

## MAPPING VALUE STREAM AND POLICY FOR FURNITURE MAKING INDUSTRIES

Shabeer Ahmed<sup>1</sup>, Usman Ghani<sup>2</sup>, Kiran Raheel<sup>3</sup>, Ahmad Junaid<sup>\*4</sup><sup>1</sup>Department of Industrial Engineering, University of Engineering and Technology Peshawar, Pakistan<sup>2</sup>Department of Industrial Engineering, University of Engineering and Technology Peshawar, Pakistan<sup>3</sup>Department of Computer Science, CECOS University of IT and Emerging Sciences Peshawar, Pakistan<sup>\*4</sup>Department of Electrical Engineering CECOS University of IT and Emerging Sciences Peshawar, Pakistan<sup>1</sup>shabeer@uetpeshawar.edu.pk, <sup>2</sup>usmanghani@uetpeshawar.edu.pk, <sup>3</sup>kiran@cecos.edu.pk,<sup>\*4</sup>ahmadjunaid@cecos.edu.pkDOI: <https://doi.org/10.5281/zenodo.20179188>**Keywords**

Furniture exports, Value chain mapping, Supply chain analysis, Technology adoption

**Article History**

Received: 11 March 2026

Accepted: 21 April 2026

Published: 14 May 2026

Copyright @Author

**Corresponding Author: \***  
**Ahmad Junaid****Abstract**

Exports are an important element in the economic growth and development in a country. Other products are traded in the international market in the form of agricultural products, textiles, machinery, and chemicals, to the highly advanced military equipment. Furniture can be described as a personalized product that is fundamental in homes, offices, hotels and other environments. In 2018, China had the largest share in the global furniture export market with a total sale amount of 28 billion dollars that is approximately 31.5% of the total furniture export. After China came Germany (9%), Italy (8.8%), Poland (6%), Vietnam (5.2%), the United States (3.4) in their respective shares of the world furniture export market that year. In 2018, the furniture exports of Pakistan were only 0.01% of the total furniture export market in the world. Some of the major challenges faced in this sector in Pakistan are; old technology in manufacturing, lead time, high cost of production and lack of government policies aimed at exploring and diversification of markets. Although the country has skilled craftsmen and other developments such as CPEC are underway, the country lacks advanced machinery and other relevant training programs. Moreover, the supply chain analysis and mapping of the furniture industry in terms of value chain is notably lacking. This research primarily aims to develop value chain mapping for the furniture industry along with appropriate mapping tools for analysis. The findings will contribute to establishing a value chain framework for Pakistan's furniture industry, which, when implemented, should result in increased exports, reduced imports, and enhanced overall revenue generation for the country.

**INTRODUCTION****Background**

The value chain concept has become widespread for various products across the globe today. Many developing nations are working to create and implement value chain concepts for promising products to boost their overall exports. Value

chain development aims to streamline the entire supply chain by removing unnecessary elements and enhancing value—such as reducing lead times, enhancing product quality, and lowering costs through technological integration. Porter first introduced the value chain concept in 1985 (Zamora 2016).

A value chain encompasses the full range of activities required to bring a product or service from its conception through various production stages, delivery to end consumers, and final disposal after use (Kaplinsky 2014). In today's globalized world, value chain mapping has become crucial for product and service exports. This mapping serves as a key strategy to compete effectively and deliver quality products or services at competitive prices, both domestically and internationally.

It is difficult to be a successful product seller or service provider nationally or internationally without applying the value chain analysis. This challenge is attributable to the fact that there was no analysis of various value chain factors, which include excessive costs attributed to redundant processes, long lead times brought about by outdated technology, inadequate work studies and other inefficiencies. Significant research has been done on agricultural products such as Citrus (B. Ahmad et al. 2018) and Rice in both Bangladesh and Tanzania (Wilson and Lewis n.d.), among other agricultural products.

There is similar research work on electronics products in Japan (T. J. Sturgeon et al. 2016) and one of the biggest electronic companies, Samsung (Awadalla n.d.). Value chain mapping has been reported in the service industry in Electronic Commerce (Bhatt and Emdad 2005) and Agricultural logistics (Taylor 2012). Simply, value chains show their paramount significance across various sectors, i.e., agriculture to dairy and meat products, cotton to garment brands, furniture (Purnomo, Guizol, and Muhtaman 2009) to electronics and many other commodity products and services industry.

Exports form a major aspect in the economic development and growth of countries. Different goods such as agricultural goods, cotton, machinery and chemicals among others as well as complex defense equipment are exchanged among the various countries. Furniture is a customized product that is vital in homes, offices, hotels, and virtually every environment. China has become one of the major production centers with regard to furniture production and exportation. China According to Chinese National Bureau of

Statistics and custom statistics, the value of furniture production in China increased to 11,300 billion yuan in 2012 as compared to 1,400 billion yuan in 2001. This constitutes 2% of the total gross domestic product (GDP) of China and 25% of all furniture manufactured around the globe (Xiong, Lu, et al. 2017).

In 2018, China exported wooden furniture with a value of 53.6 billion US dollars, securing 38.2% of the total furniture export to the world. Germany (6.9%), Poland (5.6%), Italy (5.3%), the United States (3.9%), and Vietnam (3.6%) are the countries that follow China in their market share of world furniture exports (ITC and Trade Map). It is evident that furniture is one of the most important tradable goods in the international market.

The total furniture export of Pakistan in 2018 is about 3.5 million US dollars which is merely 0.00036% of the global market (ITC and Trade Map). One of the main reasons why Pakistan has a very low percentage of furniture exports in the world is the lack of a well developed value chain in the Pakistan furniture industry. This indicates insufficiency of modern technologies and strategic solutions at different levels of the supply chain needed to compete favorably in the global markets. Moreover, the domestic furniture demand in Pakistan itself grows by about a quarter in a year (PSDF 2015). The furniture industry is still a very labor intensive industry according to the Small and Medium Enterprise Development Authority in Pakistan. Furniture production therefore is characterised by long lead times, which translates to high cost of production and very low level of customer satisfaction.

In Pakistan, research on value chain mapping has been conducted for various products including cotton crop (Batool et al), rice, fruits such as citrus (B. Ahmad et al. 2018), mangoes (Badar, Ariyawardana, and Collins 2015), and several other products across different sectors. However, value chain analysis for the furniture sector is notably absent in Pakistan, despite furniture being a potentially significant trade commodity capable of capturing substantial markets in the Middle East, Europe, United States, and United Kingdom. Although Pakistan has exported

furniture products to the United States and United Kingdom in recent years (ITC and Trade Map), some efforts have been made to improve worker skills, but research on integrating both labor and technology intensiveness remains unavailable.

Therefore, this research focuses on developing value chain mapping for the furniture industry in KPK, Pakistan. The objectives include establishing state-of-the-art research practices specifically for the furniture industry in KPK, integrating and modifying current furniture manufacturing business processes for more cost-effective production techniques, developing a module/Decision Making Tool in VB.net/VBA using research studies and survey data for production cost and RTA decision-making, and formulating a comprehensive policy from downstream to upstream marketing with a global perspective.

The primary challenge in Pakistan's furniture industry is the inefficient manufacturing process. Conventional methods lead to:

- High production costs due to labor-intensive practices
- Increased lead times reducing responsiveness to market demands
- Limited capacity to compete globally due to technological gaps

Without a comprehensive value chain mapping and adoption of modern techniques, Pakistan's furniture industry cannot expand its footprint in international markets.

### Research Objectives

To develop state of art research practices based on this research in furniture industry particularly in KPK. To integrate and modify the current business process techniques of furniture making for more cost-effective practices manufacturing techniques. To form the overall policy from downstream to upstream marketing in global perspective.

### LITERATURE REVIEW

The value chain concept was introduced by Porter (1985) to describe activities from product creation through consumption, focusing on value creation

through cost reduction or quality improvement (Zamora, 2016; Kaplinsky, 2014). Value chain analysis employs both qualitative and quantitative methods, including interviews and surveys, and is widely implemented across industries and Global Value Chains (GVCs) to foster economic advancement through specialization and global connections (Sturgeon et al., 2012; Ernst, 2004). While developed countries utilize value chains to enhance exports and increase revenue, emerging economies concentrate on improving product quality and cost effectiveness. Optimizing production stages leads to increased output, expanded exports, and improved livelihoods. The studies of agricultural value chains, such as rice in Bangladesh and Tanzania, citrus and mangoes, and poultry in Kenya and Serbia (Minten and Reardon, 2013; Carron et al., 2017; Ahmad et al., 2018) can offer valuable insights into improving export strategies. In Pakistan, in particular, cotton and citrus value chain studies have been undertaken to enhance export strategies (Batool et al.; TDAP Report). The increasing environmental issues have forced stakeholders to engage in sustainable operations as a response to regulatory, reputational and competitive pressures (Rusinko, 2007). China leads in the world furniture exports (China: \$53.7B in 2018), followed by the Southeast Asian nations. Furniture exports in Pakistan are small (3.5M), although the local demand is increasing. The development of weak value chain and the lack of research stop the development of the sector. The major weaknesses in the furniture industry of Pakistan consist of the unavailability of skilled labor, international standards and certifications, old-fashioned methods of manufacturing, and not well-defined marketing strategies. These are highly restrictive in terms of export potential, innovation, and competitiveness in the global markets (PSDF 2015; Ratnasingam & Yoon 2013; Hassim et al. 2018). Pakistan has a total of 4.48 million hectares of forest with Khyber Pakhtunkhwa (including merged FATA) having the largest share of 1.46 million hectares (32%). The abundance of plant species at KP has made it a key wood source within the furniture industry, and a potential cluster to

develop industry (Forestry Sector Review 2019; WWF 2010).

The major furniture-making areas in Pakistan are Karachi, Gujrat, Chiniot, Lahore and Peshawar with Karachi being the largest producer of furniture (SMEDA). The most common furniture style is the Antique, Mughal, Modern (Italian), and Oriental, using Sheesham, teak, walnut, oak, plywood and keekar. The major product lines include living, office, kitchen and household furniture. The furniture value chain stretches between the raw materials to the final user with a focus on manufacturing value addition to facilitate the growth of the sector (PSDF 2015).

A Decision Support System (DSS) is a computer-based tool which assists in making speedy and precise decisions based on the analysis of data. Its implementation is made easier by such tools as Excel VBA. DSS applications cut across many fields such as sales forecasting, agriculture and resource planning, facilitating the effective and data-driven results.

Form postponement postponing final assembly until customer orders are received allows mass customization, and lowering inventory risks and improving responsiveness. This methodology strikes the right balance between the benefits of make-to-stock and make-to-order approaches, optimizing efficiency, creating cost savings, and improving supply chain performance.

Ready-to-Assemble (RTA) furniture, or DIY furniture, or flat-pack furniture, is inexpensive, has

space-saving properties, and is easy to transport. It facilitates self-assembly by the customers and is highly popular in the European and American markets. Research areas of interest are standardization of implementation of the circular economy, interlocking designs of tool-free assembly, better portability solutions, and fastener innovations to improve durability and ease assembly. Areas of research that are key include: standardization of circular economy, interlocking design of tool-free assembly, higher portability and designs of fasteners to enhance durability and ease.

## RESEARCH METHODOLOGY

### Introduction

In chapter 2, value chain mapping for furniture industry in Pakistan is significant to solve manufacturing problem and cost, to fulfil the domestic demand, to reduce foreign imports and to introduce some features in the furniture manufacturing like Ready-to-Assemble (RTA). The next sections describe the research goals and explain in detail the research methodology.

### Research Methodology

In order to achieve the stated goals a structured research methodology was developed and illustrated in figure 3. The methodology comprises several phases from data collection, analysis to recommendation. The following are some of the keys steps taken.

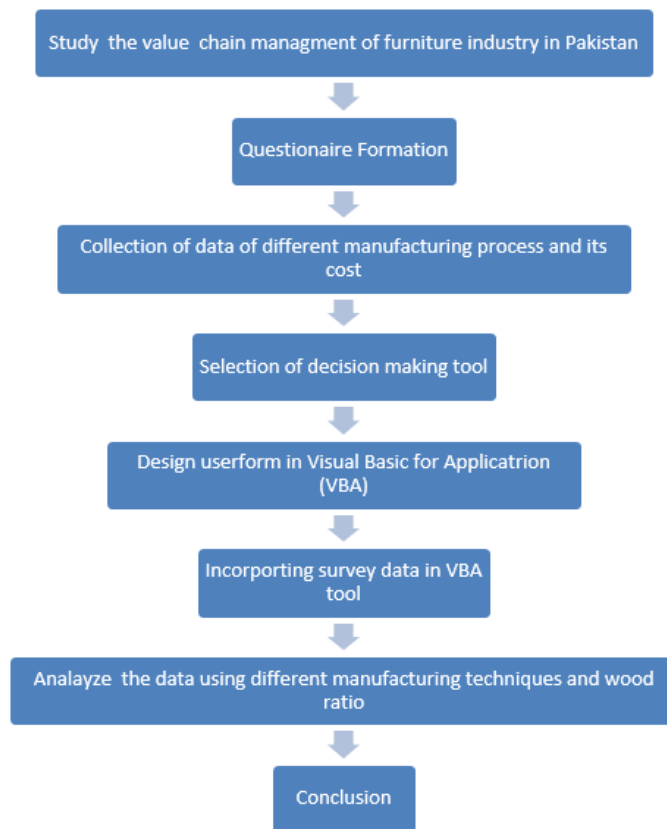


Figure 1 Research Methodology Flowchart for Analyzing Value Chain Management in the Pakistani Furniture Industry.

A comprehensive literature and industry survey were carried out to gain insight into the practices, challenges and opportunities of the furniture industry including insights from the international and national perspective. The primary data were collected through structured questionnaires and semi-structured interviews with small and large scale furniture manufacturers in industrial areas of Peshawar and surrounding areas. The survey centered on four key areas: workforce skills, technology uptake, sourcing of materials, manufacturing process flow, logistics and distribution, product types and customisation options, and export restrictions.

The value chain was representative with a purposive sampling method that included traditional wood workers, modern RTA producers, logistics workers and industry regulators. A total of 30 companies were

contacted, with 22 companies responding in full. The gathered data was applied to different areas of the furniture value chain such as design, raw materials procurement, manufacturing, packaging, transportation, retailing and post-sales services. This analysis aided in the identification of inefficient material flow and labour utilization, highlighted area with cost overruns and degradation in quality and assessed technological gaps with international standards.

To quantify potential improvements in the selected case studies, Value Stream Mapping was used to visualize the current process and the ideal process and identify non-value-adding activities, as well as estimate cycle times, lead times and inventory levels. A Pareto chart was used to prioritize the top industry issues by frequency and severity as shared by stakeholders. The main issues that were identified were inadequate skilled

workforce, obsolete machinery usage, production layout issues, poor availability of quality raw materials and high wastage with low yield ratio.

Cost benefit analysis, time efficiency analysis and quality benchmarking were conducted to compare the traditional methods of furniture production with modern RTA furniture production. A series of strategic and operational recommendations were formulated in the light of these analyses for the improvement of the efficiency of the processes, reduction of cost, and competitiveness, especially for the manufacturers of Peshawar area.

## RESULTS, ANALYSIS AND DISCUSSIONS

### Introduction to Results

The present chapter reviews the manufacturing processes of furniture industry in Pakistan with emphasis on manufacturing processes of Khyber Pakhtunkhwa region and its related benefits of modernization of the manufacturing processes of furniture industry by applying modern machining techniques. It will consider how these innovations can optimize the value stream, lower production costs, improve efficiency, and make the production more competitive both nationally and internationally. Comparative analysis of conventional and modern manufacturing method takes into consideration cost of production, materials used, labour and energy consumed. The results indicate that there are certain aspects of the

modern techniques which are better than the traditional methods, with a focus on improvements in terms of efficiency, cost effectiveness and environmental protection.

Data was gathered using field survey techniques, industry reports and interviewing experts, specifically with a small-scale furniture manufacturing unit called "Peshawar Royal Furniture". Key factors were estimated in a cost benefit analysis using research-based studies, under varying manufacturing scenarios. Findings are then reported in tables and charts to clearly demonstrate the benefits of introducing these modern technologies and make policy recommendations to promote the use of these technologies.

### Current State Analysis of the Furniture Industry

Conventional furniture manufacturing in KPK is labor intensive and manual, which includes the procurement of raw materials, cutting, assembly, finishing, quality checking and packing. The main problem areas are that 20% of the materials are wasted, there is a lot of dependency on labour, the lead-time to create a chair is 20 hrs, the quality is not consistent, and storage is an issue. Low scalability because of manual tools and low standardization, high production cost and rework/rejection.



Figure 2 Furniture manufacturing flow chart

The Value Stream Map (Fig.1) identifies inefficiencies in cutting, assembly, and finishing with significant material waste and delays between stages, indicating major bottlenecks. The Value Stream Map points to cutting and assembly as the key bottlenecks, which create high wastage and

high lead time. These inefficiencies are presented in Table 1, where cutting reduction is at 20%, and assembly is very labor dependent. There is significant potential for automation to significantly increase efficiency.

Table 1 manufacturing cost elements and considerations

| Process Stage         | Time Taken (hrs) | Material Waste (%) | Labor Requirement (hrs) | Key Bottlenecks                       |
|-----------------------|------------------|--------------------|-------------------------|---------------------------------------|
| Raw Material Handling | 2                | 5                  | 4                       | Poor storage conditions               |
| Cutting               | 5                | 20                 | 6                       | Manual cutting, high wastage          |
| Assembly              | 7                | 10                 | 8                       | Skilled labor dependency, variability |
| Finishing             | 4                | 5                  | 4                       | Inconsistent application              |
| Quality Control       | 1                | -                  | 1                       | Lack of standardized checks           |
| Packaging             | 1                | -                  | 1                       | Poor storage and handling             |

Modern machining techniques enhance furniture manufacturing by improving cost efficiency, reducing production time, and optimizing

material use, as demonstrated by hypothetical data.

**Cost Efficiency Analysis**

The cost distribution of the furniture types indicates that conventional methods spend most money on sofas, with 41.8%, and the least money on chairs with 10.6%. With automation, there is a more even distribution of costs for all furniture

types, as sofa continues to have the highest share (39.8%) in modern methods. A cost analysis of a wooden chair shows that modern techniques can result in considerable economies, especially in labor costs.

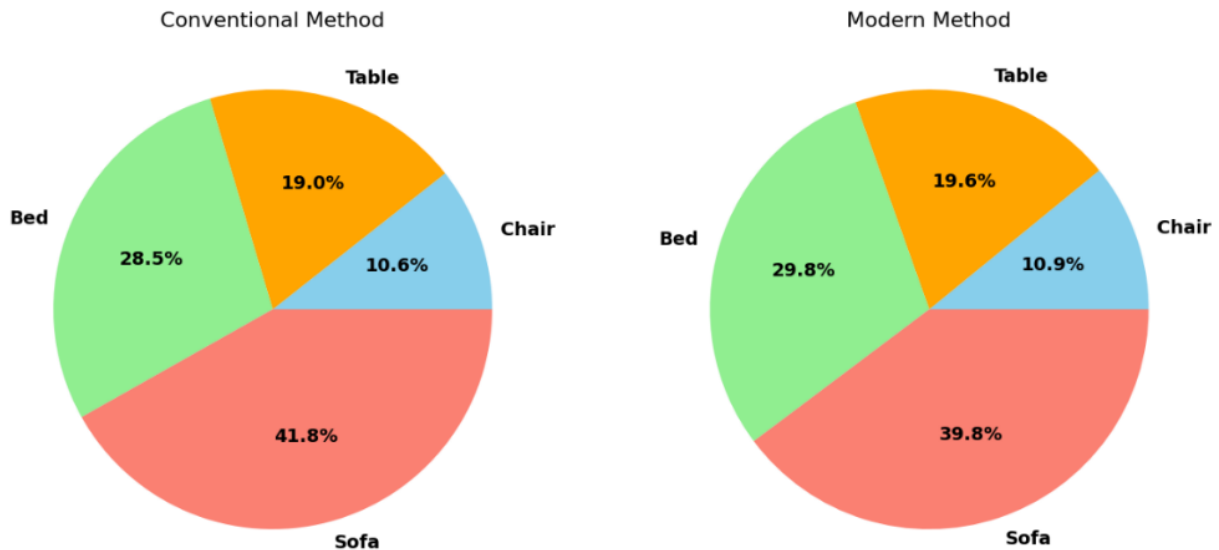


Figure 3 Cost Distribution Across furniture types

**Analysis**

**Labor Cost:** Traditional method: 32000 Pkr, with automation and CNC it is reduced to 10,000 Pkr (62.5% decrease).

**Material Cost:** Precision cutting is applied for conventional material cost is 40,000 Pkr and modern is 34,000 Pkr(15% reduction).

**Energy Cost:** Modern method: 2,500 Pkr, increased from 500 Pkr because of using advanced machinery, but as a whole it will be more efficient.

Modern machining drastically reduces time in production:

- Chair: 20 hrs to 5 hrs (75% savings)
- Table: 40 hrs to 12 hrs (70% savings)
- Bed: 60 hrs to 18 hrs (70% savings)
- Sofa: 80 hrs to 25 hrs (68.75% savings) through automation and precision techniques.

Table 2 Comparison of manufacturing time and time savings

| Furniture Type | Conventional Method (hrs) | Modern Method (hrs) | Time Savings (%) |
|----------------|---------------------------|---------------------|------------------|
| Chair          | 20                        | 5                   | 75%              |
| Table          | 40                        | 12                  | 70%              |
| Bed            | 60                        | 18                  | 70%              |
| Sofa           | 80                        | 25                  | 68.75%           |

By implementing modern methods such as automation and CNC technology, furniture production time is greatly reduced because these allow for faster, more precise operations, less material handling and setup, and performing multiple tasks simultaneously while eliminating downtime. Case studies and industry reports provide real-time data showing these techniques consistently outperform conventional methods in speed and efficiency

**Time and Cost Calculations:**

**Conventional Methods:**

It takes 16 hours to make a chair using conventional methodology, which includes 5 hours of cutting time, 7 hours of assembly time and 4 hours of finishing time.

Taking into consideration a rate of 2,000 Pkr per hour and 16 hours of work, the labor costs amount to 32,000 Pkr. The material cost is 40,000 Pkr including a 15% wastage factor. Energy cost is 500 Pkr (based on a consumption of 5 kWh at 100 Pkr per kWh). Using conventional methods, the total cost to produce a chair is 72,500 Pkr, combining labor, material and energy expenses.

**Time and Cost Calculations for Modern Methods:**

The total production time for a chair is 7 hours, distributed as 2 hours for cutting, 3 hours for assembly, and 2 hours for finishing. Labor at 14,000 Pkr, materials at 34,000 Pkr (after 15 percent savings) and energy at 2,500 Pkr results in a total of 46,500 Pkr.

Modern methods significantly reduce production time by 56 percent and production cost by 36 percent in comparison with conventional methods through automation, precision cutting, and optimized processes. The increase in energy costs is offset by substantial savings in labor and materials.

**Comparison Between Conventional and Modern Furniture Manufacturing**

Modern furniture manufacturing methods significantly outperform conventional techniques in terms of time, cost, and material efficiency.

**Time Comparison**

The modern manufacturing method cuts production time greatly: reducing cutting time from 5 to 2 hours, assembly time from 7 to 3 hours, and finishing time from 4 to 2 hours. The total time is shortened from 16 to 7 hours (table 4). This represents an overall time savings of 56.25 percent compared to the conventional process.

**Table 3 Time Comparison**

| <i>Manufacturing Method</i> | <i>Cutting Time (hrs)</i> | <i>Assembly Time (hrs)</i> | <i>Finishing Time (hrs)</i> | <i>Total Time (hrs)</i> | <i>Time Savings (%)</i> |
|-----------------------------|---------------------------|----------------------------|-----------------------------|-------------------------|-------------------------|
| Conventional                | 5                         | 7                          | 4                           | 16                      |                         |
| Modern                      | 2                         | 3                          | 2                           | 7                       | 56.25%                  |

**Cost Comparison**

Table 4 shows that there is reduction in the labor cost from 32000 to 14000 PKR, material cost from 40000 to 34000 PKR for the modern manufacturing method compared to conventional

manufacturing method, although the energy cost is higher for the modern manufacturing method. In total, these savings will bring down the total cost from 72,500 to 50,500 PKR, or 30.34% cost savings.

**Table 4 Comparison of Manufacturing Methods**

| <i>Manufacturing Method</i> | <i>Labor Cost (PKR)</i> | <i>Material Cost (PKR)</i> | <i>Energy Cost (PKR)</i> | <i>Total Cost (PKR)</i> | <i>Cost Savings (%)</i> |
|-----------------------------|-------------------------|----------------------------|--------------------------|-------------------------|-------------------------|
| Conventional                | 32,000                  | 40,000                     | 500                      | 72,500                  |                         |
| Modern                      | 14,000                  | 34,000                     | 2,500                    | 50,500                  | 30.34%                  |

**Material Savings**

In the conventional manufacturing, material cost is 40,000 PKR. With modern manufacturing, the cost has been reduced to (34,000) PKR, which is 15% of the material cost as shown in table 5.

Overall, the application of contemporary furniture manufacturing technologies has many benefits over traditional technologies, such as shorter production times, lower production costs, and better use of materials.

**Table 5 Material Cost Analysis**

| <i>Manufacturing Method</i> | <i>Material Cost (PKR)</i> | <i>Material Savings (%)</i> |
|-----------------------------|----------------------------|-----------------------------|
| Conventional                | 40,000                     |                             |
| Modern                      | 34,000                     | 15%                         |

**Conventional vs Modern Manufacturing**

The use of modern methods has helped to cut production time by 56.25% which has led to better efficiency. Although the energy use is increased, the total cost is reduced by 35%, and significant savings in labor and material are realized. Plus, accurate CNC cutting will reduce material costs by 15%. In all, modern techniques are faster, cheaper and more efficient, suitable for scale up and improve the competitiveness in the market.

**Manufacturing Process**

The cutting and shaping process is by CNC or hand and the assembly by joinery or fasteners. Finishing consists of sanding, varnishing and painting. During the quality control stage defects are corrected or even rejected.

**Impact of RTA Furniture**

From the cost perspective, labor cost is decreased at the factory and passed onto the consumer. The use of materials like MDF and particleboard is more affordable than the use of traditional wood and the flat-pack shipping reduces the rate of damage and logistics expenses. This means that the overall production and delivery cost is reduced. In terms of time, manufacturing is quicker, as the modules can be used in a wide variety of different ways; assembly time is passed from the manufacturer to the consumer, however, and can depend on how skillfully they can assemble the module. With regard to quality, modern methods can lead to lower durability and aesthetics than traditional furniture with solid wood and advanced craftsmanship. But for budget markets, these products are adequate, and are getting better with each new design and with the introduction of new materials. Hardwoods are usually employed in expensive furniture items, whereas softwoods and MDF are utilized in cost-effective furniture items. Other materials include screws, adhesives and upholstery.

**Logistics**

The logistics strategy is based on sorting packaging, which provides flat-packed RTA solutions as well as conventional items which are already assembled. In addition, storage and distribution of products to ensure efficient distribution is handled by multimodal transport (road, sea, air).

**Use & After-Sales value chain Summary**

Retail strategies cover all types of stores, all channels and direct-to-consumer strategies, and marketing is tailored to product types, with budget flexibility being the key in RTA and quality and luxury in conventional. Customer assembly of RTA units is provided as an after-sales service, along with warranties as well as spare parts and recycling services to further improve the long-term service and sustainability of the products.

The value chain refers to the full process, from raw materials to manufacturing (cutting, assembly, finishing and quality control), logistics, retail marketing and after-sales service. In addition, it identifies the unique RTA assembly step creating a comprehensive PLM solution.

**Material Efficiency**

Table 6 below shows that conventional manufacturing uses more wood, upholstery and metal than modern manufacturing. This decrease represents a savings of 15% on wood and

upholstery, and 10% on metal, which is more efficient in the use of resources.

Table 6 Material efficiency

| <i>Material</i> | <i>Conventional</i> | <i>Modern</i>        | <i>Savings</i> |
|-----------------|---------------------|----------------------|----------------|
| Wood            | 10 ft <sup>3</sup>  | 8.5 ft <sup>3</sup>  | 15%            |
| Upholstery      | 5 yd <sup>2</sup>   | 4.25 yd <sup>2</sup> | 15%            |
| Metal           | 3 ft                | 2.7 ft               | 10%            |

Modern tools reduce waste, lower costs, and support sustainability.

**Material Utilization Analysis**

This is minimized using modern methods of precise CNC cutting: Wood: The amount of wood used decreases from 10 ft<sup>3</sup> to 8.5 ft<sup>3</sup> (↓15%) because it is cut accurately and waste is minimized. Upholstery, 5 → 4.25 yard<sup>2</sup> (↓15%) by automated cutting.

Metal: Precision tools to cut from 3 ft to 2.7 ft (↓10%). With these savings, the costs are reduced

and it contributes to the production with an ecological approach as seen in figure 5.

**Energy Consumption & Environmental Impact**

The conventional process uses only 5 kWh, and costs \$1.00 with manual tools. Modern approach is 25 kWh cost of \$5 due to CNC/automation which is offset by material and labor efficiency. Figure 4 shows the comparison between energy consumption of conventional and modern methods.

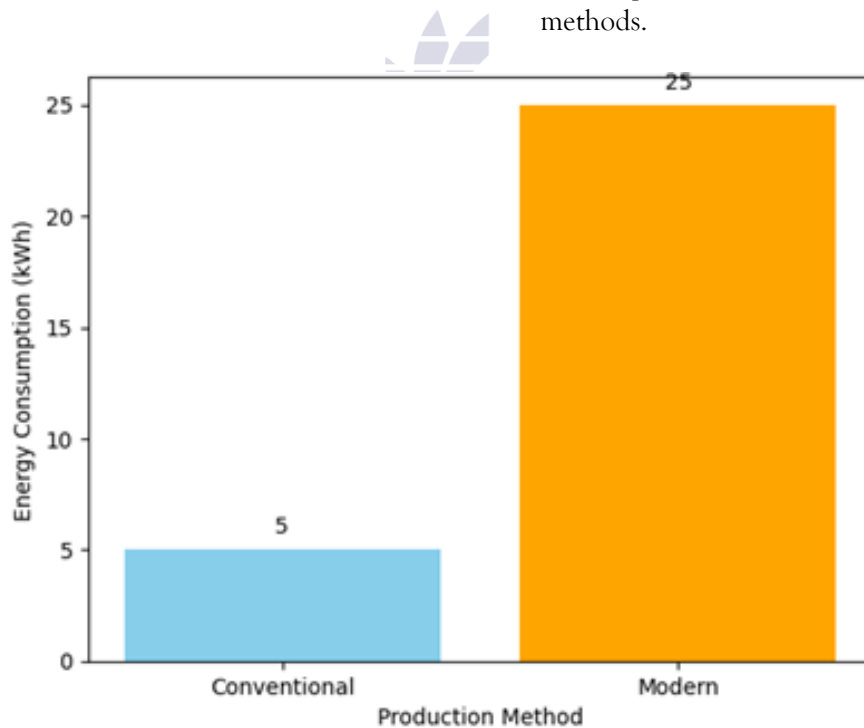


Figure 4 Energy Consumption comparison between Conventional and modern methods

**Environmental Impact**

Modern techniques save 15% less wood and upholstery, 10% less metal, etc., and this decreases the amount of raw material used and wasted. While these methods are more energy consuming, the reduction of rework and waste due to precision cutting is a smaller issue in the grand scheme of things, and renewable energy can be a solution.

**Sustainable Practices**

CNC, Energy Efficient Machines, Renewable Energy, Eco Friendly Materials and waste reduction (recycling) all contribute to a reduction in the extraction of resources, reduction in waste, reduction of energy use and reduction of carbon footprint. The sustainable measures listed in table 8 help reduce the environmental footprint of the production process as well as create better indoor air quality and enable resource recovery.

**Table 6 Environmental Benefits of Sustainable Practices in Furniture Manufacturing**

| <i>Sustainable Practice</i>    | <i>Environmental Benefit</i>                              |
|--------------------------------|---|
| Precision Cutting (CNC)        | Reduced material waste, lower resource extraction         |
| Energy-Efficient Machinery     | Decreased energy consumption per unit produced            |
| Renewable Energy Sources       | Lower carbon footprint, reduced reliance on fossil fuels  |
| Eco-Friendly Materials         | Reduced environmental impact, improved indoor air quality |
| Recycling and Waste Management | Reduced landfill use, resource recovery                   |

Modern techniques improve sustainability by minimising waste, improving energy efficiency and utilising sustainable materials in a circular economy.

**Policy Gaps, Strategic Roadmap & Recommendations**

The analysis reveals significant policy gaps, such as the absence of incentives to take up technology, inadequate financing of SMEs, deficient workforce training, low R&D infrastructure, and ineffective enforcement of environmental regulations. It proposes tax breaks, subsidies, SME-specific financing, CNC and automation training specific to the SME, increased funding of R&D, and more stringent eco-certification measures, all within a National Furniture Industry Strategy. The proposed strategic roadmap to technology adoption will constitute a cycle of assessment, skill development, technology integration, pilot testing and scaling and continuous improvement through lean methods and sustained R&D investment. Additionally, the importance of effective government-industry cooperation is highlighted, and such initiatives as public-private financing, joint R&D projects, training facilities, favorable regulatory conditions, and shared best practices in

the industry are discussed. These steps combined can lead to major cost savings, increased production efficiency, reduction of waste and increased sustainability, which in turn will improve productivity and profitability through modern machining technologies.

**Conclusion**

These initiatives hold an important future for the furniture industry. They will increase growth, efficiency and competitiveness, and help to sustain production and reach eco-sensitive markets. To realize these benefits will require a partnership effort by all stakeholders, policy change, targeted training initiatives, research and development, and collaboration. This will contribute toward establishing a resilient and scalable industry that will meet global standards and market needs.

**REFERENCES**

- Rogath, H. (2010). *Analysis of value chain for pigeonpea in Tanzania* (Master's thesis, Høgskolen i Molde).

- Kaplinsky, R., Memedovic, O., Morris, M., & Readman, J. (2003). The global wood furniture value chain: What prospects for upgrading by developing countries. *UNIDO Sectoral Studies Series Working Paper*.
- Yadav, R., & Mahara, T. (2018). An exploratory study to investigate value chain of Saharanpur wooden carving handicraft cluster. *International Journal of System Assurance Engineering and Management*, 9, 147-154.
- Taqi, H. M. M., Ahmed, H. N., Paul, S., Garshasbi, M., Ali, S. M., Kabir, G., & Paul, S. K. (2020). Strategies to manage the impacts of the COVID-19 pandemic in the supply chain: implications for improving economic and social sustainability. *Sustainability*, 12(22), 9483.
- Yun, J. Open Innovation: Technology, Market, and Complexity, (2024).
- Bhatia, A., & Sehgal, A. K. (2023). Additive manufacturing materials, methods and applications: A review. *Materials Today: Proceedings*, 81, 1060-1067.
- Liu, J., Liu, Z., Yang, Q., Osmani, M., & Demian, P. (2022). A conceptual blockchain enhanced information model of product service systems framework for sustainable furniture. *Buildings*, 13(1), 85.
- Dhanore, R., & Kohli, D. (2024). Comparative Analysis of Corrugated Fillers and Molded Paper Packaging Solutions: A Case Study at IKEA.
- Satalkina, L., & Steiner, G. (2020). Digital entrepreneurship and its role in innovation systems: A systematic literature review as a basis for future research avenues for sustainable transitions. *Sustainability*, 12(7), 2764.
- Bellver, David Fernández, M. Belén Prados-Peña, Ana M. García-López, and Valentín Molina-Moreno. "Crafts as a key factor in local development: Bibliometric analysis." *Helicon* 9, no. 1 (2023).
- Kremer, M., Went, R., & Engbersen, G. (2021). *Better work: The impact of automation, flexibilization and intensification of work* (p. 204). Springer Nature.
- Zhu, L. (2024). The big data thinking in furniture innovative design under the environment configuration of modern Chinese houses. *Australian Journal of Electrical and Electronics Engineering*, 1-16.
- Buckley, P. J. (2020). The theory and empirics of the structural reshaping of globalization. *Journal of International Business Studies*, 51(9), 1580.
- Christopher, M. (2022). *Logistics and supply chain management*. Pearson Uk.
- Iqbal, F. (2024). Role of logistics innovation capabilities in supply chains operations at manufacturing firms. *South Asian Journal of Operations and Logistics*, 3(2), 295-309.
- Waqas, M., Honggang, X., Ahmad, N., Khan, S. A. R., Ullah, Z., & Iqbal, M. (2022). Triggering sustainable firm performance, supply chain competitive advantage, and green innovation through lean, green, and agile supply chain practices. *Environmental Science and Pollution Research*, 1-22.
- Akhtar, N., Bokhari, S. A., Martin, M. A., Saqib, Z., Khan, M. I., Mahmud, A., ... & Amir, S. (2022). Uncovering Barriers for Industrial Symbiosis: Assessing Prospects for Eco-Industrialization through Small and Medium-Sized Enterprises in Developing Regions. *Sustainability*, 14(11), 6898.
- Batista, I. F. T. H. (2021). *Impact of E-commerce on Warehouse Management of a Retail Company* (Master's thesis, ISCTE-Instituto Universitario de Lisboa (Portugal)).
- García Santamaría, L. E., Fernández Lambert, G., Mayett Moreno, Y., Alarcón Ruíz, T., & Parra Hernández, N. A. (2023). Rural supply chains to produce wooden furniture in Misantla, Veracruz. *Revista mexicana de ciencias forestales*, 14(78), 58-86.
- Soori, M., Jough, F. K. G., Dastres, R., & Arezoo, B. (2024). Sustainable CNC machining operations, a review. *Sustainable Operations and Computers*, 5, 73-87.

- Musca, G., Mihalache, A., & Tabacaru, L. (2016, November). Increase productivity and cost optimization in CNC manufacturing. In *IOP Conference Series: Materials Science and Engineering* (Vol. 161, No. 1, p. 012019). IOP Publishing.
- Gherghea, I. C., Bungau, C., & Negrau, D. C. (2019, August). Lead time reduction and increasing productivity by implementing lean manufacturing methods in cnc processing center. In *IOP conference series: materials science and engineering* (Vol. 568, No. 1, p. 012014). IOP Publishing.
- Ratnasingam, J. (2022). Automation Technology in Furniture Manufacturing. In *Furniture Manufacturing: A Production Engineering Approach* (pp. 155-167). Singapore: Springer Singapore.
- Handfield, R. B., Walton, S. V., Seegers, L. K., & Melnyk, S. A. (1997). 'Green' value chain practices in the furniture industry. *Journal of operations management*, 15(4), 293-315.
- Purnomo, H., Achdiawan, R., Melati, Irawati, R. H., Sulthon, Shantiko, B., & Wardell, A. (2014). Value-chain dynamics: strengthening the institution of small-scale furniture producers to improve their value addition. *Forests, Trees and Livelihoods*, 23(1-2), 87-101.

