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POSSIBLE TECHNOLOGICAL INNOVATIONS FOR INDUSTRY 4.0 PRACTICE IN FURNITURE INDUSTRY OF BANGLADESH

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ABSTRACT

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The Furniture Industry of Bangladesh has grown from the cotton industry in the early '90s. It comprises 71034 firms of which 81 are medium-scale factories and 70953 are micro and small scale factories. Both local and global remarkable rapid growth of the furniture industry has made this sector a profitable investment sector. This giant export market is dominated by China and Malaysia because of their technological innovations, up-gradation, and rapid technology transfer mechanisms to meet the requirements of industry 4.0. To catch this big furniture export market, Bangladeshi furniture manufacturers need to be updated by innovations and technologies with industrial revolution 4.0 (IR 4.0). This study tries to find out some possible technological innovations for furniture manufacturers of Bangladesh for upgrading with industrial revolution 4.0 (IR 4.0), such as composite raw materials development, digital manufacturing, jointer machine, additive manufacturing technology, and 3D printing technology, etc. As technology transfer (TT) mechanism stimulates the innovation activities, this paper also shows a partially true modified technology transfer (MTT) model for small and medium enterprises (SMEs), start-ups, and large companies. Moreover, some existing technologies and pieces of machinery of Bangladeshi furniture manufacturers are illustrated with their applications.

Contribution/Originality: This paper depicts existing technologies and pieces of machinery used by furniture manufacturers of Bangladesh. This study aims to illustrate some possible technological innovations as well as a modified technology transfer (MTT) model that can be employed soon age of industry 4.0 by the furniture industry of Bangladesh.

1. OVERVIEW OF FURNITURE INDUSTRY OF BANGLADESH

By tradition, the furniture industry sector of Bangladesh advanced as a cottage-based industry. Bangladesh furniture industry flourished from cottage based industry to mechanical equipment based and automated bulk manufacturing-oriented industry in the early '90s and had transformed into a major economic contributor of Bangladesh. Following that furniture business was initiated to propagate with accommodating advanced technological machinery, innovative unique designs, and introduces the application of divergent materials. Different items of furniture are manufactured from wood, processed wood, medium density fiber (MDF) board, melamine board, laminated board, particleboard, rattan/bamboo, wrought iron, and steel, etc. [1]. Still, people prefer solid

wood as raw material for their home furniture. The popularity of composite and combined materials like solid wood with rattan, cane, laminated boards, MDF, and plywood are also increasing because of their lucrative design, longevity, strength, and toughness. Offices furniture designs of many offices and corporate offices are usually focused on the more up-to-date style and furniture materials like MDF, plastic, laminated boards, wrought irons, and steel [2].

Currently, Bangladesh is manufacturing a divergent amount of furniture domestically and has been able to achieve the major market share by providing the international standard quality. Previously, this industry got accustomed to greatly depend on imported furniture from Thailand, Malaysia, and India to fulfill the growing consumer demand. Figure 1 shows the innovation trends of furniture industry of Bangladesh concerning time.

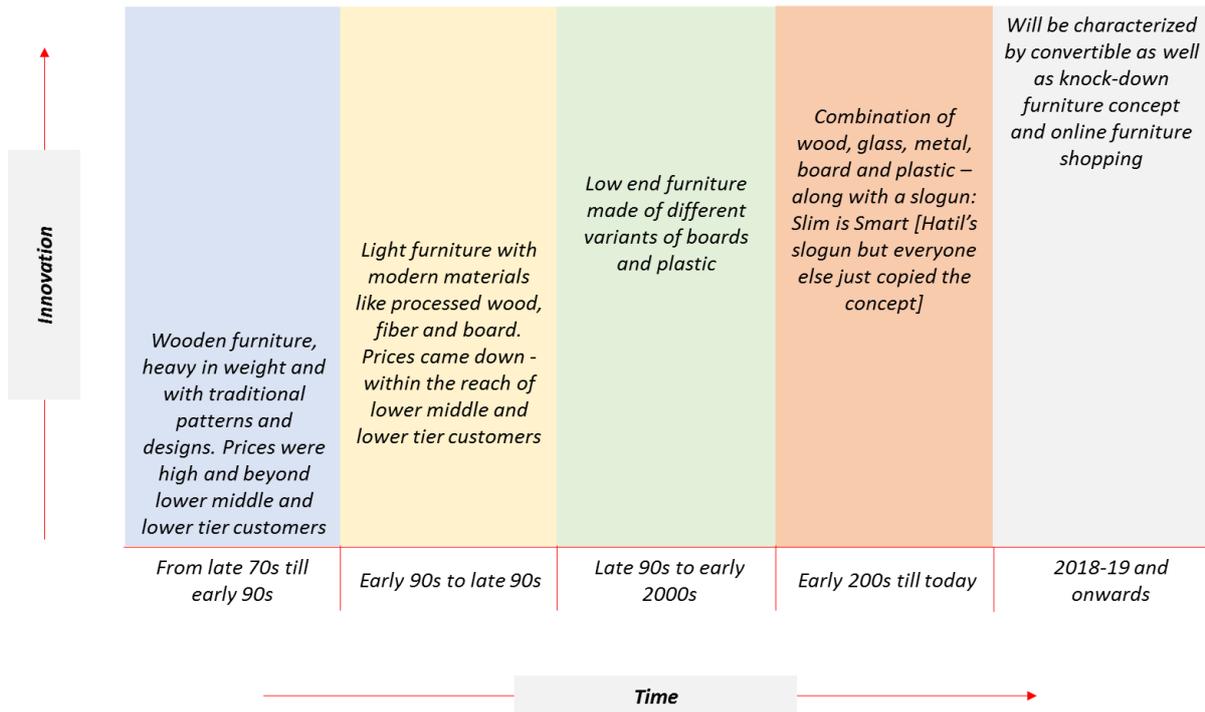


Figure-1. Innovation trends of furniture industry of Bangladesh in different periods.

Source: Light Castle Partners Bangladesh [3].

In Bangladesh, the total amount of furniture produced among them around 70% is the home furniture and 30% is office furniture. As the customers of Bangladesh are now focusing on local furniture instead of foreign furniture, the furniture manufacturing companies are now prioritized on the customer's demand. Moreover, since 1995 furniture and allied products are exported in different counties of the world. It is noted that the furniture industry of Bangladesh has demonstrated marvelous performance over the last ten years, showing an average of 25% export growth. Also, about 2.5 million workers are currently employing in this sector that has been marked as the second (2nd) source of employment after ready-made garments (RMG). This sector has occupied the domestic market worth BDT 67 Billion and is showing an increasing trend. This furniture market is dominated by various small, micro, medium, and large scale organizations. Around 80 % of medium and large-scale organizations located in Dhaka and Chittagong are dominating this market [3].

The furniture sector is becoming competitive in the international market due to the low-cost manpower in Bangladesh. Bangladesh has a large number of people engaged in this labor-intensive sector. Therefore, Bangladesh has excellent potential for exporting furniture in the world market. Now, it is high time for Bangladesh to take up a sizable market share in the world's export of furniture. In 2014, the total furniture export of Bangladesh was equivalent to 0.02% of world total furniture export. It was also expected that by the end of the year 2018

Bangladesh will gain export potential of furniture worth USD 60 million along with crafts furniture accessories worth USD 20 million.

In Bangladesh, there are now two (2) active associations that are diligently working on equipping and materializing the potential of this furniture sector and they are Bangladesh Furniture Export Association (BFEA) and Bangladesh Furniture Industries Owners Association (BFIOA). BFEA consists of 19 members and its valuable member is Partex Furniture Industries Ltd. BFEA is acting as Manufacturer, Buying Office, Trading Company, Distributor/Wholesaler, Agent and providing business service like transport, travel, finance, ads, etc. It is also working with the government ministry, bureau, and commissions. The main business market of BFEA is Asia, America, Africa, Europe, the Caribbean, Oceania, and the Middle East [4]. BFIOA is the prime association of the furniture sector in Bangladesh has operated first in 1976. Today it is actively functioning as a business association focusing to deliver support to 1300 listed members from the different origin of the country [5].

The furniture industry sector of Bangladesh has been declared as 'Thrust Sector' by the Bangladesh government. At this moment, approximately 2.5 lakh semi-skilled and un-skilled people and nearly about 45,000 enterprises are engaged in this thrust sector. Average 60% of the raw materials of furniture sector like timber, wood coating materials, world-class fabrics, hardware, and accessories, etc., are imported from different countries. High import duties of some raw materials like good fabrics, coating and finishing materials, hardware and accessories, shortage of electricity and gas, etc., are main mentionable problems of this sector. Moreover, shortage of skilled and trained manpower in handling modern machinery and equipment is restraining the prospect of growth of this thrust sector [1].

2. FOREIGN EXPORT TREND OF BANGLADESH FURNITURE INDUSTRY

The furniture sector of Bangladesh is one of the high-growth potential sectors for small and medium-sized enterprises (SMEs) of Bangladesh. In 2013, PKSF Bangladesh (Palli Karma-Sahayak Foundation) had conducted a project study of the furniture sector and the study found that the growth rate of the furniture sector is 19% per year and contribution in GDP of the country is 0.29%. Increasing demand in the domestic market is stimulating the prospective growth of this sector as well as the ongoing growth of export. Due to continuing economic prosperity of the people, the local demand for furniture has been enhancing day by day. Also, because of its comparatively low-cost advantage, international market demand is becoming remarkable. Industry experts are opinioned that the furniture industry sector has enormous opportunity to propagate; especially in the context of global market growth [6].

Bangladesh Export Promotion Bureau data shows that in the last fiscal year (FY) of 2011-12, Bangladesh achieved 16% export growth in furniture to earn over USD 31 million. Figure 2 showed that the volume of furniture export was USD 19 million in the fiscal year 2009-10, while it amounted to USD 21.38 million in FY 2010-11, USD 27.14 million in FY 2011-12, USD 31 million in FY 2012-13, USD 42.18 million in FY 2013-14, USD 38.94 million in FY 2014-15, USD 46.25 million in FY 2015-16, USD 49.79 million in FY 2016-17, USD 63.18 million in FY 2017-18, and USD 74.89 million in FY 2018-19 (18.53% export growth) [4].

Bangladesh Furniture Industries Owners Association (BFIOA) opinioned that at present, Furniture exporters of Bangladesh have been exporting the furniture to Canada, US, UK, Australia, Gulf countries, Middle East, and other Asian countries like Japan, India, Singapore, Taiwan, Vietnam, and Thailand. In the furniture marketplace, Akhtar Furnishers Ltd, Otobi, Navana Furniture, Hatil, Partex Furniture, etc., are the main players. Independent research and consulting company named Center for Industrial Studies (CSIL) founded in Milan was conducted a study on "Export markets entry strategy for Bangladeshi furniture manufacturers" and they predict that Bangladesh will export USD 1 (one) billion by 2020 because of better market linkage, increased productivity, and ensured compliance standards [4]. Textile and Garments industries are the major export-oriented industry in Bangladesh and Bangladesh is mostly known for it. But, other potential industries have enough possibility to take

over the global market in near future. The furniture industry sector is one of the industries that can hold a position in the global marketplace. The furniture industry sector was incorporated as a Special Development Sector in the Export Policy 2009-2012, in Export Policy 2012- 2015, in Export Policy 2015-2018 and it has been improved as an utmost priority sector due to high export potentials.



Figure-2. Fiscal year foreign export trend of Bangladesh furniture industry.

3. CATEGORIES OF FURNITURE FACTORIES OF BANGLADESH

The furniture enterprises and farms of Bangladesh can be categorized based on the product type and raw material or both types. A study by Jalil [6] on 43 different sized factories in various regions of Bangladesh had shown that 25% of the firms produce both furniture and raw materials while the remaining 75% only produces furniture. Based on product type and raw material the furniture enterprises can be categorized as followings:

- **Solid Wood Furniture:** All kinds of home and office furniture produced from timber are known as solid wood furniture. The majority of the raw material wood is imported from Malaysia, Myanmar, the USA, Canada, Ivory Coast, Ghana, and other European countries. The import duty of wood is about 10.22%.
- **Metal Furniture:** Mostly office furniture made from Stainless Steel. Stainless Steel is imported from China.
- **Processed Wood Furniture:** The main products of this category are melamine laminated board, medium-density fiberboard (MDF), veneered particleboard and plywood, etc. These processed woods are imported from China, India, and Malaysia except particleboard. The duty of import for processed wood is 92.30%.
- **Cane and Rattan Furniture:** Decorative and home furniture are made from cane and rattan. Cane and Rattan have hoarded both the native sources and imported sources like Malaysia and Indonesia.
- **Bamboo Furniture:** The raw materials for Bamboo furniture are mainly collected locally. Mainly these types of furniture are made in rural areas of Bangladesh and rapidly used in the rural villages. Also in some urban areas, it is found as traditional furniture.
- **Plastic Furniture:** The main raw material for producing plastic furniture is Polyethylene Terephthalate (PET). This material is thermoplastic which means that we can recycle it easily. In Bangladesh, these types of furniture applications are increasing day by day because they are too cost-effective. Also, the longevity and aesthetic view of this type product snatch the customer's minds.
- **Leather Furniture:** This type of furniture is mainly imported from Malaysia and China. Synthetic Leather is used to manufacture these furniture goods. It is highly used in corporate offices. Also, solvent people are buying

these types of leather goods as their luxurious items. General import duty is 25% and 0.15 VAT rate applicable in Bangladesh.

4. DISTRIBUTION OF FURNITURE FIRMS

The furniture firms of Bangladesh can be classified into three categories large, medium, and small. As per national industrial policy, the size of the enterprise is determined by the number of employees and capital investment. A survey report of Jalil [6] on 43 different sized firms in various regions of Bangladesh had shown that according to the industrial policy the large firm of Bangladesh employs more than 1000 employees or that invests more than TK. 500 million. Medium-sized factories have employees less than 1000 or capital investment is the range of TK. 150 million to less than TK.500 million. Only 31 to 120 employees or capital investment between TK. 7.5 million to TK. 150 million is required for a small firm. According to the industrial policy, Table 1 shows the firm's size and their geographical locations in various regions of the country.

Table-1. Allocation of firms by size and location.

SI.	Size of Firms	Number of Factories/Firms	Geographical Locations
1.	Large and Medium Firms	9	Manikgong, Vatara (Dhaka City), Savar, Hemayatpur, Narayangonj, Rupgong
2.	Small Firms	34	Chottogram, Narayangonj, Bogra, Sylhet, Barisal and Dhaka City (Mirpur, Panthapath, Badda, Chankharpul, Shajahanpur,Gandaria)
	Total	43	

Source: Adapted from Jalil [6].

5. EXISTING MACHINERIES AND TECHNOLOGIES IMPLEMENTED IN BANGLADESH FURNITURE INDUSTRY

In the present world, the top branded furniture manufacturing companies are now technologically updating with the continuum progress of the technological advancement of the world to increase the production capacity, to improve the quality of product, and finally to increase the revenue of the company. In respect of the world technological advancement, Bangladeshi furniture manufacturers should be updated timely by new technologies and new pieces of machinery.

Figure 3 shows some existing machinery and technologies of Bangladeshi furniture manufacturers, their specific applications, and their country of origin. In 2017, Jalil [6] studied skill levels in the furniture sector of Bangladesh and they showed pictorial description and manufacturing country of some machines that are used in the furniture industry of Bangladesh. A research paper of Kamal [7] on OTOBI Furniture Company of Bangladesh showed the benefits and applications of technologies in the furniture industry. This research paper also revealed the features and applications of some existing technologies and machinery of the furniture industry of Bangladesh. This study suggested applying a linear programming-based mathematical model to optimize the product mix of laminated board furniture in terms of profitability.



Short Cycle Machine for melamine Paper Lamination (Imported from Germany)

Applications:

For direct lamination of melamine, this machine is used. This machine is working based on the hot pressing principle on melamine paper by the use of chrome texture stainless steel press plate to create diverse types of embossing outward on board.



Straight Edging Machine (Imported from China)

Applications:

A straight edging machine is used as a tool for drawing straight lines, checking their straightness in the workpiece, and checking the evenness of machined mating surfaces.



Plastic Injection Moulding Machine (Imported from Germany)

Applications:

A plastic injection molding machine or injection press is a machine for manufacturing plastic products by the injection molding process. There are mainly two components in a plastic molding machine; one is an injection unit and another one is a clamping unit. First, the machine heats the plastic materials to produce the liquid plastic. Secondly, the nozzle of the injection molding machine injects the melted liquid plastic into the mold. Finally, the filled mold cavity with liquid plastic is cooled to get a desired solid product.



Bending Machine (Imported from Taiwan)

Applications:

A bending machine is also known as a forming machine tool used to produce bend on a workpiece material during linear or rotary travel.



Shearing Machine (Imported from England)

Applications:

A shearing machine is one type of forging machine having an upper blade and a lower blade. The upper blade is moving and the lower blade is fixed used to apply shearing force to several thick sheet metals by allowing a reasonable blade gap to break the sheet metals apart according to the desired size and shape.

Power Press Machine (Imported from India)

Applications:

A power press machine compresses the workpiece materials to cut and shape by feeding the workpiece materials into a cutting tool.



Vacuum Foaming Machine (Imported from China)

Applications:

A vacuum forming machine is one kind of thermoforming machine. It heats plastic sheets to a forming temperature and then stretches the plastic sheet onto a single-surface mold and finally creates a force against the mold by a vacuum. This mechanism is also used to form plastic materials into permanent products like roadside turn signs and protective covers to the final products. Typically, a recommended draft angle minimum of 3° is provided in the design of the mold to remove the formed plastic from the mold easily.



Air Compressor (Imported from India)

Applications:

An air compressor is a pneumatic device that sucks and filters the atmospheric air and then stores the air in the storage tank by reducing the volume of the air through a compression mechanism. This stored air is used for cleaning activities.



CNC Machine Technology

Applications:

CNC wood processing machine is used to process wood point to point. With the help of software technology 'WoodWOP'; cutting operation, grooving operation, DET operation, boring operation, routing operation, etc.



Chair Cycle Wrapping Machine (Imported from China)

Applications:

This wrapping machine is used for wrapping horizontal shapes such as sheets, windows, doors, floorboards, etc.



Generator Machine (Imported from USA)

Applications:

During the electricity power cut-off, generators are commonly used to prevent discontinuity of power supply on the production floor.



Panel Saw Machine

Applications:

This machine looks heavy and rigid in construction to confirm high cutting accurateness and efficiency. Any kind of panel is prepared by cutting operation through the use of a standard scorer saw blade unit.

are done in the CNC machine of OTOBI furniture company of Bangladesh. A programmable Logic Controller (PLC) is used to control the machine.



Double-End Tenoner Machine

Applications:

This machine is used for manufacturing panels or solid wood furniture. It has various features for mass production operations like cutting, sizing, trimming, hogging, squaring, molding, tenoning, grooving, rounding, chamfering and sanding, etc.



Manual Copy Router Machine

Applications:

This high-speed machine is used to create the profile according to the design requirements of the product part. The strip connected with the motor guides the router bit.



Table Trimmer Machine

Applications:

A small and simple table trimmer is applied for the removal of residual of the edge bonder materials from finished parts. Cutting action is done by the trimming cutter of the machine.



Band Saw Machine

Applications:

A motor pulley mechanism is used in this machine. This machine is used for cutting the wood and prepared the wood for manufacturing the final product.



Profile Edge Banding Machine Technology

Applications:

This machine is glued edges of PVC materials, melamine on round, straight and shaped panels with hot melt glue.



Straight Edge Banding Machine

Applications:

By using hot melt glue, this linear series machine is used for edging straight panels (180° panel). PVC, veneer, and melamine-based edging materials are used in the operation.



Large Multi Borer Machine

Applications:

This machine can produce smooth and exact holes in a workpiece by enlarging existing drilled holes. Horizontal and vertical boring/drilling operations are done by this machine at a time. PLC is used to control the cutting tool of this machine.



Small Multi Borer Machine

Applications:

This semi-automatic machine tool of this machine is able to finish existing drilled holes in three ranges through a single adjustment of the head.

Figure-3. Applications of existing machinery and technologies used in furniture industry of Bangladesh.

Source: Information is adapted from Jalil [6] and Kamal [7].

6. POSSIBLE TECHNOLOGICAL INNOVATIONS FOR FURNITURE INDUSTRY

Over the past several decades, a revolutionary change has occurred in the furniture manufacturing industry. As the consumers or buyers test for furniture is changed frequently, the top-class level furniture manufacturers are now using high-tech design and manufacturing process to manufacture furniture. Today, Manufacturers are now adopting large automated machinery much of which are controlled by computers; advance digital technology like virtual or physical studios, universal internet of thing (IoT) devices, green technology, full-body stimulation through carbon capture, optimum energy consumption, etc. The application of high-tech machinery in the manufacturing process not only increases the precision, accuracy, and manufacturing speed, but also reduces much involvement of the craftsmanship. Some new pieces of machinery and possible technological innovations for Bangladeshi furniture manufacturing companies are listed below:

6.1. Innovative Raw Materials Development

New Material development is vital for the Bangladesh furniture manufacturing industry because customers are now demanding new types of materials furniture like human finished composite materials. New materials processing could be primary thought, with a last stage of manufacturing called the secondary process of manufacturing that converts materials into products. In many circumstances, the manufacturing of the raw materials and the manufacturing of the final product occur at the same time. For example, for furniture foam molding raw constituents are used to create polyurethane resin (PUR) is now a common raw materials process.

Plywood is another raw material that is developed through technological innovations which are popularly used in the furniture industry. Plywood can resist compound forces because of its construction. Plywood looks like a sheet produced from cross-laminated veneers. Minimum 35 steps are used to produce plywood in the modern manufacturing process. A veneer company named Reholz, a german manufacturing company has developed advanced plywood technology that is a novel form of manufacturing plywood. In 2003, the Gubi chair is designed by Komplot in which deep three-dimensional curves is firstly used. The three-dimensional curves are manufactured through the patented process. Other raw materials like plastics and polymers are now used to produce the finest art furniture as these materials are cheap and vulgar. Figure 4 shows a table that was designed and prepared by artist-designer James Shaw. He employs 'High-Density Polyethylene (HDPE)' materials these are usually used to produce drain piping and plastic bags [8].



Figure-4. HDPE polymer table designed by artist James Shaw.

Source: Adopted from Dennis [8].

6.2. Digital Manufacturing with CAD and CNC System

The combination of the CNC (Computer Numerical Control) operation and the CAD (Computer-Aided Design) system are the main components of Digital Manufacturing. Shaping tasks like mortises, inlets, slots, grooves, keyways, etc. are made by CNC router technology in the modern furniture manufacturing industry of the world. The final product's shape is designed through the CAD system. The designed shape is entered into the computer to produce the shape automatically by CNC router. CNC router technology can be used for both metal and wood.

The two main categories of Digital Manufacturing are CNC and Rapid Prototyping. Common operations like drilling, milling, engraving, laser cutting, wood routers, water jet machining, etc. are processed in the CNC machinery. Intricate and simple geometric designed shapes are produced by Rapid Prototyping technology. Figure 5 demonstrates the advanced manufacturing systems with others subsystems like MIS, SCM, MRP, ERP, CIMS, CAI, LP, GIT, MC, AM, VM, etc. [9].

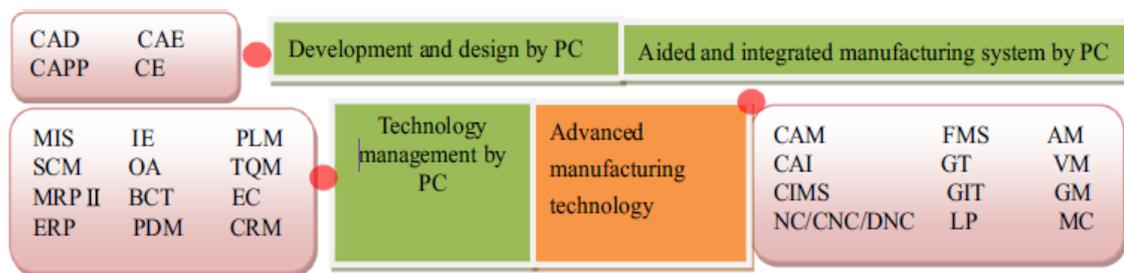


Figure-5. Advance manufacturing technology of furniture.

Source: Adopted from Xiong, et al. [9].

6.3. Planners, Jointers, and Edgers Technology

Rough timber is smoothed, flattened, and processed to precise measurements employing planers, jointers, and edgers. Jointers hold the distortion and twist out of the foot of a board so that it will remain flat and straight when it undergoes through the planner. Planners make the top of the board flat and cut it down to the preferred thickness. Edgers hold the uneven wood and any twist or curve off the ends of a board. High volume manufacturing facilities frequently combine these tasks in particular multi-purpose machines that are capable of joint, plane, and edge in a solo pass [10].

6.4. Additive Manufacturing and 3D Printing Robotics Technology

3D printing projects started in 2012, while new specialized crafting technology Drawn Figure 6 was created by French entrepreneurs Sylvain Charpiot and Samuel Javelle. 3D furniture printer with a robotic arm named a.k.a

Galatea (named after a mythological Greek sculptor) was created by the support and assistance from the researchers and investors [11]. An old manufacturing assembly line robot of an automotive industry was designed and improved to Galatea especially for manufacturing furniture. These types of 3D printer robotic arms are 40 times quicker than traditional ones for manufacturing furniture [12]. The layer quality of the 3D printed objects is extremely uniform. The various fastened layers appear in the objects, the multiple layering is noticeable to the human eye looks flat and stable like other “Fused Deposition Modeling” based 3D printed objects [11].

For economic development, manufacturing is crucial in today’s competitive technological environment. There are several types of waste occurred in conventional production systems, such as the movement of material between stations. Moreover, due to drilling operation, cutting operation, assembly, and other transactions materials revolve around their axis and cause leeway. Conventional furniture production floors have several workstations, but in additive manufacturing (AM) technology there are decreased workstations that result in just about no wastage and leeway. As a result of this, products can be practically processed and finished in few stations like a single computer used for modeling and generating the production data, a single 3D printer for manufacturing and finishing processes for surface quality [12].



Figure-6. Drawn a Robotic Arm 3D Furniture Printer.

Source: Adopted from Top for 3D Printing [11].

6.5. Advance Table Saw Machines

Table saws are convenient and the portable instrument can be used in the job place. These are able to slice small size wood to behemoth size wood. Household smaller saws are operated on 110 or 220 Volts, while larger industrial saws are operated by 3 phase motors or 440 Volts. Power feeds and Laser guides of industrial wood saws control the speed up and automatic mechanism while processing wood raw materials [10]. Figure 7 shows an advanced table saw machine. Customary panel saw and table saw machines are used for the production of furniture in many furniture factories in Bangladesh [7].



Figure-7. Table Saw Machine.

Source: Adopted from MARTIN [13].

6.6. Application of Green Supply Chain Management System and Recycle Wood Waste

Green Supply Chain Management (GSCM) concept mainly focuses on the recycling of all wood waste from the furniture industry because the wastes are not environment friendly and it is green manufacturing practices of the furniture industry. The GSCM system is an advanced method employing in the production processes and products to improve performance by maintaining environmental regulations and requirements. Zhu and Sarkis [14] define GSCM as it starts from the beginning of purchasing stage of the supply chain by following green concept or environmental friendly concept from the supplier to manufacturer, to distributor or warehouse, to the consumer or customer and reverse logistics that closes the supply chain loop. Hervani, et al. [15], opinioned that GSCM practice consists of different components in supply chain stages and one component is green purchasing, green production or manufacturing, green material management, green distribution, green marketing and reverse logistics [15]. The main form of wood waste is small wooden chips produced in the production processes. These wood chips can be reused and recycled by producing wood-based boards and panels through adhesion, composite development, and lamination.

A study by Susanty, et al. [16], found that collection and transportation of wood waste is the main problem of recycling wood waste. Specifically, the problem related to available information about the wood waste that incorporates the producer to generate the wood waste and finally use or recycle it. In this study, they have designed an application of internet GIS by using Software Development Life Cycle (SDLC) process. For solving the problem, the SDLC process includes some significant information and databases like furniture manufacturers (Small and Medium Enterprises shortly SMEs) name, location and phone number as they are the producer of wood waste, the amount and price of the wood waste, wood waste collector name, location and phone number, delivery charges for each type of transport medium used and the total distance the particular materials to be conveyed [16]. Figure 8 is a contextual diagram that represents the proposed SDLC system indicating the boundaries of the system, interacted outward entities with the system, and the main information streams between the entities and the system. The proposed SDLC system was applied between two districts of Indonesia Jepara and Surakarta because most of the SME furniture industries are located there. This proposed model can also be applied in the furniture industry sector of Bangladesh because Bangladesh is also now emphasizing the environmental issues and recycling of hazardous wastes.

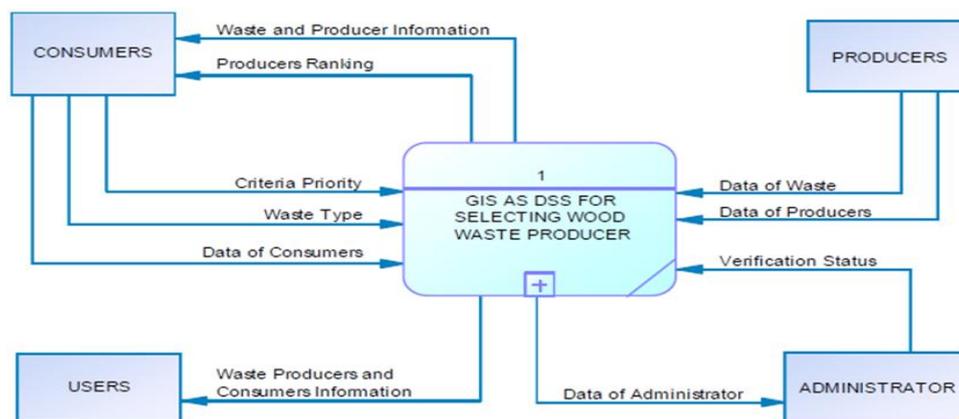


Figure-8. Context diagram of software development life cycle (SDLC) process.

Source: Adopted from Susanty, et al. [16].

6.7. Job Shop Scheduling Approach in Custom Furniture Industry

Scheduling of machines is required for the furniture industry as there are a variety of designed products on the production floor. Proper scheduling optimizes the processing times of jobs and minimizes the waiting time. The quality of the schedules is evaluated by the variety of products range, inadequate experience in the manufacturing

process, and the different contradictory criteria. Besides, the intricacy of the production process and the influence of people in each manufacturing stage reduce the precision of schedules [1].

In Bangladesh, the furniture manufacturing companies are following the job shop or flow shop scheduling process. There are lots of traditional approaches to solving the job shop scheduling problems (JSSP) like the Branch and Bound (BB) algorithm techniques which are used to minimize the makespan in the traditional job shop scheduling process (JSSP). Though these methods are very suitable for minor to medium size problems, their application is quite difficult for large problems because of excessive computing time. Many operation research approaches, such as mixed integer programming or dynamic programming, have been used for solving the JSSP. These operation research-based methods require the formulation of mathematical models, the number of constraints and variables that become very bulky even for small and medium-size problems, and for that reason, those efforts are not very effective and suitable for large size problems.

In 2011, Juan, et al. [17] had described a real-life problem of job shop scheduling that is solved by combining neural network and evolutionary computing to lessen the effect of the vast search space and the integral problem of computing the processing times in custom manufacturing [17].

6.8. Flow Shop Scheduling Approach in Custom Furniture Industry

Flow shop scheduling optimizes the arrangements of resources like machine overtime to carry out a group of tasks in the flow shop production line. In general, in a production line, there are lots of jobs that are processed in a sequence by different machines. Every job must pass through each machine by maintaining a series or a sequence for multiple job process problems so that a machine can process every job successfully. When the number of machines and jobs is quite high, the scheduling and sequencing of the jobs become too difficult for a production officer or in charge. This is a common phenomenon in production in the furniture industry of Bangladesh that results in loss of production time and increases production cost per unit.

To mitigate this type of job sequencing problem an algorithm was developed by Johnson known as 'Johnson Algorithm'. The first developed method of Johnson was well known for flow shop problem having machine not more than three (3). For solving multiple machine problems having machine more than three (3) in a production line, different heuristics and meta-heuristics are introduced like Palmer Heuristics, Campbell Dudek Heuristics, Nawaz Enscore Ham (NEH), and Gupta's Heuristic algorithm. Among the Heuristics NEH results in the best optimal makespan [18].

Rayhan and Chakma [18] have shown in a paper that among the heuristic algorithms the Nawaz Enscore Ham (NEH) resulted in the best possible job sequence in a production line (flow shop of 5 jobs and 5 machines) with minimum makespan (total processing time of sequenced jobs) [18]. Also, Hossain, et al. [19], has shown 4 jobs and 10 machines flow shop scheduling problem of Bangladeshi furniture company (Hatil Complex Ltd.) and solved this practical problem by using Palmer Heuristics, Campbell Dudek Heuristics, Nawaz Enscore Ham (NEH) algorithms [19].

7. INDUSTRIAL REVOLUTION 4.0 (IR 4.0) AND TECHNOLOGY TRANSFER IN FURNITURE INDUSTRY OF BANGLADESH

'Industry 4.0' is a scientific term that was first introduced at Hanover fair Germany in 2011, where it was used for representing the transformation process in the global chains of value creation. Russian scientist V. N. Knyaginina finds the most important feature of Industry 4.0 that differentiates Industry 4.0 from the traditional industrial production is complete integration and interactivity of all production processes of an industrial enterprise, confirmed employing modern digital technologies [20]. Industry 4.0 can be defined as a golden age of technological innovations, where digital and fully automatic technologies (Smart Manufacturing Technologies) and

machines are implemented for industrial production. The basic distinguishing characteristics of Industry 4.0 are listed below:

1. Shift from physical work to robototronics, which confirms automatization of all production processes.
2. Modernization of transportation systems, initiated by the bulk supply of unmanned vehicles.
3. Growth of intricacy and accuracy of manufactured technical products, production of new structured materials due to development of production technologies; improvement of inter-machine communications and self-management of physical systems, lead with the help of internet of things (IoT).

The 4th Industrial Revolution (IR 4.0) is the period of improvement of knowledge in which the lines between digital, physical, and biological spheres are being indistinct. Every IR has transformed the way of living, the way of working, and the way of interacting with each other. In this shifting situation, the managers and the employees have to promptly adjust to the new environment. They have to be opened and ready for new tactics and to realize the fact that risk and innovation are inevitable. Organizations are unable to enter this ever-changing situation without proper knowledge and lack of ability for renewal. Managers need to manage the institute in such a way that the employees will change their vision, ideas, and attitudes in the long term [21]. At present, Chinese and Malaysian furniture industries are practicing industry 4.0 and they are adopting this industrial revolution 4.0 because of their technological innovations and rapid technology transfer mechanism. In this situation, to sustain the current demand for Bangladeshi furniture in the world market, Bangladeshi furniture industries need to practice industry 4.0 technologies. That's why this study tries to expose some possible technological innovations for Bangladeshi furniture industries and these are represented in section 6. Moreover, the furniture industries of Bangladesh need to select a suitable technology transfer mechanism for furniture manufacturing.

Technology Transfer (TT) is a scientific process of transferring and disseminating scientific knowledge and findings, technologies, tools, methods, processes, manufacturing process, equipment, machines, apparatus, etc. from one group or organization or institute to another for further improvement and commercialization. Primarily, there are two ways for acquiring technology (i) developing it through Research & Development (R&D) (ii) purchasing it. The second way of getting technology is usually called 'Technology Transfer'. TT process is very vital for the extensive applications, operations, and up-gradation of technology that need to be developed [22].

There is a strong relationship between technology transfer mechanism and innovation because technology transfer mechanism stimulates innovative activities of a country. In 2015, [Abdurazzakov \[23\]](#) analyzed the effectiveness of technology transfer mechanisms in hastening innovations and showed that technology transfer mechanisms enable commercialization of research through transforming the research conducted by research institutions and universities and placing them in a form that is useable and operable by technology pursuers and seekers, for instance, SMEs, start-ups, and government. [Le Grange and Buys \[24\]](#) showed numerous technology transfer management tools like technology reviews, technology space maps, and technology balance sheets and proposed a new model for technology transfer.

[Kumar, et al. \[25\]](#) identified and evaluated the critical factors (CFs) to the technology transfer (TT) process through extensive literature review. The critical factors were categorized into five dimensions using experts' opinion and multi-criteria decision making (MCDM) method, analytical hierarchy process (AHP) methodology was used for ranking of dimensions and CFs of technology transfer. [da Silva, et al. \[26\]](#) contextualized TT in the supply chain of industry 4.0 scenario concentrating on the supply, manufacturing industry, and end-user stages.

As [Figure 9](#) shows, a modified technology transfer (MTT) model where large companies, research institutions, universities, incubation centers are worked as technology generators, innovators, and inventors. The developed technology will be translated into a usable form by a technology transfer mechanism. The Technology Transfer Offices (TTO), science parks, innovation centers are the main catalyst of this TT mechanism. Technology pursuers and adopters are small and medium enterprises (SMEs), start-ups, and large companies seeking the technology for their use.

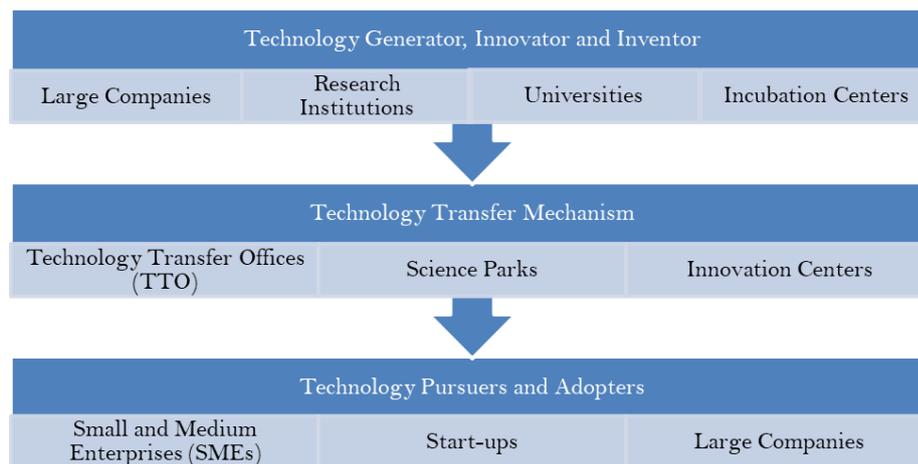


Figure-9. Modified Technology Transfer (MTT) Model.

Source: Concept is adapted from Abdurazzakov [23]

8. FINDINGS OF THIS STUDY

This paper explicitly shows the current scenario of the Bangladesh furniture industry, the demand for Bangladeshi manufactured furniture products in local and global markets. Also, the current machinery of the Bangladeshi furniture industries is represented in this study. This study figures out some possible technological innovations and pieces of machinery for industry 4.0 practice that could be utilized in the furniture manufacturing company of Bangladesh to maintain higher productivity and better quality. To upgrade with industrial revolution 4.0 (IR 4.0), composite raw material technology, flow and job shop scheduling process, green supply chain system, digital manufacturing technology, additive manufacturing technology, 3D printing technology, jointer machine, and advanced table saw machines need to be added in the furniture firms of Bangladesh. Up-gradation with technology is an innovation process that follows a suitable technology transfer mechanism. That's why; this study also illustrates a partially true modified technology transfer (MTT) model for small and medium enterprises (SMEs), start-ups, and large companies.

9. CONCLUSION AND FUTHER SCOPE OF RESEARCH

Because of the comfort, aesthetic and decorative purposes the furniture is needed for every human at the end of the day. Human beings are now becoming more luxurious day by day. As a luxurious item, every human wants to have items of furniture in their houses and offices. As a result of this functionality of the furniture is changed frequently and new innovative designs of ergonomically fitted furniture are demanded by the customers. The global and local demand for high-quality furniture increases with the growth of population and improvement of living standard of the global and local population. In 2013, United Nations has predicted that by the year 2050, the population of the world is projected to be 9.6 billion, with an increasing rate of 38 percent from 2010. Geographically, 54 percent population of the world lives in city areas, a fraction that is estimated to increase to 66 percent by 2050. For this growing population demand for furniture will increase with time. As a result of this, a big export market opportunity will create for Bangladesh to increase the GDP. It is noticeable to all that the world is moving toward industry 4.0 technologies. The quality of products manufactured by industry 4.0 technologies is better than industry 3.0/2.0/1.0 technologies. So, replacing the existing facilities like technologies and machinery of the furniture sector with innovative technologies and machinery relevant to industry 4.0 is a prerequisite to compete in the global market. For this reason, this paper tries to show some possible technological innovations for furniture manufacturers of Bangladesh for upgrading with industrial revolution 4.0 (IR 4.0) and a partially true modified technology transfer (MTT) model for technology up-gradation.

Further studies can be carried out to find out suitable technology transfer (TT) mechanisms and technology diffusion mechanisms for the furniture industry of Bangladesh. Identification and evaluation of critical factors and barriers for technology transfer in the furniture sector of Bangladesh by Delphi technique, multi-criteria decision analysis (MCDA) techniques need to be conducted in the future. Also, a comparative study of the innovation process and TT mechanism of Bangladesh to other technology developed countries need to be conducted for identifying the technology gaps of Bangladesh.

10. DISCUSSION

In this competitive market dynamics, Bangladeshi furniture manufacturers can't survive in both local and global markets without innovation activity. Upgrading the existing technologies by the new one and mounting the new types of machinery in the factory is the part of innovation. The innovation affects the customers' requirements and changes the customer's opinions like new features; upgrade materials, business processes, technologies, and products. Innovation is crucial for the survival and development of Bangladeshi furniture companies. One company's innovation strategy and policy are different from others that will create competitive advantages and ensure the survival of the company on the market. Unfortunately, for a developing country like Bangladesh, an innovation activity faces many different resistances of change and barriers. Some barriers of Bangladeshi Furniture Company are depicted below in Table 2;

Table-2. Barriers of Bangladeshi Furniture Industry.

Internal Resistance	External Resistance
<ul style="list-style-type: none"> • Innovation costs is high 	<ul style="list-style-type: none"> • Lack of government support
<ul style="list-style-type: none"> • Risk of failure 	<ul style="list-style-type: none"> • Economic shocks
<ul style="list-style-type: none"> • Shortage of expert staff 	<ul style="list-style-type: none"> • Lack of marketing information
<ul style="list-style-type: none"> • Adaptation capability of the employee is very poor 	<ul style="list-style-type: none"> • Lack of regional infrastructure
<ul style="list-style-type: none"> • Lack of technological knowledge of the Bottom line management 	<ul style="list-style-type: none"> • Absence of information on new technologies
<ul style="list-style-type: none"> • Absence of internal training for employees 	<ul style="list-style-type: none"> • Lack of opportunities for external partners

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