive, and digital technology provides a means. However, (Abu et al., 2019) state that personnel-related concerns, a lack of implementation know-how, and employee resistance impede the implementation of lean practices in organizations. Adopting digital technology and its numerous capabilities can assist in overcoming these obstacles.

Digital technology is critical to the supply chain of the furniture industry. According to Caridi et al. (2012), supply chain decisions are affected by the complexity and creativity of products and can be customized to optimize performance. The industry can use digital technology to help it connect its supply chain with product characteristics and optimize performance. Digital technology can improve machine precision, efficiency, and accuracy, lowering costs connected with traditional manufacturing processes (Vidal et al., 2011).

Digital technology can also improve the furniture industry's sustainability practices. According to Azizi et al. (2016), high-priority sub-criteria include economic stability, developing industrial furniture clusters, adjusting furniture and wooden product importation tariffs, reducing volatile organic compounds, and marketing and union reinforcement creation of a competitive environment (Szczurek et al., 2021). Industry can use digital technology to help them meet these sub-criteria by decreasing waste, optimizing resource usage, and introducing sustainable manufacturing methods. Furthermore, digital technology may assist businesses in monitoring their environmental footprint and making necessary modifications (Linkosalmi et al., 2016).

The implementation of digital technology in the furniture industry needs to be improved. One issue is a need for more implementation expertise and employee resistance to change (Abu et al., 2019). Another area for improvement is the high expense of integrating digital technologies. The traditional market-pricing model understates financial losses. As a result, before making decisions, businesses must weigh the cost-benefit of integrating digital technologies.

Finally, the furniture sector must adopt digital technologies to compete in the digital age. Industry can use digital technology to optimize supply chains, increase sustainability practices, and minimize costs associated with traditional manufacturing methods. On the other hand, the industry must overcome hurdles relating to implementation know-how and employee resistance to change. Furthermore, businesses must weigh the cost-benefit of integrating digital technologies before making decisions. As the furniture industry evolves, digital technology will play an increasing role in altering the industry in the digital age.

3.3. Digital Transformation In The Furniture Industry

3.3.1. Challenges and Opportunities of the Furniture Industry

The furniture sector has a variety of difficulties and opportunities. Due to the industry's complexity, one crucial problem is matching supply chain decisions with product flexibility and innovativeness (Caridi et al., 2012). This problem has an impact on new product development as well as the implementation of modular furniture design. Another area for improvement is the high expense of integrating new technology, such as automatic control, and the requirement for skilled people to run and maintain the machinery. The

high cost of technology deployment can negatively influence small and medium-sized firms' capacity to compete in the market.

The furniture sector faces environmental challenges as well. For example, Vicente et al. (2023) find that electrocoagulation treatment efficacy is insufficient to meet legal water discharge standards. The health risks associated with wood dust impair industrial personnel's health. The industry sector must adopt long-term policies and implement measures to ensure the safety of workers.

Furthermore, the furniture sector needs help in implementing new developments and technologies. According to Abu et al. (2019), technical knowledge, training, and financial resources are significant hurdles during the early stages of implementing lean manufacturing in the sector. Adopting new technology can impact competitiveness and limit the potential to develop (Han et al., 2009).

The references provided also emphasize prospects in the furniture sector. One possibility is using sustainable solutions, such as green value chain practices and Life Cycle Assessment (LCA) (Iritani et al., 2015). Adopting sustainable solutions can assist in addressing environmental issues while also increasing industry competitiveness. Another potential is using new technologies, such as Agile Product-Service Design with VR technology (Freitag et al., 2018). Using new technology can boost the industry's innovative skills and furniture producers' competitiveness.

The furniture industry's historical reliance on manual craftsmanship and skill has evolved dramatically with the advent of digital technology. Traditional methods were characterized by labour-intensive processes and long production cycles, often resulting in higher costs and limited scalability. In contrast, the industry's current state is defined by a synergy between skilled artisans and advanced technologies, leading to a renaissance in production and design.

A pivotal case study that exemplifies this evolution is the journey of 'Integral Surface Design (ISD)' a once-traditional manufacturer that embraced digital transformation. Integrating advanced CNC machinery into its production lines, Integral Surface Design increased its output by 50% while reducing material waste by 30%. Their adoption of 3D printing technology further allowed for rapid prototyping, enabling them to bring products to market in half the time previously required. This agility has been critical in maintaining its competitive edge in a market driven by fast-changing consumer preferences.

Another example is IKEA, a startup that disrupted the market by leveraging virtual reality (VR) to offer immersive design experiences to its customers (Kostecka & Kopczewska, 2023). Agile Product-Service Design with VR-technology: A use case in the furniture industry (Freitag et al., 2018). This technology allowed clients to visualize custom furniture pieces within their homes, leading to a 40% increase in customer satisfaction and a significant uptick in bespoke orders. IKEA has set a new standard for customer engagement in the digital age, showcasing the potential for technology to enhance the manufacturing process and the end-user experience.

These cases underscore a broader industry trend: companies that integrate digital technologies set benchmarks for efficiency, innovation, and customer engagement. As a result, they are redefining success in the furniture industry, proving that integrating digital tools is not merely an operational upgrade but a strategic imperative for growth and sustainability in the 21st century.

Finally, as emphasized in the referenced references, the furniture sector faces various difficulties and opportunities. Aligning supply chain decisions with the complexity and creativity of products, deploying new technologies, and addressing environmental and health risks are all challenges. Opportunities in the industry, on the other hand, include the adoption of sustainable practices and new technologies. The furniture industry must adopt innovative technologies and sustainable techniques to remain competitive and overcome the issues it confronts.

3.3.2. Case Studies of the Furniture Industry

The furniture business is undergoing a tremendous transition in the digital age, with digital technologies resulting in various benefits and issues. One significant

benefit of digital technology in the furniture sector is better efficiency, workplace organization, and space use. According to Abu et al. (2019), technical expertise, training, and financial resources are all mentioned as hurdles during the early stages of implementation. Additionally, anticipating and preempting evolving environmental rules and customer expectations is essential in incorporating environmentally friendly activities into all value chain stages (Linkosalmi et al., 2016).

However, the furniture business faces various hurdles when it comes to using digital technology. According to Caridi et al. (2012), the critical obstacle is the difficulty in aligning supply chain decisions with product modularity and innovativeness due to the industry's complex character, which hinders supply chain performance alignment. Another area for improvement is the cost of deploying technology and the required qualified staff to run and maintain the devices. Ahmed et al. (2020) also address the difficulty of optimizing pyrolysis parameters, with the resulting bio-oil characteristics differing depending on the feedstock.

Although innovative technology and human integration are required to mitigate market risk for new product-service systems, Freitag et al. (2018) observe that this integration might be complex for enterprises. The challenges of enhancing process measurement instruments, process control, and quality assurance also exist. Contradictions between traditional manufacturing technology and new automation techniques can also be problematic. The use of integrated management and stakeholder management systems in small and medium-sized firms in the furniture industry impedes enhanced social and environmental implications of management decisions (Jaďuďová et al., 2015).

The advantages of digital technology within the furniture industry extend beyond operational efficiencies, profoundly enhancing product customization and customer experience (Falheiro et al., 2022; P. et al., 2022). Digital technologies, such as CAD/CAM software, have empowered customers to participate directly in the design process, tailoring furniture to their preferences and space requirements. This level of customization has transformed customer interactions from passive purchasing to active creation, resulting in a more engaged and satisfied customer base.

One illustrative example is 'Newport Furniture Parts,' which utilizes CNC machinery and CAD software to produce high-quality furniture parts. By adopting these technologies, they have ensured precision, reduced waste, and increased productivity. Their use of modern technology has helped them maintain their position as a leader in the wood component industry. Such innovations underscore the strategic value of customization in today's market, where differentiation is critical to capturing consumer attention and loyalty.

Despite these advantages, the furniture industry faces significant hurdles in implementing digital technologies. The challenge often lies in overcoming the inertia of established practices and the apprehension towards the perceived complexity of new systems. Successful change management strategies have been central to navigating these challenges. This global company, IKEA, uses materials from sustainable sources such as FSC-certified wood and recycled materials. They have implemented energy-efficient manufacturing processes and waste reduction initiatives and use renewable energy sources. They also use innovative designs such as modular furniture and have a product line made from recycled PET bottles and reclaimed wood.

Herman Miller uses sustainable materials such as recycled content and rapidly renewable resources. They design furniture for durability and longevity, incorporate eco-design principles, and have embraced modular design principles. Herman Miller has also integrated technology, such as the Live OS system, with their products.

West Elm uses source sustainable materials like FSC-certified wood and organic cotton and partners with suppliers who share their commitment to sustainability. West Elm has also implemented energy-efficient manufacturing processes and offers recycling programs for their products.

Blu Dot Uses eco-friendly materials such as FSC-certified wood and recycled content and focuses on producing durable furniture. They have adopted energy-efficient manufacturing processes, waste reduction initiatives, and use renewable energy sources. Blu Dot is also known for implementing computer-controlled cutting and advanced robotics.

Ekomia Specializes in sustainable furniture manufacturing using materials like FSC-certified wood, recycled materials, and natural fibres. Their designs focus on durability and longevity and support the circular economy with furniture rental and buy-back programs. Ekomia also uses intelligent manufacturing processes and has embraced 3D printing technology for efficient production.

These case studies exemplify how digital technologies can be harnessed to drive the furniture industry's growth, efficiency, and sustainability. The synthesis of these experiences within the industry shows that while digital technology brings considerable benefits in customization and customer engagement, its successful deployment hinges on thoughtful change management strategies. These strategies must prioritize human factors, ensuring that technology adoption is about the tools and the people who use them.

Finally, the furniture sector is undergoing a substantial shift in the digital age, with digital technology resulting in various benefits and obstacles. There are several benefits to adopting digital technology, including increased efficiency, improved workplace organization and space utilization, and enhanced environmental performance. However, the industry faces challenges such as high implementation costs, difficulty adapting supply chain decisions to product complexity, and the requirement for skilled labour to operate and maintain machines, which impede widespread adoption. New product-service systems require novel technology and personnel integration to mitigate market risk. Businesses must face these issues to benefit from implementing digital technology and prosper in the digital age.

In the digital age, the furniture sector is undergoing a revolution. Freitag et al. (2018) emphasize using virtual and augmented reality technology in the furniture sector for agile product-service design, allowing customers to sample their desired products before purchasing, improving their buying experience. Tsang et al. (2022) also discuss that using big data analytics in the furniture industry has led to intelligent product design frameworks that allow for greater flexibility and self-improvement mechanisms and optimize production processes, reducing manufacturing costs and improving efficiency.

Another example of digital transformation in the furniture business is using information systems to reduce the wastage of raw materials created during manufacturing (O. Oliveira et al., 2016). Furniture makers can discover places where waste can be eliminated by collecting and evaluating data on the manufacturing process, resulting in cost savings and enhanced sustainability (O. Oliveira et al., 2016). Furthermore, de Lima Mesquita et al. (2018) highlight the usage of eco-particleboards derived from alternative raw materials such as acai fruit fibres as a more sustainable alternative to regular particleboards in the construction and furniture industries.

Even with the advantages of digital transformation in the furniture sector, there are still hurdles. The rapid growth of microelectronics and advanced automation techniques may result in incompatibilities between traditional manufacturing technologies and automation techniques. Furthermore, the furniture sector must handle the issue of hazardous waste generated throughout the manufacturing process. According to Vaajasaari et al. (2004), excess paint leftovers formed during the spray-painting process contain dangerous substances that persist in the solid waste, and toxicity may leak from residues in contact with water at landfill sites. As a result, furniture makers must establish sustainable manufacturing techniques that limit waste and harm the environment.

Finally, digital change in the furniture sector enables better consumer experiences, cost reductions, and sustainability. Furniture makers are adopting virtual and augmented reality technology, big data analytics, and information systems to enhance production processes and eliminate waste. However, inconsistencies between

traditional manufacturing technology, automation techniques, and hazardous waste generation must be addressed to achieve sustainable change.

3.4. Strategies For Maintaining Competitive Advantage

In the realm of modern furniture manufacturing, the integration of advanced technologies like Artificial Intelligence (AI), the Internet of Things (IoT), automation, 3D modelling, CNC machinery, and Enterprise Resource Planning (ERP) systems is not just a trend but a paradigm shift. AI is revolutionizing design processes through predictive analytics and customized design solutions, enhancing creativity and efficiency. IoT, with its network of interconnected devices, offers unparalleled monitoring and control over production processes, leading to significant improvements in operational efficiency. Automation, in its many forms, from robotic assembly lines to automated logistics, redefines furniture production's speed and precision.

Furthermore, 3D modelling has opened new horizons in furniture design, allowing for intricate and precise models that can be easily modified and visualized before production. CNC machinery complements this by turning these digital designs into reality with unmatched accuracy, drastically reducing the time and material waste traditionally associated with manufacturing. Lastly, ERP systems are the backbone of supply chain management, integrating various processes from inventory management to customer relations, ensuring a seamless flow of information and resources across the entire value chain.

Together, these technologies are streamlining production and design and reimagining the entire supply chain management, making it more responsive, efficient, and customer-centric. By exploring these technologies in greater depth, we can better understand their transformative impact on the furniture industry, paving the way for a future where innovation, efficiency, and sustainability are intrinsically linked.

The industry must adopt effective strategies to maintain a competitive edge in the highly competitive furniture industry. One approach is to develop and implement sustainable practices, such as using environmentally friendly materials and reducing waste. Another critical strategy is to prioritize innovation, constantly seeking new and creative designs that meet the evolving needs of consumers. Collaboration with relevant stakeholders, such as designers and suppliers, can also provide a competitive advantage by facilitating the exchange of ideas and expertise. Furthermore, leveraging digital technologies such as automation and artificial intelligence can improve production efficiency, reduce costs, and enhance product quality. Ultimately, a thriving furniture industry must be agile and adaptable, able to respond quickly to changes in the market and continually evolve its strategies to stay ahead of the competition.

3.4.1. Enhancing Product Quality

Because the furniture sector is characterized by fierce competition, businesses must constantly seek ways to maintain their competitive advantage. One strategy is to improve product quality, which is critical in satisfying client needs and maintaining a positive reputation (Robb & Xie, 2003).

Furthermore, innovation is critical in upgrading the value chain, aided by collaboration among essential stakeholders such as the government, industry actors, and individual enterprises (Epede & Wang, 2022). Global value chains have intensified competition in the wooden furniture industry. Collaborating with the right stakeholders can enable successful upgrading, as supported by their research and the findings of (Azizi et al., 2016), who developed a strategy for assessing the sector's long-term growth using multi-criteria decision-making. Their research identified high-priority sub-criteria such as increased economic stability, development of industrial furniture clusters, adjustment of furniture and wooden product import tariffs, reduction of volatile organic compounds, marketing, union reinforcement, and creation of a competitive environment.

In terms of technology, automatic control systems are critical for enhancing the efficiency and precision of machines in the furniture and construction industries. These technologies improve precision, efficiency, and

accuracy, producing higher product quality. Additionally, Ayrilmi (2022) discovered that due to the development of low-temperature curing powder coatings and the fabrication of special-grade MDF panels, electrostatic powder coating had acquired broad application on wood-based panels. This technology improves product quality, making it essential for maintaining a competitive advantage.

The furniture industry is highly competitive, and maintaining a competitive edge requires continual improvements in product quality. The strategy will be achieved by developing flexible and innovative goods, collaborating with relevant stakeholders, implementing automatic control systems, and utilizing advanced technologies like electrostatic powder coating. By implementing these techniques, businesses in the furniture sector can separate themselves from competitors and retain a positive reputation among clients.

3.4.2. Enhancing Production Efficiency and Effectiveness

Improving manufacturing efficiency and effectiveness in the furniture sector is critical for maintaining a competitive advantage in the digital age. Using lean manufacturing, which focuses on waste elimination and process optimization, is one way to do this. According to Abu et al. (2019), lean businesses may need help with problems such as employee-related concerns, lack of implementation knowledge, and reluctance to change. However, the advantages of lean manufacturing are evident since it results in better resource use, shorter cycle times, and higher output.

Another technique for increasing production efficiency and effectiveness in the furniture and construction industries is to use automatic control systems. These methods improved machine precision, efficiency, and accuracy, allowing for more control and reduced human error in production operations. Similarly, intelligent product design frameworks based on big data analytics can improve manufacturing efficiency and effectiveness through increased flexibility and self-improvement mechanisms in product design evolution (Tsang et al., 2022).

Effective supply chain management improves performance and competitiveness. Caridi et al. (2012) discovered that product modularity and innovativeness influence supply chain decisions. Aligning supply chain choices with these product qualities might maximize performance. According to Epede & Wang (2022), expanding global value chains has impacted the furniture business by increasing competition. The participation of major stakeholders such as government, industry actors, and individual enterprises can result in successful value chain upgrading (Scott, 2006).

The furniture sector can use many innovations and technologies to reduce waste and promote sustainability. Eco-particleboard manufacture employing acai fruit fibres, for example, resulted in superior mechanical qualities and could be used as raw materials for medium-density homogeneous particleboards in the building and furniture industries (de Lima Mesquita et al., 2018). Using life cycle assessment (LCA), Iritani et al. (2015) identified two sustainable strategies: optimizing transportation systems using alternative raw materials and using 100% wood waste, which is more sustainable for medium-density particleboard manufacture. Figure 1 shows sustainable manufacturing practices using recycled plastic in furniture production. The benefits of using sustainable furniture practices include reducing waste and pollution, conserving natural resources, and promoting ethical production standards. The implementation of closed-loop production systems to reduce waste and the use of eco-friendly finishes or coatings that are free of harmful chemicals.

Enhancing occupational health and safety in the furniture sector can boost productivity and effectiveness. Ergonomic treatments, such as hand tool redesign, can considerably reduce risk factor exposure and enhance awareness of musculoskeletal problems and unsafe postures among small-scale furniture workers ((Jain et al., 2020); (Mirka, 2005). According to Ratnasingam et al. (2012), contract employees in the furniture business had a lower risk of occupational accidents and a more positive attitude toward safe working procedures.

Finally, the furniture business can preserve a competitive edge in the digital age by improving production efficiency and effectiveness. Lean manufacturing, autonomous control systems, intelligent product design frameworks, and effective supply chain management can optimize resource utilization, cut cycle times, and boost productivity. Furthermore, reducing waste, promoting sustainability, and improving employee health and safety can help the furniture industry's production efficiency and effectiveness.

3.4.3. Advancements in Marketing

In the digital age, the furniture business faces more competition and upheaval. Businesses must embrace creative techniques, such as marketing improvements. Azizi et al. (2016) proposed a multi-criteria decision-making strategy for assessing the long-term viability of the wooden furniture sector. As a high-priority sub-criteria, the study emphasizes the importance of economic stability, the construction of furniture manufacturing clusters, the elimination of volatile organic compounds, and the creation of a competitive environment. Businesses that prioritize these factors are more likely to get a competitive advantage.

Industry must focus on innovation and sustainability. Ng Thiruchelvam (2012) conducted a case study on Malaysia's Muar furniture cluster, highlighting the role of innovation in the industry's success. The industry must be creative and adaptable in product creation, production, and marketing approaches (Wu et al., 2023). Figure 2 shows an example of AR/VR technology used in the furniture industry: the IKEA Place app. This app allows users to use their smartphone camera to visualize how IKEA furniture would look in their homes. Using AR technology, the app can overlay furniture images onto the user's camera view, giving them an idea of how it would fit into their space.

Another example is the Wayfair app, which includes an AR feature called "View in Room." This feature allows customers to use their smartphone camera to place a 3D model of a piece of furniture into their room and see how it would look in real-time. It gives customers a better sense of the furniture's size and scale and helps reduce the risk of purchasing something that does not fit well in their space.

Furthermore, Jácome et al. (2021) suggested a methodology for establishing innovation as a dynamic competence for furniture sector organizations. The research finds organizational elements that promote the development of dynamic capabilities, thereby supporting businesses in sustaining a competitive advantage (Guimaráes et al., 2016).

The industry must thoroughly know its market and client requirements to implement these strategies correctly. The green value chain activities in the furniture sector conclude that businesses must identify environmentally friendly methods in various value chain functions. Businesses prioritize meeting customers' demands while implementing sustainable practices. Additionally, (Carpano et al., 2006) emphasize the significance of changes in the mature localized sector due to international rivalry and the firm's resource-based orientation. Businesses that recognize and adapt to market developments are more likely to sustain their competitive advantage.

On the other hand, the industry must examine potential hurdles to implementing marketing enhancement initiatives. According to Abu et al. (2019), as implementation challenges, lean organizations encounter staff-related issues, a lack of implementation knowledge, and employee reluctance to change. These difficulties highlight the importance of good change management and staff engagement in successfully implementing marketing improvement plans.

The furniture industry must implement new strategies focused on sustainability, innovation, and client needs to preserve a competitive advantage in the digital age. Addressing possible roadblocks, such as employee resistance to change, is critical for successfully implementing these techniques. The industry may revolutionize the furniture sector in the digital age by emphasizing these criteria and successfully adopting marketing optimization tactics.

Figure 1. Examples of sustainable manufacturing practices in the furniture industry (credit: Pixabay). Some images from Pixabay have been merged and modified by adding additional labels and text.
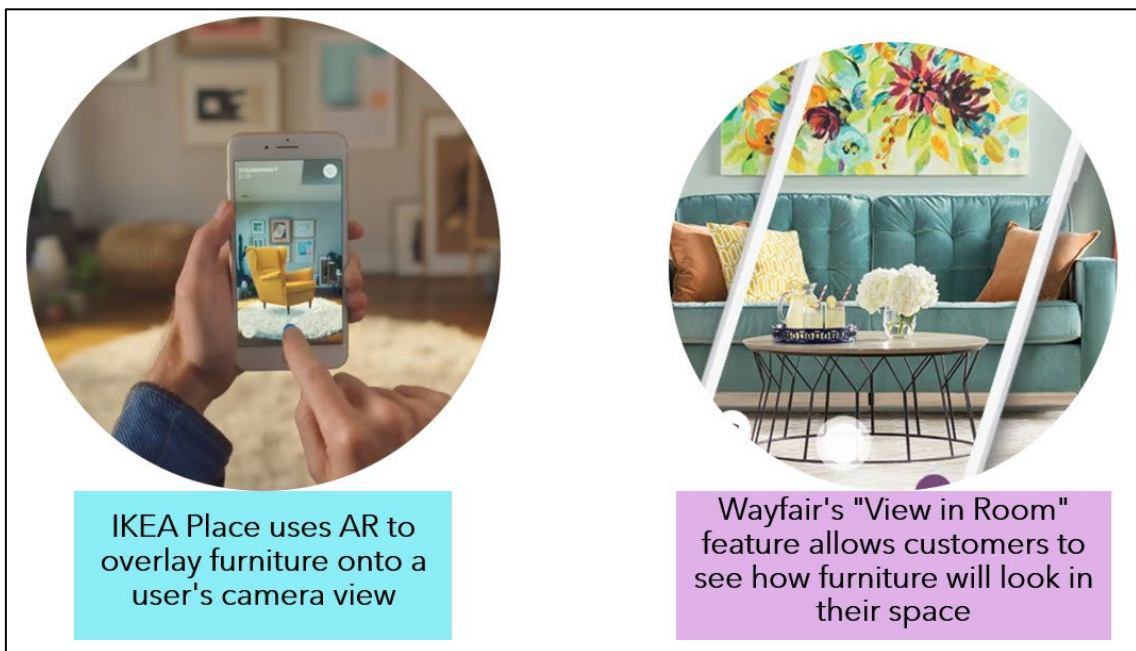

Figure 2. Examples of augmented reality (AR) and virtual reality (VR) technology are being used in the furniture industry (credit: IKEA and Wayfair)—images from IKEA and Wayfair are modified by adding additional labels and text.

4. CONCLUSION

The journey of the furniture industry into the digital age has been marked by a series of transformative changes driven by the adoption of digital technology. The analysis underscores the pivotal role of technologies such as CNC machinery, 3D modelling, and ERP systems in revolutionizing production, design, and supply chain management. These technologies have enhanced operational efficiencies and opened new avenues for product customization, elevating the customer experience to unprecedented levels.

The case studies of Integral Surface Design (ISD), IKEA, Newport Furniture Parts, Herman Miller, West Elm, Blu Dot, Ekomia, and others serve as testaments to the economic benefits and competitive advantages that digital technology can yield. However, the successful integration of these technologies is contingent upon overcoming challenges inherent in digital transformation. It requires robust change management strategies sensitive to workforce concerns and committed to fostering a culture of continuous learning and innovation.

As the furniture industry looks forward, it must not only embrace current digital trends but also remain vigilant to the evolving technological landscape. Continuous innovation and adaptation are not mere options but necessities for sustaining growth and relevance in an increasingly digital marketplace. The future of the furniture industry lies in its ability to leverage technology not just as a tool for efficiency but as a cornerstone for creating value, driving creativity, and delivering solutions that resonate with the dynamic needs of consumers.

The digital age is not a phase but a new reality for the furniture industry. Companies that understand and act upon the imperatives of digitalization will lead the way in setting standards for quality, sustainability, and customer satisfaction. Through this lens, the furniture industry can envisage and shape its future—a digital, innovative, and inclusive future.

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REFERENCE

Abu, F., Gholami, H., Mat Saman, M. Z., Zakuan, N., & Streimikiene, D. (2019). The implementation of lean manufacturing in the furniture industry: A review and analysis on the motives, barriers, challenges, and the applications. Journal of Cleaner Production, 234, 660–680. https://doi.org/10.1016/j.jclepro.2019.06.279

Ahmed, A., Abu Bakar, M. S., Sukri, R. S., Hussain, M., Farooq, A., Moogi, S., & Park, Y. K. (2020). Sawdust pyrolysis from the furniture industry in an auger pyrolysis reactor system for biochar and bio-oil production. Energy Conversion and Management, 226. https://doi.org/10.1016/j.enconman.2020.113502

Andrikos, I., Stefanou, K., Bellos, C., Stergios, G., Alchera, E., Locatelli, I., & Alfano, M. (2023). EDIT Software: A tool for the semi-automatic 3D reconstruction of bladder cancer and urinary bladder of animal models. Computer Methods and Programs in Biomedicine, 232, 107448. https://doi.org/https://doi.org/10.1016/j.cmpb.2023.107448

Ayrilmis, N. (2022). A review on electrostatic powder coatings for the furniture industry. International Journal of Adhesion and Adhesives, 113. https://doi.org/10.1016/j.ijadhadh.2021.103062

Azizi, M., Mohebbi, N., & De Felice, F. (2016). Evaluation of Sustainable Development of Wooden Furniture Industry Using Multi criteria Decision Making Method. Agriculture and Agricultural Science Procedia, 8, 387–394. https://doi.org/10.1016/j.aaspro.2016.02.034

Caeiro, C., Calado, J. S., Sarraipa, J., & Jardim-Gonçalves, R. (2022). Framework for Validation of Furniture

Smartification Processes. IFAC-PapersOnLine, 55(2), 499–504. https://doi.org/https://doi.org/10.1016/j.ifacol.2022.04.243

Caridi, M., Pero, M., & Sianesi, A. (2012). Linking product modularity and innovativeness to supply chain management in the Italian furniture industry. International Journal of Production Economics, 136(1), 207–217. https://doi.org/10.1016/j.ijpe.2011.11.012

Carpano, C., Rahman, M., Roth, K., & Michel, J. G. (2006). International competition in mature, localized industries: Evidence from the U.S. furniture industry. Journal of Business Research, 59(5), 630–637. https://doi.org/10.1016/j.jbusres.2005.11.001

Chopra, R., Sawant, L., Kodi, D., & Terkar, R. (2022). Utilization of ERP systems in manufacturing industry for productivity improvement. Materials Today: Proceedings, 62, 1238–1245. https://doi.org/https://doi.org/10.1016/j.matpr.2022.04.529

Colak, M., Cetin, T., & Engin, B. (2015). Reasons for Inability of Organizations Furniture Industry to Get into International Markets. Procedia Economics and Finance, 26, 818–826. https://doi.org/10.1016/s2212-5671(15)00886-2

de Lima Mesquita, A., Barrero, N. G., Fiorelli, J., Christoforo, A. L., De Faria, L. J. G., & Lahr, F. A. R. (2018). Eco-particleboard manufactured from chemically treated fibrous vascular tissue of acai (Euterpe oleracea Mart.) Fruit: A new alternative for the particleboard industry with its potential application in civil construction and furniture. Industrial Crops and Products, 112, 644–651. https://doi.org/10.1016/j.indcrop.2017.12.074

Epede, M. B., & Wang, D. (2022). Competitiveness and upgrading in global value chains: A multiple-country analysis of the wooden furniture industry. Forest Policy and Economics, 140. https://doi.org/10.1016/j.forpol.2022.102737

Falheiro, M. S., Sato, A. K., Bigon, C. B., Souen, J. H., Nascimento, J. B. P., Martins, E., & Tsuzuki, M. S. G. (2022). Smart Configurator to Integrate Customized Furniture Design and Fabrication. IFAC-PapersOnLine, 55(2), 205–210. https://doi.org/https://doi.org/10.1016/j.ifacol.2022.04.194

Farooq, A., Valizadeh, S., Rhee, G. H., Lee, J., Jae, J., Jung, S. C., … Park, Y. K. (2022). Valorization of furniture industry-processed residue via catalytic pyrolysis with methane. Energy Conversion and Management, 261. https://doi.org/10.1016/j.enconman.2022.115652

Feil, A. A., de Quevedo, D. M., & Schreiber, D. (2015). Selection and identification of the indicators for quickly measuring sustainability in micro and small furniture industries. Sustainable Production and Consumption, 3, 34–44. https://doi.org/10.1016/j.spc.2015.08.006

Freitag, M., Westner, P., Schiller, C., Nunez, M. J., Gigante, F., & Berbegal, S. (2018). Agile Product-Service Design with VR-technology: A use case in the furniture industry. In Procedia CIRP (Vol. 73, pp. 114–119). Elsevier B.V. https://doi.org/10.1016/j.procir.2018.03.305

Guimarães, J. C. F. de, Severo, E. A., Dorion, E. C. H., Coallier, F., & Olea, P. M. (2016). The use of organizational resources for product innovation and organizational performance: A survey of the Brazilian furniture industry. International Journal of Production Economics, 180, 135–147. https://doi.org/10.1016/j.ijpe.2016.07.018

Han, X., Wen, Y., & Kant, S. (2009). The global competitiveness of the Chinese wooden furniture industry. Forest Policy and Economics, 11(8), 561–569. https://doi.org/10.1016/j.forpol.2009.07.006

Hisjam, Muh., Guritno, A. D., Supriyatno, N., & Tandjung, S. D. (2015). A Sustainable Partnership Model among Supply Chain Players in Wooden Furniture Industry Using Goal Programming. Agriculture and Agricultural Science Procedia, 3, 154–158. https://doi.org/10.1016/j.aaspro.2015.01.030

Iritani, D. R., Silva, D. A. L., Saavedra, Y. M. B., Grael, P. F. F., & Ometto, A. R. (2015). Sustainable strategies analysis through Life Cycle Assessment: A case study in a furniture industry. Journal of Cleaner Production, 96, 308–318. https://doi.org/10.1016/j.jclepro.2014.05.029

Jácome, N. R., Medina-Tovar, F., Rodríguez-Herás, J., Vásquez-Peñaloza, L., & Gómez-Charris, Y. (2021). Model for the development of innovation as a dynamic capability for an organization in the furniture industry. In Procedia Computer Science (Vol. 198, pp. 542–547). Elsevier B.V. https://doi.org/10.1016/j.procs.2021.12.283

Jaďuďová, J., Zelený, J., Marková, I., Tomaškinová, J., & Vicianová, J. H. (2015). Stakeholder Management as Part of Integrated Management System in the Furniture Industry. Procedia Economics and Finance, 34, 129–133. https://doi.org/10.1016/s2212-5671(15)01610-x

Jain, R., Bihari Rana, K., Lal Meena, M., & Sidh, S. (2020). Ergonomic assessment and hand tool redesign for the small scale furniture industry. In Materials Today: Proceedings (Vol. 44, pp. 4952–4955). Elsevier Ltd. https://doi.org/10.1016/j.matpr.2020.12.762

Kaba, K., Purnell, B., Liu, Y., Royall, P. G., & Alhnan, M. A. (2023). Computer numerical control (CNC) carving as an on-demand point-of-care manufacturing of solid dosage form: A digital alternative method for 3D printing. International Journal of Pharmaceutics, 645, 123390. https://doi.org/https://doi.org/10.1016/j.ijpharm.2023.123390

Koc, K. H., Erdinler, E. S., Hazir, E., & Öztürk, E. (2017). Effect of CNC application parameters on wooden surface quality. Measurement, 107, 12–18. https://doi.org/https://doi.org/10.1016/j.measurement.2017.05.001

Kostecka, Z., & Kopczewska, K. (2023). Spatial CRM and location strategy: E-commerce solutions in the furniture industry. Case of IKEA pick-up points in Poland. Electronic Commerce Research and Applications, 62, 101308. https://doi.org/https://doi.org/10.1016/j.elerap.2023.101308

Kremensas, A., Vaitkus, S., Vėjelis, S., Członka, S., & Kairytė, A. (2021). Hemp shivs and corn-starch-based biocomposite boards for furniture industry: Improvement of water resistance and reaction to fire. Industrial Crops and Products, 166. https://doi.org/10.1016/j.indcrop.2021.113477

Lengnick-Hall, C. A., Lengnick-Hall, M. L., & Abdinnour-Helm, S. (2004). The role of social and intellectual capital in achieving competitive advantage through enterprise resource planning (ERP) systems. Journal of Engineering and Technology Management, 21(4), 307–330. https://doi.org/https://doi.org/10.1016/j.jengtecman.2004.09.005

Linkosalmi, L., Husgafvel, R., Fomkin, A., Junnikkala, H., Witikkala, T., Kairi, M., & Dahl, O. (2016). Main factors influencing greenhouse gas emissions of wood-based furniture industry in Finland. Journal of Cleaner Production, 113, 596–605. https://doi.org/10.1016/j.jclepro.2015.11.091

Long, G. J., Lin, B. H., Cai, H. X., & Nong, G. Z. (2020). Developing an Artificial Intelligence (AI) Management System to Improve Product Quality and Production Efficiency in Furniture Manufacture. Procedia Computer Science, 166, 486–490. https://doi.org/https://doi.org/10.1016/j.procs.2020.02.060

Michalski, G. (2015). Relation Between Cash Levels and Debt in Small and Medium Wood and Furniture Industry Enterprises with Full Operating Cycle. Procedia Economics and Finance, 34, 469–476. https://doi.org/10.1016/s2212-5671(15)01656-1

Mirka, G. A. (2005). Development of an ergonomics guideline for the furniture manufacturing industry. In Applied Ergonomics (Vol. 36, pp. 241–247). Elsevier Ltd. https://doi.org/10.1016/j.apergo.2004.10.003

Navas-Alemán, L. (2011). The impact of operating in multiple value chains for upgrading: The case of the brazilian furniture and footwear industries. World Development, 39(8), 1386–1397. https://doi.org/10.1016/j.worlddev.2010.12.016

Ng, B. K., & Thiruchelvam, K. (2012). The dynamics of innovation in Malaysia's wooden furniture industry: Innovation actors and linkages. Forest Policy and Economics, 14(1), 107–118. https://doi.org/10.1016/j.forpol.2011.08.011

Nijdam, J. J., Agarwal, D., & Schon, B. S. (2022). An experimental assessment of filament-extrusion models used in slicer software for 3D food-printing applications. Journal of Food Engineering, 317, 110711. https://doi.org/https://doi.org/10.1016/j.jfoodeng.2021.110711

Oliveira, O., Gamboa, D., & Fernandes, P. (2016). An Information System for the Furniture Industry to Optimize the Cutting Process and the Waste Generated. In Procedia Computer Science (Vol. 100, pp. 711–716). Elsevier B.V. https://doi.org/10.1016/j.procs.2016.09.215

Oliveira, P. F., Calado, J. S., Sarraipa, J., & Jardim-Gonçalves, R. (2022). A Framework for Embedded Hardware on Furniture Smartification Design. IFAC-PapersOnLine, 55(2), 493–498. https://doi.org/https://doi.org/10.1016/j.ifacol.2022.04.242

Rabiei, F., & Yaghoubi, S. (2023). A comprehensive investigation on the influences of optimal CNC wood machining variables on surface quality and process time using GMDH neural network and bees optimization algorithm. Materials Today Communications, 36, 106482. https://doi.org/https://doi.org/10.1016/j.mtcomm.2023.106482

Ratnasingam, J., Ioras, F., & Abrudan, I. V. (2012). An evaluation of occupational accidents in the wooden furniture industry - A regional study in South East Asia. Safety Science, 50(5), 1190–1195. https://doi.org/10.1016/j.ssci.2011.12.035

Robb, D., & Xie, B. (2003). A survey of manufacturing strategy and technology in the Chinese furniture industry. European Management Journal, 21(4), 484–496. https://doi.org/10.1016/S0263-2373(03)00079-3

Scott, A. J. (2006). The Changing Global Geography of Low-Technology, Labor-Intensive Industry: Clothing, Footwear, and Furniture. World Development, 34(9), 1517–1536. https://doi.org/10.1016/j.worlddev.2006.01.003

Susanty, A., Sari, D. P., Budiawan, W., Sriyanto, & Kurniawan, H. (2016). Improving Green Supply Chain Management in the Furniture Industry Through Internet-Based Geographical Information System for Connecting the Producer of Wood Waste with Buyer. In Procedia Computer Science (Vol. 83, pp. 734–741). Elsevier B.V. https://doi.org/10.1016/j.procs.2016.04.161

Szczurek, A., Maciejewska, M., Zajiczek, Ż., & Mościcki, K. (2021). Detection of emissions from the combustion of wood-based materials being furniture industry waste. Atmospheric Pollution Research, 12(2), 375–385. https://doi.org/10.1016/j.apr.2020.11.018

Teng, W., Liu, W., Shao, X., & Wu, Q. (2023). Emission characteristics, environmental impact assessment,

and priority control strategies derived from VOCs' speciation source through measurement for the wooden furniture manufacturing industry in China. Science of The Total Environment, 162287. https://doi.org/10.1016/j.scitotenv.2023.162287

Tikul, N., Hokpunna, A., & Chawana, P. (2022). Improving indoor air quality in primary school buildings through optimized apertures and classroom furniture layouts. Journal of Building Engineering, 62, 105324. https://doi.org/https://doi.org/10.1016/j.jobe.2022.105324

Tsang, Y. P., Wu, C. H., Lin, K. Y., Tse, Y. K., Ho, G. T. S., & Lee, C. K. M. (2022). Unlocking the power of big data analytics in new product development: An intelligent product design framework in the furniture industry. Journal of Manufacturing Systems, 62, 777–791. https://doi.org/10.1016/j.jmsy.2021.02.003

Vaajasaari, K., Kulovaara, M., Joutti, A., Schultz, E., & Soljamo, K. (2004). Hazardous properties of paint residues from the furniture industry. Journal of Hazardous Materials, 106(2–3), 71–79. https://doi.org/10.1016/j.jhazmat.2003.11.004

Vicente, C., Silva, J. R., Santos, A. D., Silva, J. F., Mano, J. T., & Castro, L. M. (2023). Electrocoagulation treatment of furniture industry wastewater. Chemosphere, 328. https://doi.org/10.1016/j.chemosphere.2023.138500

Vidal, J. C., Mucientes, M., Bugarín, A., & Lama, M. (2011). Machine scheduling in the custom furniture industry through neuro-evolutionary hybridization. In Applied Soft Computing Journal (Vol. 11, pp. 1600–1613). https://doi.org/10.1016/j.asoc.2010.04.020

Werner, J., Aburaia, M., Raschendorfer, A., & Lackner, M. (2021). MeshSlicer: A 3D-Printing software for printing 3D models with a 6-axis industrial robot. Procedia CIRP, 99, 110–115. https://doi.org/https://doi.org/10.1016/j.procir.2021.03.018

Wu, Z., Zong, F., Zhang, F., Wang, J., Zhu, Z., Guo, X., & Cao, P. (2023). Investigation of the customized furniture industry's Production management systems. Journal of Engineering Research, 100072. https://doi.org/10.1016/j.jer.2023.100072