Review

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Strength, Durability and Aesthetics of Corner Joints and Edge Banding in Furniture Design: A Review

Zoran Vlaović, Tomislav Gržan *, Ivica Župčić, Danijela Domljan and Goran Mihulja

University of Zagreb, Faculty of Forestry and Wood Technology, 10000 Zagreb, Croatia
* Correspondence: tgrzan@sumfak.unizg.hr

Abstract: Corner joints and edge banding play crucial roles in the strength, durability, and aesthetics of furniture made from particleboards. This review highlights the importance of edge banding on corner joints in enhancing the overall quality of panel furniture. The choice of joint type, materials, and construction techniques can significantly influence the overall appearance and design of the furniture. The quality and design of corner joints directly affect the durability and longevity of furniture. Strong and well-designed corner joints ensure that furniture can withstand various forces and loads without failure or deformation. In addition, corner joints contribute to the aesthetics of furniture by providing seamless and visually appealing connections between different elements. Edge banding plays a crucial role in influencing the strength of corner joints in the furniture. Different edge-banding materials have varying levels of resistance to impact, scratches, and abrasion, which protect furniture surfaces. Overall, edge banding not only enhances the visual appeal of furniture, but also ensures its durability and longevity, both in the service of its purpose and during disassembly and/or transport due to the remodeling of the living space or its relocation. The findings aim to unify the knowledge and set parameters for further research on the quality of corner joints and edge bands in particleboard furniture.

Keywords: edge banding; corner joints; furniture design; strength; durability; aesthetics; particleboard; glue

1. Introduction

The introduction Corner joints and edge bandings play a key role in the overall quality of furniture made from particleboards, especially in improving the strength, aesthetics, protection, and structural integrity of the furniture. The choice of joint type, materials, and construction techniques can significantly influence the overall appearance and design of the furniture. Therefore, paying attention to the strength and aesthetics of corner joints and edge bands is essential for creating high-quality visually pleasing furniture. They are the primary connection points between different components, such as panels and frames, and are responsible for providing rigidity and structural integrity to the furniture.

The quality and design of corner joints directly affect the durability and longevity of furniture. Strong and well-designed corner joints ensure that furniture can withstand various forces and loads without failure or deformation. In addition, corner joints contribute to the aesthetics of furniture by providing seamless and visually appealing connections between different elements.

Edge banding plays a crucial role in influencing the strength of corner joints in the furniture. Jivkov [1] highlighted that edge banding affects the bending strength of the end-corner joints in particleboard furniture. Cai and Wang [2] emphasized that the stiffness of corner joints in furniture is influenced by edge banding, as discussed in research on case furniture. Factors such as the type, thickness, and material of edge banding, as well as the gluing parameters, angularity of boards, and panel properties, all contribute to determining the overall quality of joints in furniture.

The choice of edge-banding materials, such as polyvinyl chloride (PVC), melamine, or wood veneers, can affect the overall look and feel of furniture [3]. It is used to cover the exposed sides of wood materials such as plywood, particleboard, and medium-density fiberboard (MDF), giving the appearance of a solid or more valuable material [4]. Miškinytė and Juknelevičius [5] highlights the importance of edge-banding materials and their thickness in improving the quality of furniture. Zhou et al. [4] identified potential factors leading to edge-banding cracking in panel furniture, emphasizing the need for proper wood moisture content and adhesives. Different edge banding materials have varying levels of resistance to impacts, scratches, and abrasion, providing protection to the furniture surface. Edge banding helps to suppress the absorption of water and humidity, preventing damage to furniture [5,6]. For some materials, such as particleboard, which has a lower resistance to delamination, the presence of some edge material certainly increases this resistance, but also increases the resistance of the edge to impact, preventing damage to the edge when assembling/disassembling furniture. Even so, if the strength of edge bending (edge material and its bonding to the base material) is sufficiently high, it can also be expected to strengthen the joints and corners of the furniture, improving its structural integrity. Overall, edge banding not only enhances the visual appeal of furniture, but also ensures its durability and longevity.

Studies have specifically examined the effects of adhesives, wood species, and modifications on the withdrawal strength and durability of dowels and their interactions with wood composite materials [7–12]. Research includes the impact of dowel materials, diameter, and direction of withdrawal strength, particularly the withdrawal strength from the faces and edges of materials, such as MDF and particleboard, highlighting the influence of material properties and manufacturing processes. The polyurethane adhesive (PUR-D4) demonstrated a higher embedded strength than polyvinyl acetate (PVAC-D4), with PUR-D4 expanding to fill gaps and enhance mechanical adhesion [11,12]. According to the above-mentioned papers, respecting the mutual differences of the experiments, beech dowels exhibited the highest embedded strength, attributed to the density and structural properties of the wood, while Scots pine dowels showed lower strength due to their lower density and structural characteristics. The thickness of PVC edge banding significantly influenced embedded strength, with 0.8 mm thickness showing superior performance over 1 mm and 2 mm thicknesses, suggesting that thinner edge banding may provide better adhesion and mechanical strength.

This study aims to review previous research and highlight the importance of using edge-banding on corner joints to increase the strength, visual aesthetics, protection, and structural integrity of furniture made of wooden panels, especially particleboards. The purpose of the analysis of previous research was to unify the knowledge and set parameters for further research on the quality of corner joints and edge bands on wooden panels and furniture made of particleboards.

Also, this study represents the first phase of research within the project "The role of edge covering in the aesthetic and technical improvement of panel furniture", which is carried out at the Faculty of Forestry and Wood Technology University of Zagreb, funded by the Ministry of Science and Education, Republic of Croatia.

2. Methods

A targeted literature search was conducted across key databases including the Web of Science Core Collection (WoS CC), Scopus, and Google Scholar, focusing on open-access scientific resources in the technical, biotechnical, natural, and interdisciplinary sciences. The search strategy employed both controlled vocabulary and keywords, with the main search concepts being "edge-banding," "corner joints," "corner joint visual design," "particleboard," and "adhesive application techniques." No filters were applied to limit the retrieval by study type, but editorials, letters, newspaper articles, and opinion pieces were excluded. Where possible, the search was restricted to English-language documents published between January 1, 1993, and January 31, 2024.

A single reviewer screened and selected studies. Initially, titles and abstracts were scrutinized, and potentially relevant articles were retrieved for further analysis. Full-text articles were then evaluated based on the inclusion criteria outlined in Table 1. Articles were excluded if they did not meet the selection criteria described in Table 1, were duplicate publications, or were published prior to 1993.

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Table 1. Studies selection criteria.

Criteria	Description
Subject	Furniture design studies or material sciences, specifically focusing on edge-banding and corner joints in wood materials, including particleboard, medium-density fiberboard (MDF), and similar materials used in furniture design and manufacturing.
Intervention	Studies examining the application of edge-banding techniques and adhesive methods to corner joints, specifically aimed at improving visual design and structural stability in wood-based materials.
Comparator	Studies comparing traditional or alternative methods of edge-banding and adhesive application to untreated wood or particleboard edges, including various techniques for edge-banding and corner joints or variations in adhesive methods.
Outcomes	Measures of adhesive performance, edge-banding durability, aesthetic quality of corner joints, structural integrity, and ease of application during manufacturing, including strength, durability, adhesion quality, and overall effectiveness in furniture design
Study designes	Experimental studies, case studies, technical reports, and systematic reviews relevant to adhesive and edge-banding technology, including design comparisons and investigations specifically focused on edge-banding and corner joints.

3. Results and Discussion

In the analysis, the studies that dealt with the research on corner joints and those that described the research results on edge banding were separated. Although corner joints and edge bands in particleboard furniture are often interdependent, most studies separate these two concepts, and research rarely unites them to achieve interdisciplinary parameters of aesthetics and overall product quality. Therefore, the articles were first divided into two groups: those that investigated the parameters and application of edge bands (e.g., studies that investigated the influence of particleboard processing on the joint with the edge band, the influence of the type of glue, and the technique of applying glue on the quality of the glued joint), and studies that dealt with the research of corner joints (e.g., investigate the influence of different types of corner joints and numerous factors on the overall strength, load-bearing capacity, and durability of particleboard furniture, or investigate the influence of the design of corner joints on the visual appeal of particleboard furniture). Finally, key points and cluster possibilities for further research are discussed.

Several types of corner joints are commonly used in furniture construction, such as dowel joints, biscuit joints, confirmat screw joints, and cam lock joints. The type of joint, such as dowel joints, and factors such as dowel size and edge-banding thickness are crucial for furniture strength. Dowel joints connect elements with wooden dowels and glue to provide a strong and durable joint. A biscuit joint is a type of joinery technique that involves connecting furniture elements with oval-shaped solid beech wood biscuits inserted in slots and glued with the ability to create strong, invisible joints. Confirmat screw joints using specialized screws were inserted into the pre-drilled holes to provide a secure connection. Each type of joint has advantages and considerations, such as the materials being joined, the desired strength and durability, and the aesthetic preferences of the furniture manufacturer. The factors known to influence corner joint strength include the type of joint, adhesive

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used, and base material. Different types of joints, such as single-dowel, double-gluing, and grooved-dowel joints, can significantly affect the strength of the joints. The use of proper adhesives and gluing techniques can improve the nominal strength of joints. Thoroughly covering the walls of dowel holes with adhesives is important for maximizing connection strength [3,13–16]. The type of base material, such as particleboard or medium-density fiberboard (MDF), can also affect the strength of the corner joints. The density and gradation of the materials used in furniture can significantly affect the joint strength. Acrylonitrile butadiene styrene (ABS), polyvinyl chloride (PVC), melamine, and wood veneers are commonly used for edge bending. ABS are known for their impact resistance, durability, and overall appearance. PVC edge banding is manufactured using high-impact modifiers that provide excellent machinability and impact resistance. Melamine-impregnated paper is absorbed with resin and covered with a lacquer surface, resulting in a high strength and resistance to impacts, scratches, and abrasion. Wood veneer edge banding is performed on slices of real wood, allowing it to be painted or varnished to match other furniture parts [3–6]. Each material has unique properties and advantages, making it suitable for different applications in edge-banding.

3.1. Edge Band Studies

Edge banding, particularly melamine, has been found to improve the strength of corner joints in furniture, particularly in tension and compression tests [3]. This improvement in strength is further enhanced when using coated MDF with edge banding, because it can increase the load-bearing capacity and service life of cabinets [17]. The use of rebated and covered edges in case furniture can further enhance the tension and compressive strength of corner joints [18] However, [19], in their research on corner joints constructed with wood biscuits, found that the strength of corner joints was primarily derived from the edge gluing of the face and butt member, rather than the glued biscuits. Tankut and Tankut [3] found that melamine-edge-banding material provided better structural integration and higher strength compared to PVC and wood-veneer edge-banding materials with the positive role of its 0.4 mm edge banding on 18 mm particleboard of corner joints in case furniture. Miškinytė and Juknelevičius [5] found that the type and thickness of the edge-banding material can influence the bending and tensile strength of the particleboard, which in turn can affect the quality of different glued joints.

Different methods can be found in the literature to investigate edge bonding quality: from a pull-off test in accordance with EN ISO 4624:2017 to measure the force required to detach the edge band from the wood-based panel Džinčić and Palija [20]; or EN 28510-1:2014, which involves peeling of glued flexible and rigid specimens together at an angle of 90° [5]; or EN 311:2004 standard, which, among others, specifies assessing the surface soundness of coated wood-based panels and uncoated particle boards, used to determine the adhesion of the edge banding to the particleboard samples [21]; and up to the test on the peel strength of PVC edge bands on curved edge parts in accordance with Chinese standard QB/T3655 [22].

The Influence of the Type of Glue on Quality of the Glued Joint

The type of glue used in furniture construction significantly affects the strength and durability of joints. Different types of glue have different adhesive properties and bonding strengths, which can affect joints of different edge bend material and or overall furniture joint performance. Altinok et al. [23] found that the combined use of dowel and spline joints with polyvinyl acetate (PVAC) glue resulted in the highest tension strength in the corner joints. Tankut and Tankut [14] further emphasized the importance of the glue type, with PVAC adhesive leading to higher diagonal tension and compression strength in case-type furniture corner joints. Dizel and Uzun [24] investigated the gluing of a wooden edge strip to the edge of a particleboard and found that the use of a PVAC adhesive resulted in the highest bonding strength. Imirzi et al. [25] further emphasized the importance of the type of adhesive, where the PVAC adhesive along with the screw provides the highest moment-carrying capacity in L-type corner joints. Therefore, it is crucial to consider glue application techniques, surface quality, and edge-banding materials when aiming for high-quality glued joints in furniture design.

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Different glue application techniques can also affect the quality of the glued joint of the edge band on a three-layer particleboard in the furniture design. The surface quality of the particleboard plays a significant role in the wetting and adhesion of glue. Preparation of the surface before gluing can affect superficial deterioration and local weaknesses in the joint [26]. Hlavatý and Tesařová [27] highlighted the potential impact of temperature on the stability of glue joints, with a decrease in the joint stability observed at higher temperatures. Tankut and Tankut [3] explained the correlation between pressure and tension forces on adhesive tapes and quality of furniture. Džinčić and Palija [20] pointed out the variability in glue applications owing to gaps between the edge material and the application roller due to deviation of the edge to the wider side of the panel in terms of the angle and straightness of the joint, which occurred during the milling process before the edge banding and can lead to uneven adhesive layers with potentially weaker bonds.

The Influence of the Edge Surface Treatment of Three-Layer Particleboard

The quality of gluing the edge band to the three-layer particleboard was influenced by the processing method used. Szwajka and Trzepieciński [26] found that the cutting speed and feed per tooth during milling can affect the delamination factor, which may in turn affect the quality of gluing. Denkena et al. [28]further emphasized the importance of cutting-edge design, with rounded cutting edges improving the tool life and product quality. The state of the edge of particleboard is an important criterion for assessing the quality of wood-based materials [4]. According to Sales et al. [29], the thickness of the glue joint is related to the surface quality, and it is important to determine the optimal machining conditions for preparing the surface for gluing. Sawing and milling can damage the laminate in the vicinity of the processing zone and bead of the particleboard edge, leading to delamination during machining [26]. Wear of the cutting tool also plays a significant role in the delamination process [6]. Therefore, the processing method and tool wear should be carefully considered to minimize delamination and ensure the quality of gluing the edge band on the three-layer particleboard. The findings of Džinčić and Palija [20] have significant practical implications for the edge-bonding quality. This study highlights the critical influence of panel squareness on edge bonding strength, suggesting that maintaining minimal angular deviation during manufacturing can enhance joint strength. In particular, the influence of squareness after processing using pre-cutters and the position of the glue application roller were investigated. This insight is crucial for manufacturers aiming to improve product durability and reduce failure rate. The lack of defined minimum strength standards for edge bonding in existing regulations underscores the need for industry-wide benchmarks to ensure consistent quality.

These findings collectively suggest that the selection of glue, application technique, preparation of gluing surface, and gluing parameters are crucial in ensuring the strength and durability of edge banding.

Edge banding improves corner joint strength compared with unbanded joints in cabinet furniture. The ultimate strength of cabinets constructed with edge banding was found to be 1.8 times greater than that of cabinets made without edge banding [17]. Based on the results of Tankut and Tankut [3], cabinets made of melamine-coated MDF with edge bands had a higher load-bearing capacity than cabinets made of uncoated MDF without edge bands. The type of edge-banding material used also has a significant impact on the strength of the corner joints, with melamine edge-banding material providing the highest diagonal tension and compression strength [4].

During the testing of the edge bonding quality (EN ISO 4624:2017), several factors were considered: the squareness of wood-based panels after processing by pre-cutters, position of the glue application roller, and angular deviation of the edge to the wider side of the panel. The properties of the particleboard (density, moisture content, and delamination strength of the layers) were considered but were not directly investigated [20]. The influence of gluing parameters, including the glue temperature and method of application, was found to affect the bonding quality. The research indicated that the optimal glue temperature for the EVA adhesive used in this study was 210 °C, with an application quantity of 110 g/m ^{2} and a feed speed of 15 m/min. The gluing parameters were controlled using an automatic edge-banding machine. Variations in these parameters can lead to

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changes in the bonding strength, with the highest strength observed in the samples with the smallest angular deviation from the edge to the wider side of the panel. The study also highlighted that the properties of the glue, such as its ability to fill gaps, are crucial, as evidenced by the performance of EVA glues in accommodating a gap created by a 2° slope.

The study in [5] utilized SolidWorks simulation for both static and thermal analysis, applying mathematical finite element method (FEM) virtual modelling to assess the mechanical properties of ABS and oak veneer lamination materials, suggesting that oak veneer edges offer superior mechanical properties and adhesion to particleboard compared to ABS edges. During the peel-off testing phase (EN 28510-1:2014), researchers considered mechanical properties, such as resistance to peeling forces, which were evaluated using a standard test method. The thickness of the lamination material is another critical factor, as it was hypothesized to influence the strength and quality of the furniture. Their research indicated that a thicker edge band (i.e., 2 mm oak veneer) could potentially enhance the strength and quality of the furniture, as well as improve its resistance to peeling forces. Static analysis showed that the probability of deformation of furniture boards/elements decreased with thicker lamination, suggesting that thicker edges adhered more strongly to the particleboard. Additionally, thermal analysis revealed that the 2 mm thick ABS edge was the most heat-resistant, while the 1 mm thick oak veneer edge retained the most heat, indicating that the thickness also affected the thermal properties of the materials. This research also highlights the importance of considering the elasticity of lamination materials, especially for curved parts, where ABS's higher modulus of elasticity of ABS could reduce lamination issues.

The findings of Lyu et al. [22] have significant practical implications for the furniture manufacturing industry, particularly for small- and medium-sized enterprises specializing in panel furniture with curved edges. The optimal technical parameters were identified: temperature of applying EVA glue at 140-150 °C, glue dosage of 363-379 g/m^2, and feed rate of 13-15 m/min – can be directly applied to improve the peel strength of PVC edge bands, thereby enhancing product durability and reducing failure rates during use. This study also highlights the importance of maintaining these parameters within specific ranges to avoid issues such as insufficient peel strength due to premature drying of the adhesive or inadequate pressure application, which are critical for ensuring the quality and longevity of edge-banded furniture components. This study is structured into three separate experiments, each focusing on one of these factors. The glue dosage was carefully measured to balance between sufficient bond strength and the avoidance of quality issues, such as glue line and glue stain. The feed rate was assessed to find a balance between the adhesive opening time and the workers' ability to apply proper pressure, which is crucial for achieving adequate peel strength without causing edge breakage. A universal testing machine was used for the peel tests, with the peel speed set to 48 mm/min. The results were calculated and analyzed according to the Chinese standard QB/T3655.

Saçli [6] showed that the type and thickness of edge-banding materials, as well as the duration of heat exposure, substantially affect the bending and tensile strength of MCP, with thicker PVC edge banding showing increased strength over time. This knowledge can guide manufacturers to select appropriate edge-banding materials and thicknesses to enhance furniture durability and performance. PVC (0.4, 0.8, 1, and 2 mm) and melamine (0.4 mm) were used as edge-banding materials. The edge bands were affixed using hot-melt adhesive with iron at 200 °C for melamine and with an auto edge banding machine for PVC (at 200 °C and feed speed of 12 m/min). The mechanical properties, including the bending and tensile strengths, were measured using a universal testing machine 20, 30, 40 and 50 days after edge-bending and product weathering treatment of different indoor temperatures. Edge banding significantly influences the bending and tensile strengths of melamine-coated particleboards (MCP). Thicker PVC edge bands, specifically 2 mm, have been shown to provide the highest bending and tensile strengths after 50 days, indicating that edge banding can effectively enhance the mechanical properties of MCP over time. Conversely, non-banding or the use of thinner edge bands, such as 0.4 mm melamine, results in lower strength.

Borysiuk et al. [21] indicated that the choice of edge band material and thickness has a significant impact on the mechanical and physical properties of particleboard slats, which are critical in furniture design and manufacturing. Contrary to expectations, the use of 2 mm thick PVC and ABS edges notably reduced the modulus of rupture (MOR) and modulus of elasticity (MOE), which could influence the structural integrity and load-bearing capacity of furniture components. Additionally, these materials significantly limit swelling and water absorption, thereby enhancing the durability of the furniture under humid conditions. However, the susceptibility of PVC and ABS to deformation compared to other materials, such as veneers, must be considered in applications where dimensional stability is crucial. This study underscores the need for further research on the influence of edge bands on furniture strength, particularly for narrow slats, to inform the material selection and design decisions in the furniture industry. The application of 2 mm thick PVC and ABS edges decreased the MOR and MOE values, potentially affecting the structural integrity of furniture components. Despite this, 1 mm thick PVC and ABS edges exhibit the best adhesion to particleboard when using EVA hot-melt adhesive, indicating a strong bond and finish quality. It is important to note that the adhesion of the edges was tested using different methods in various tests, which could influence the outcomes. It is also important to consider environmental implications, as PVC waste requires specialized processing owing to the release of toxic compounds upon uncontrolled burning, whereas ABS is safer for human health and the environment. ABS edges are gaining popularity for ecological reasons, despite PVC's current market dominance due to its lower cost.

Özcan et al. [8] and Kurt et al. [7] were motivated by the increased use of composite materials and wooden dowels in furniture. However, they noted a lack of detailed information on the best ways to combine these materials to achieve the maximum strength. This study tested dowels made from different types of wood, including beech, oak, mulberry, apple, and fir, to determine which works best with particleboard and MDF. Dowels with different diameters (6, 8, and 10 mm) were tested to determine how well they were held on boards when bonded with two types of adhesives: PVAC and polyurethane (desmodur-vinyl trieketonol acetate [D-VTKA]). The researchers followed specific standards, such as TS 4539 for testing the withdrawal strength and ASTM 1037 for setting the loading rate during the tests, ensuring the consistency and reliability of the methodology. The results showed that the face direction in MDF had the highest withdrawal strength, D-VTKA adhesive outperformed PVAC adhesive in terms of withdrawal strength, and MDF showed better results than particleboard owing to its higher density and more homogeneous structure. Similar to the previous two papers, Karaman [12] tested dowels made from five different types of wood–beech, Scots pine, Turkish fir, chestnut, and olive–to see how well they worked when used in particleboards for furniture making. PVC edge banding with thicknesses of 0.8 mm, 1 mm, and 2 mm was used to understand its impact on the strength of the dowel joints in the particleboard, by using two types of water-resistant adhesives: polyvinyl acetate (PVAC-D4) and polyurethane (PUR-D4). The study found that dowels made from beech wood and bonded with polyurethane adhesive showed the highest strength, while PVC edge banding with a thickness of 0.8 mm significantly increased the strength of the dowel joints compared to other thicknesses, indicating that thinner edge banding performs better in this application.

Merdzhanov [10] optimized the edge-banding process by developing mathematical models and a computerized program that could predict the best settings for different materials, ensuring that the adhesive layer was minimal, and the bond strength was maximized under varying conditions. This study aimed to understand how well different types of edge-banding materials stick to particleboards when using a specific hot-melt adhesive, focusing on determining the best conditions for a strong bond by examining various factors such as the glue amount, temperature, and pressure applied during the process. This study tested three types of edge-banding materials on particleboards: beech veneer edge strips, melamine edge foil, and PVC edge foil. The adhesive compound was applied with a tensile load perpendicular to the veneering surface using a T-shaped steel body attached to the edge material by a cyanoacrylate adhesive to evenly spread the tensile forces. The author found that not all materials worked in the same way; therefore, he had to adjust the glue temperature and pressure to obtain the best stickiness. For example, melamine foil requires higher pressure when the glue is hotter, and PVC materials work best at a specific temperature and lower pressure.

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Kubit et al. [11] wanted to understand whether increasing the thickness of the glue layer at certain points could help absorb more energy and reduce the risk of joint breakage under repeated use, which is crucial for industries that require lightweight and strong connections. This study explored how making small changes to the edges of the parts being glued together can significantly improve how long and well they hold up under repeated use. Specifically, it looks at adding a slant (chamfer) or rounded edge (fillet) to the part where the glue is applied, aiming to make the glue layer thicker in spots where stress is high, which helps the joint last longer and perform better under fatigue or repeated stress. Researchers have conducted tests using a special machine that shakes parts at a specific frequency to mimic the stress of repeated use. They found that these small changes, especially the rounded edge, greatly increased the strength and lifetime of the glued joints under stress, showing a notable improvement in how the glue absorbs energy and handles stress without breaking. The best improvement was observed with a rounded edge (fillet R2), which made the glued joint last over three times longer and increased its strength by 33.1 % compared to a standard joint without these modifications. This improvement occurs because the changes in shape help spread the stress and allow the glue to absorb more energy, which slows down the damage caused by repeated bending and pulling.

3.2. Corner Joints Studies

When selecting corner joints for particleboard furniture, trade-offs exist between the strength, durability, and aesthetics. Research indicates that the type of fastener used significantly affects joint strength and bending moment resistance [30]. For instance, cam connecting fittings and glued dowel joints can enhance strength but may not be as durable as other options [31]. Additionally, the thickness of the edge-banding materials can influence the joint strength under compression tests, highlighting the importance of material choice for durability [1]. Moreover, the number and spacing of dowels in ready-to-assemble furniture joints can affect the bending moment capacity, showcasing the interplay between the strength and aesthetics [32]. Therefore, when choosing corner joints, it is crucial to balance these factors to achieve the desired strength, durability, and visual appeal of the particleboard furniture.

The Influence of Different Types of Corner Joints to the Overall Strength and Durability of Particleboard Furniture

The corner joint design choices affect the overall strength of particleboard furniture. Particleboards exhibit higher creep deflection under cyclic conditions, indicating susceptibility to stress over time. However, certain joint types can mitigate this effect [33]. Research has shown that factors such as the type of composite board, gluing technique, and spacing between fitting elements such as biscuits or dowels play a crucial role in determining the strength of corner joints in particleboard furniture [9,34,35]. For example, corner joints constructed with wood biscuits glued in slots tend to be stronger than those made with plastic biscuits, demonstrating the importance of material and construction method choices [36]. Glued-in dowel joints show lower strength loss after cyclic loading than other types of joints [37]. Additionally, the spacing between biscuits in multiple-biscuit corner joints can affect the total strength in tension and compression tests, highlighting the need for strategic design decisions to optimize the strength and durability of particleboard furniture joints [19]. Using wood biscuits with edge-banded MDF, joints are stiffer than those constructed with edge-banded particleboards [9,30]. The bending moment capacity of corner joints increases with the number of dowels and decreases with a certain dowel spacing. Tankut and Tankut [19] showed that the composite board used influences the strength of the joints, with melamine-coated fiberboards exhibiting a 40 % higher bending moment resistance than melamine-coated particleboards.

The type of fastener used, quality of the particleboard, and method of loading affect the joint capacity and bending moment resistance [30,38]. By comparing the strengths of different types of corner joints using various fittings and inserts, Prekrat et al. [39] explained how each element of an angle joint affects and contributes to durability. The strength of corner joints varies with the type of fastener used, impacting the technical quality of the furniture. For example, confirmat screws exhibited the highest strength among the tested fasteners, providing four times the momentum value compared to the weakest connection with the Lamello Clamex fittings. This suggests that confirmats are particularly suitable for applications requiring a high load-bearing capacity, but they are aesthetically less acceptable than dowels or elliptical fittings unless the screw head is hidden. In contrast, Lamello Clamex P 15 and Lamello Invis Mx offer lower strength values, indicating their suitability for lighter applications. The Minifix bolts, which are 34 and 24 mm in size, show a nuanced difference in strength, with the longer bolt slightly outperforming the shorter bolt, although the difference is not significant. As a supplement to previous research, Imirzi et al. [25] found that particleboard demonstrated lower moment-carrying capacities than other wood and wood-based materials, indicating a relatively weaker performance in load-bearing applications. When applied to particleboards, the Minifix fasteners produced the lowest moment-carrying capacity values, suggesting that the choice of fastener type is crucial for enhancing the structural integrity of the corner joints. In addition, the Clamex P fasteners exhibited high-resistance characteristics in diagonal compression and withdrawal tests, which could imply a potential for better performance in joints under specific conditions. However, the inherent material properties of particleboard, such as its susceptibility to breakage owing to excessive channel widths, can negatively impact the overall performance and durability of the joint. This analysis underscores the importance of selecting an appropriate fastener type based on the specific load requirements and structural considerations of furniture design.

Miter corner joints, studied in [31], when compared to conventional cam-connecting fittings and screw joints, exhibit a superior load-bearing capacity, enhancing the overall strength of the furniture by 8.1 and 2.6 times, respectively. This is attributed to the efficient utilization of the mechanical characteristics of the particleboard, particularly when the joints are bonded with the PVAC adhesive and the surface is veneered. Veneering the particleboard not only increases the aesthetic appeal, but also strengthens the outer layer, thereby improving the joint's capacity to carry loads by 19.5 %. The application of thin veneer overlays on particleboards reduces creep potential, indirectly mitigating warping over time [40]. The application of adhesive joints in furniture construction contributes to a longer exploitation duration and higher load tolerance than those of dismantlable joints. However, despite the enhanced strength and aesthetic benefits of miter joints, their complexity in manufacturing and assembly limits their widespread application in furniture with large dimensions and complex construction. The strength of furniture corner joints is primarily derived from edge gluing of the face and butt members, emphasizing the importance of joint tightness for durability [19]. The polyurethane adhesive provides a higher bending strength for the corner joints than the PVAC adhesive, indicating that superior glue quality enhances joint durability [36].

The Influence of Different Factors on Load-Bearing Capacity and Failure Points Specific to Particleboard Corner Joints

Factors such as the type of joint reinforcement, such as wood biscuits, significantly impact the failure load and strength of the joints [34,41]. The type of material used, whether particleboard or MDF, and the specific insert fittings utilized in the joints play a crucial role in determining the bending strength of the furniture corner joints [19]. The manner in which the joints are loaded, the gluing techniques employed, and the distribution of stresses within the joint also affect the failure points and load-bearing capacity of the corner joints [30].

Increasing the number of dowels enhances the bending moment resistance, indicating a direct correlation between dowel quantity and joint strength. Optimal dowel spacing is also critical, while increasing the spacing up to 160 mm improves the moment resistance, and further increasing it to 192 mm reduces it, suggesting a nonlinear relationship between dowel spacing and joint performance [42]. Moreover, the type of board material affects the load-bearing capacity, with melamine-coated fiberboards demonstrating superior bending moment resistance compared to melamine-coated particleboards, which is attributed to better adhesive interactions and material properties.

The load-bearing capacity and failure points of particleboard corner joints are also influenced by the moisture content of the environment, the type of adhesive used, and the method of joint construction, according to [40]. Higher humidity environments (with 90 % relative humidity compared to a dry environment with 45 % relative humidity) during the gluing process significantly increased the load-carrying capacity and stiffness of the glued dowel joints on the particleboard. This was attributed to the more effective penetration of the polyurethane adhesive and swelling of the dowel and particleboard, which resulted in a stronger joint. The mechanical properties of these joints, including their failure points, are affected by the type of mechanical fasteners and the joining method, with demountable joints showing a higher loading capacity under varying humidity conditions.

Kasal et al [32] found that corner joints are significantly influenced by the number of screws, screw size (diameter and length), and loading type (compression or tension). Specifically, increasing the number of screws enhanced the moment resistance of the particleboard corner joints, with a notable improvement observed when four screws were used compared with two or three screws. Screw length had a more pronounced effect on bending moment resistance than screw diameter, indicating that longer screws contributed more effectively to joint strength. However, the observed joints exhibited a differential response to loading types, whereas there was no significant difference in moment resistance between compression and tension loadings for joints connected with 2 mm to 5 mm diameter screws. Particleboard joints with 5 mm diameter screws with a length of 60 mm showed significantly greater moment resistance to compression loads than to tension loads. The failure modes for these corner joints typically involve the crushing of screw heads into the face member, followed by screw withdrawal from the butt members along with base material and edge splitting around the screws.

According to [1], the load-bearing capacity of particleboard corner joints is significantly influenced by the presence and thickness of edge banding. Edge banding enhances the bending strength under compression tests, with a thickness of 0.4 mm being sufficient for Minifix and Rafix connectors to achieve 15-25 % higher bending strength. The type of edging material, specifically the ABS band, and its application process also play a crucial role in the joint strength. Furthermore, the ultimate bending moment, which is a critical measure of the load-bearing capacity, was positively affected by edge banding, as evidenced by the statistical analysis of different joint types. Notably, edge banding prevents the splitting of the particleboard edge, which is a common failure point in unedged joints, thereby enhancing the overall structural integrity of the furniture.

Influences of Corner Joint Design to Visual Appeal of Particleboard Furniture

In the context of panel furniture manufacturing, the aesthetic components of corner joints are crucial for the overall appearance and consumer satisfaction. The quality of edge banding, which includes corner joints, significantly affects the aesthetic appeal of furniture, with defects such as edge collapse, glue leakage, and uneven trimming directly impacting the appearance of furniture. Specifically, for corner joints, rounded corners are an essential aesthetic component as well as safety, where edge banding with a thick edge on both sides should feature a radius of at least 1.5 mm to prevent hand scratching, indicating the importance of smooth transitions and safety in design. It should be emphasized that the possibility of edge damage to furniture is reduced if this radius exists because it is more difficult to catch the edge material and mechanical damage if it is not rounded. This detail underscores the critical role of precision in the edge-banding process, particularly at corner joints, in enhancing the visual and tactile qualities of furniture [43]. For example, according to Rechner et al. (2009) (quoted in [44]), zero-joint edge banding technology enhances aesthetic quality by providing an invisible gluing joint line, which is not achievable with conventional edge banding methods. This technology ensures a flawless transition between the edge band and the board surface, making the joint appear seamless to the human eye, thereby improving the furniture's visual appeal. The resistance of the adhesive bond to aging is increased, minimizing the impact of external influences such as water or dirt, which further contributes to the aesthetic durability of the corner joint. Aging significantly affects the aesthetics of edge-banded furniture, particularly at corners, where exposure to moisture is the most critical factor. Over time, visual appearance can deteriorate owing to factors such as discoloration, rough surfaces, and gloss changes, which are more pronounced in conventional edge-banding than in zero-joint technologies. Zero-joint edge banding,

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which avoids the use of conventional hot-melt adhesives, offers a seamless appearance that is less susceptible to the aging effects of external influences such as water or dirt, thereby maintaining a more consistent aesthetic appeal over time [44]. The thickness swelling of the zero joints was significantly lower after moisture exposure, highlighting the effectiveness of edge sealing in enhancing joint durability against moisture [45].

5. Conclusions

This review offers valuable insights into enhancing the quality of edge bandings and corner joints in furniture made from wood-based materials, identifying potential areas for further research in material properties, adhesive types, and application methods. The review of the literature covered several key factors, however, guidance for further research can be found in three directions in which there is a lack of knowledge for more effective application of materials and edge bending procedures. These are primarily comparisons of the use of possible different methods of applying edge materials, which should be observed through two different edge materials such as wood in the form of slats or veneers and "its substitute" ABS. Secondly, the need to compare different types of adhesives for the same or different application procedures, again divided into edge materials, can be highlighted. The third direction of research that would enrich the user's knowledge and contribute to a comprehensive understanding of the application of edge materials refers to the comparison of different application techniques on the strength of corner joints and aesthetic properties in furniture production.

Finally, this study provides a comprehensive overview and provides guidelines for further research on the quality parameters in panel furniture (Figure 1). So, the mutual influence between edge-banding techniques and adhesive performance can enhance quality parameters in furniture design, emphasizing the importance of effective integration for better aesthetic and structural outcomes. Both aesthetic and functional aspects of edge-banding and corner joints are crucial for consumer satisfaction and market competitiveness. The durability and visual appeal of these joints significantly impact overall furniture quality. Also, a shift towards sustainable practices is evident, with an increasing focus on biodegradable adhesives and innovative materials in response to environmental concerns.

In order to advance the field, future research should concentrate on the following areas:

- Comparison of edge materials: Investigating different methods for applying edge materials, focusing on wood slats or veneers versus ABS. Understanding the performance implications of these materials can improve edge-banding procedures.
- Adhesive evaluation: Comparing various adhesive types across the same or different application procedures, considering the implications for edge materials. This will help identify the most effective adhesives for specific applications.
- Application techniques: Researching the impact of different application techniques on the strength and aesthetic properties of corner joints. This comparison will enhance knowledge of edge banding effectiveness in furniture design.
- Interdisciplinary collaboration: Encouraging collaboration across disciplines such as material science, engineering, and design to advance edge-banding techniques and adhesive applications that meet industry needs.
- Long-term performance evaluation: Conducting longitudinal studies to assess the durability and performance of new edge-banding methods and adhesives over time, providing insights into the lifecycle and reliability of furniture designs.
- Compatibility testing: Systematically investigating the compatibility and performance of various adhesive types under different environmental conditions to identify optimal solutions for furniture manufacturing.
- Sustainability focus: Prioritizing the exploration of biodegradable adhesives and smart materials to develop functional and environmentally responsible furniture solutions

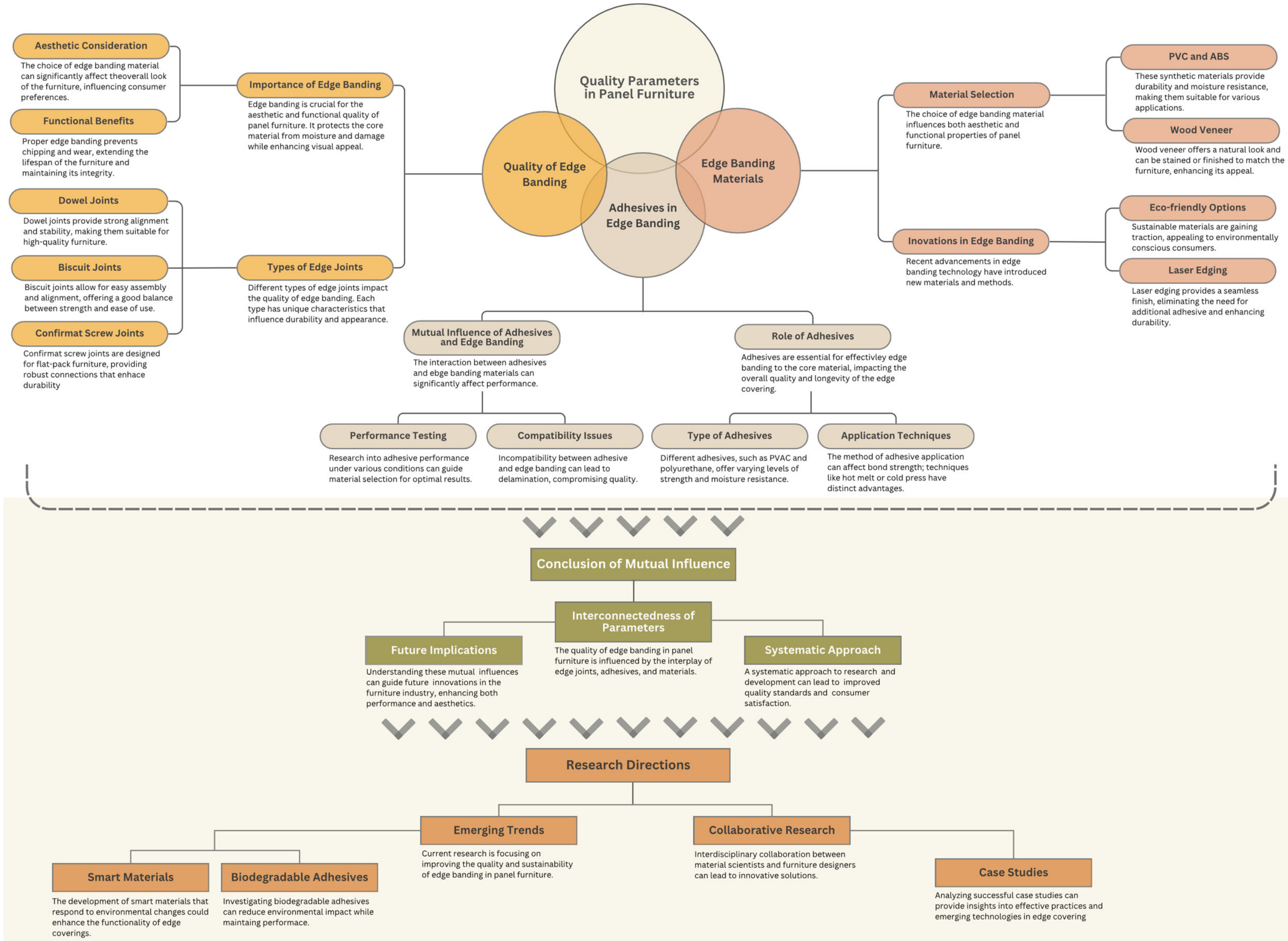

Figure 1. Overview map of quality parameters with future research directions.

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