Extent of Automation and the Readiness for Industry 4.0 among Malaysian Furniture Manufacturers

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Automation offers a promising solution to improve competitiveness for the labor-intensive furniture manufacturing sector in Malaysia. This study evaluated the level of application of automation, the factors driving it, and the readiness of the furniture manufacturers towards Industry 4.0. A questionnaire-based survey was targeted to large and medium-sized furniture manufacturers throughout Malaysia, with responses from 312 manufacturers. The results revealed that the panel-based furniture manufacturers were more responsive towards the adoption of automated technologies than other types of furniture manufacturers. The machining centers and finishing operations within the furniture factories showed the highest application of automated technologies. The factor analysis revealed that the drivers for the application of automated technologies were the desire for higher production capacity, cost involved, product characteristics, and government policy. This study emphasized that in the cost-sensitive furniture manufacturing industry, the economic benefits of applying automation outweigh any other factor in the decision to explore such technologies. The study also revealed that furniture manufacturers are not ready to adopt Industry 4.0, and any efforts by the government to push for such transformation will require the provision of incentives and other tangible economic benefits.

Keywords: Automation; Furniture; Industry 4.0; Cost benefit; Productivity

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INTRODUCTION

The Malaysian Wood-Based Industry

Since the colonial days, the Malaysian wood-based industry has remained an important socio-economic sector that provides significant employment opportunities in the rural areas of the country (Ng and Thiruchelvam 2012). Malaysia has traditionally been an important producer and exporter of tropical wood products in the world, especially saw logs and sawn timber, which are used primarily for construction purposes. In realizing the value of the forest resources, the government embarked on a series of Industrial Master Plans, aimed at transforming the wood-based industry, from being a net exporter of primary produces to become a net exporter of value-added wood products. The first IMP (1986-1995) encouraged further down-stream processing as the exportation of primary produces, were curtailed through export ban, imposition of export levy and export quotas (Ng and Thiruchelvam 2012). The second IMP (1996 – 2005) encouraged the manufacture of value-added products, especially furniture, builders, carpentry & joinery (BCJ), moldings, *etc*.,

which improved the economic value gained for wood resources. The third IMP (2006 – 2020) is focused on increasing the extent of value-addition in the furniture, BCJ, and other value-added products, through design, innovation, and branding (Ratnasingam *et al.* 2018). The formulation of the National Timber Industry Plan (NATIP) in 2009 further emphasized the commitment of the government to foresee the further development of the wood-based industry, through seven strategic pillars, which covers aspects such as raw materials supply, workforce, markets, automation, design, and branding as well as entrepreneurship (NATIP 2009). In this context, the industrial policy formulations and its implementations have contributed positively towards the transformation of the Malaysian wood-based industry into an export-oriented powerhouse of value-added wood products.

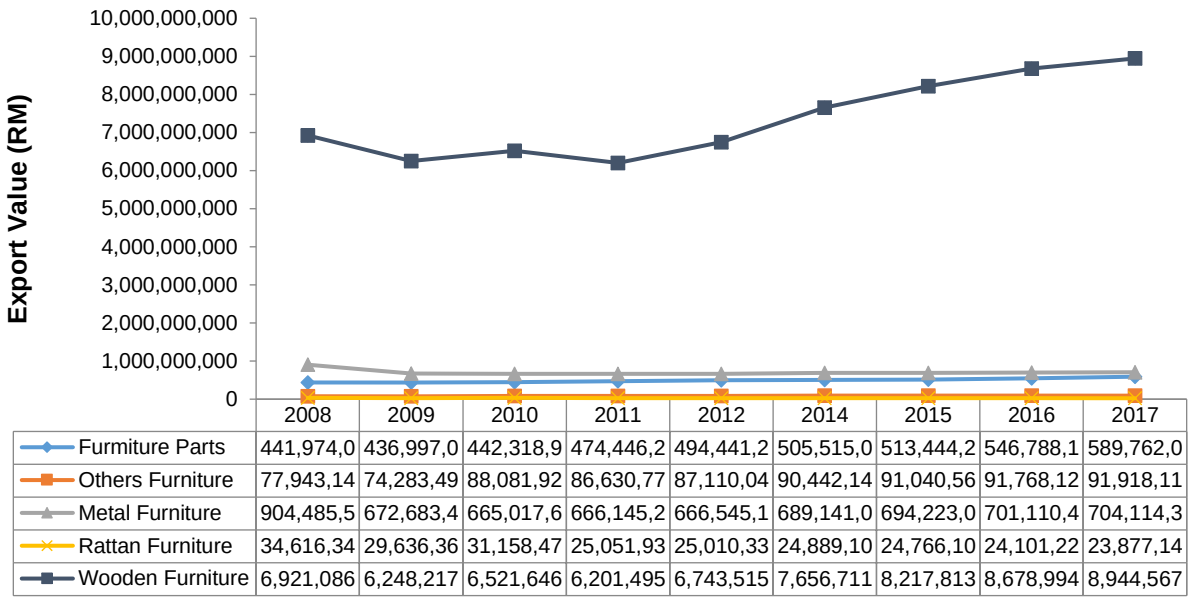
Despite the strong performance of the wood-based industry over the years, there is clear evidence that the rate of industrial growth is slowing, which is due to lost in competitiveness (Ratnasingam 2015). In order to remain viable, investigating the slowing industrial growth of the wood-based industry is of national interest, and is therefore the underlying motivation for this study.

The Malaysian Furniture Industry

From an industrial perspective, the fastest growing sub-sector within the Malaysian wood-based industry has been the furniture sector. Its rapid export growth from about RM 40 million in 1982 to RM 9.83 billion in 2018 clearly underscores the importance of this sub-sector within the overall wood-based industry (Ratnasingam 2015). The Malaysian furniture industry is currently an important socioeconomic sector in the country, contributing in excess of USD 2 billion annually in foreign exchange, while providing employment to almost 93,000 workers (Ratnasingam *et al.* 2012). When the domestic market for furniture is taken into consideration, the net volume of furniture produced within the country exceeds USD 3.2 billion per annum. Hence, the furniture industry has earned the accolade of being the star performer within the overall Malaysian wood industry.

The furniture industry in Malaysia has grown from its humble cottage-based beginnings to its present multi-billion-dollar, export-oriented industry within a period of slightly more than three decades. This growth has been fueled primarily by the availability of input factors, especially raw materials and labor force at competitive rates. Ratnasingam *et al.* (2012) noted that the rapid expansion of the Malaysian furniture industry has been driven by incremental capital inputs, as the ample supply of raw material and workforce provided a huge comparative advantage to the industry to ramp up its production in the early days. With China's accession into the World Trade Organization (WTO) in 2001, and Vietnam following suit in 2007, the comparative advantages of the Malaysian furniture industry has been slowly eroding. China and Vietnam have emerged as the two most important furniture exporters in the world, displacing Malaysia to the tenth position in the league of the 10 most important furniture exporters in the world in 2018 (CSIL 2019).

As a large export-oriented furniture manufacturer, Malaysia exports 85% of its annual furniture production volume to more than 160 countries. The main export destinations are the USA, Japan, Australia, Singapore, Europe, India, United Arab Emirates, and South Africa (MTIB 2019). The wooden furniture category is the largest constituent (Fig. 1), accounting for almost 80% of the total furniture exports. The furniture industry is on track to achieve its target of RM 12 billion in export receipt by the year 2020 (Ng and Kanagasundaram 2017; Ratnasingam *et al.* 2018).



	2008	2009	2010	2011	2012	2014	2015	2016	2017
Furmiture Parts	441,974,0	436,997,0	442,318,9	474,446,2	494,441,2	505,515,0	513,444,2	546,788,1	589,762,0
Others Furniture	77,943,14	74,283,49	88,081,92	86,630,77	87,110,04	90,442,14	91,040,56	91,768,12	91,918,11
Metal Furniture	904,485,5	672,683,4	665,017,6	666,145,2	666,545,1	689,141,0	694,223,0	701,110,4	704,114,3
Rattan Furniture	34,616,34	29,636,36	31,158,47	25,051,93	25,010,33	24,889,10	24,766,10	24,101,22	23,877,14
Wooden Furniture	6,921,086	6,248,217	6,521,646	6,201,495	6,743,515	7,656,711	8,217,813	8,678,994	8,944,567

Fig. 1. Type of furniture export from Malaysia, 2008-2017. Values are shown in RM Million. (Source: Department of Statistics, Malaysia).

Despite these achievements, the furniture manufacturing industry is a low-wage economy, with diminishing profitability attributed to lack of innovation and value-addition (Ng and Thiruchelvam 2012). It is not attractive to the local workforce due to its 3D character (*i.e.*, dirty, dangerous, and difficult) and low wages (Ratnasingam 2015; Ratnasingam *et al*. 2018). As a result, the furniture industry is highly dependent on foreign contract workers, especially those from Bangladesh, Myanmar, and Nepal, who make up almost 63% of the total workforce in the industry. The high foreign workforce content in the furniture industry impairs skills development and productivity growth due to the short-term tenure of these contract workers (Ratnasingam 2015).

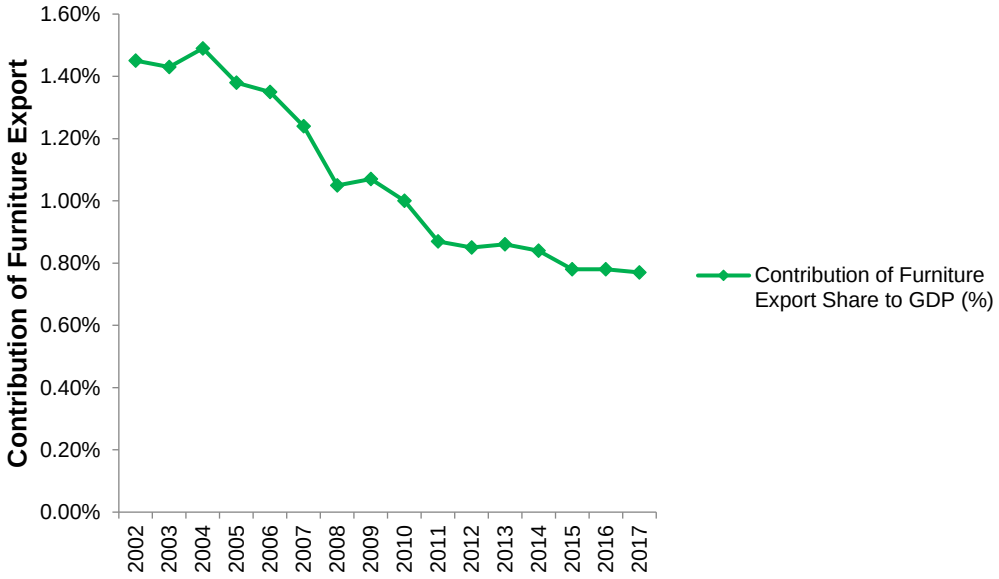


Fig. 2. Contribution of furniture export value share to gross domestic product (GDP) of Malaysia (Source: Department of Statistics, Malaysia)

Growth in the furniture industry is driven by incremental capital inputs, especially raw materials and labor; any negative impact on any of these factors may influence the growth trajectory of the industry as a whole. Figure 2 depicts the clearly declining growth rate of the furniture industry in Malaysia, suggesting that the industry is losing its comparative advantage due to diminishing advantages derived from the factor inputs (Bahrin *et al.* 2016), and its importance as an significant economic sector.

The golden years of double-digit growth of the furniture industry in Malaysia was the 20-year period between 1986 and 2005, which coincided with the 1st and 2nd Industrial Master Plans. However, since 2006 until 2018, the growth rate has decreased to an average of 2% per annum, indicating an industry losing its competitiveness to the large furniture manufacturing bases in China and Vietnam (Ratnasingam 2015). Previous studies by Ng and Thiruchelvam (2012) and Ratnasingam (2015) have identified the main challenges that adversely affects the long-term growth of the furniture industry, and its competitiveness. Whether, it is the factor inputs or other supporting factors such as degree of automation or technology application that hinders the long-term growth of the furniture industry in Malaysia is an issue that warrant further investigation.

Diminishing Returns from Factor Inputs

The advantages derived from the factor inputs, especially raw materials and labor, is on the decline (Ratnasingam 2015). The diminishing supply of rubberwood (*Hevea brasiliensis*) and the increasing labor-cost, even among foreign workers, has seriously impacted the low-cost stature and the competitiveness of the furniture manufacturing industry in Malaysia (Ratnasingam *et al*. 2012). Hardwoods from North America and Oceania in the quantum of 0.5 million m^3 are being imported to offset the short supply in rubberwood, especially among furniture manufacturers (Ratnasingam *et al.* 2018). The increasing costs of foreign-contract workers who account for almost 63% of the total workforce in the industry have adversely affected industrial production cost (Landscheidt and Kans 2016). Against the background of declining comparative advantage, the furniture industry needs to boost its competitive advantage to remain globally competitive, by moving along the value-chain through further value-addition in the manufacturing strategy.

Table 1. Value Addition Trend

Year	Value Addition Growth* (%)	Value Addition Intensity* (%)
2000	33.50%	31.77%
2001	-8.20%	31.48%
2002	-4.60%	25.08%
2003	-2.40%	24.35%
2004	14.80%	23.08%
2005	16.00%	23.56%
2006	6.10%	23.48%
2007	3.80%	22.40%
2008	7.20%	23.33%
2010	1.70%	28.00%
2012	-51.67%	26.35%
Note: Data is not available for year 2009 and 2011; *Calculation by the author. Source: DOS		

Weak Value Addition Trend

The perceived notion that the Malaysian furniture industry is steadily value-adding may be a fallacy, as growth is driven primarily by incremental inputs and not through

productivity gains (Zawadzki and Zywicki 2016). Value-addition is the amount by which the value of an article is increased at each stage of its production, exclusive of initial costs. In this context, the declining value-addition growth as evident in Table 1, reflects an industry devoid of extensive innovation. Thus, the declining growth rate and value-addition intensity result from diminishing returns from factor inputs. One pathway to reverse this declining trend is the adoption of automation and related technologies in line with the transformation towards the era of Industry 4.0 (Landscheidt and Kans 2016).

Application of Automation Technologies and Readiness for Industry 4.0

It has been argued that the high dependence on low-cost factor inputs, especially raw materials and labor by the furniture manufacturing industry in Malaysia, has restricted investments in automation and high technology (Ratnasingam 2015). Nevertheless, the extent to which automated technologies is presently used and the future intentions to adopt high technologies in the Malaysian furniture industry has not been studied in detail.

Automation and computer technologies are the intrinsic components of Industry 3.0, which is indeed a leap-frogging transformation of the industrial scene (Xu *et al.* 2018). In this context, the application of computer numerical control (CNC) workstations, robotics, and other information and computer based technologies has been pervasive throughout the furniture manufacturing processes in recent years. Therefore, this study shall pay special attention to the application of automated technologies from an operational perspective in the furniture industry.

On the other hand, the fourth industrial revolution, better known as Industry 4.0 can be described as an umbrella term, referring to a range of current concepts and touching several disciplines within industry. The key drivers for this fourth industrial revolution can be divided in two aspects: (1) the rapidly advancing technological developments of today, including Internet of Things (IoT), Internet of Services (IoS), Cyber-Physical Systems (CPS) smart objects and big data, which leads to a paradigm shift in industrial production, and (2) the demand from industrial actors to make oneself independent of high labor costs by exploiting new technology. In fact, Industry 4.0 is a collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industry 4.0, CPS monitor physical processes, create a virtual copy of the physical world, and make decentralized decisions. Over the IoT, CPS communicate and cooperate with each other and humans in real time (Wang *et al.* 2017). Via the IoS, both internal and cross-organizational services are offered and utilized by participants of the value chain.

The successful adoption of Industry 4.0 in the production environment requires three prerequisites: (1) existing application of IoT and real-time control is necessary to give unique identifications to products, components, and parts, (2) the integration and utilization of IT systems through vertical integration of the production system, and (3) pervasive application of automation and new production technologies.

Consequently, the extent of automation can be considered as one of the enabling developments to realize Industry 4.0. In the context of the furniture industry, it relates to manufacturing equipment, which will be characterized by the application of highly automated machine tools and robots. The increased automation and robotization required for Industry 4.0 will also have far reaching implications on the overall manufacturing operations within the furniture industry (Xu *et al.* 2018).

Industry 4.0 will affect the future of the furniture manufacturing industry, and it is equally important to establish whether the Malaysian furniture industry is ready for transformation from its present state of limited automated technology application (Thoben

et al. 2017). The concept of Industry 4.0 in the furniture industry encompasses 5 components, *i.e*., digital component, intelligent machine, horizontal and vertical networking, and the smart workpiece. It is about producing furniture in the most efficient manner to meet customer preferences *via* the application of digital technologies. It may be regarded as a "networked factory", whereby the minimum production batch could be 1 (Bahrin *et al*. 2016). Such factories require a constant infeed-outfeed of data from the factory shop-floor to the factory management and *vice versa* to ensure that customer orders are met on-time. The launch of the national policy framework on Industry 4.0 also enunciated the attention given by the government of Malaysia to adopt this transformation to boost economic growth of the various sectors in the country (MITI 2018).

Ng (2011) showed that automation may offer the long-term solution in reducing head count in labor-intensive industries, such as furniture manufacturing. With stagnating labor productivity within the industry at RM 69,000 per worker per year, the application of high technology and greater use of automation may reverse the trend, which promotes greater value-addition. According to a survey by the Academy of Sciences Malaysia (ASM) in 2015, despite the intentions to invest in automation, most furniture factories appear to settle for low-cost automation solutions and stand-alone work stations, such as computer-numerical-control (CNC) workstations, that perform repetitive tasks of high volumes. Despite the provision of financial incentives by the Malaysian Industrial Development Authority (MIDA) and the Malaysian Timber Council (MTC) for the acquisition of automated technologies, the response from the industry has been limited (Nair 2018).

Studies on the current diffusion of Industry 3.0, or rather automated technologies in the furniture industry and the factors that hinder its application are almost non-existent. This information gap must be filled in order to formulate the necessary policy framework to enhance the application of automated technologies in the furniture industry, which in turn will lay the groundwork for its readiness for Industry 4.0. Therefore, the objective of this study was to evaluate the extent of automation, the factors driving its application, and the readiness of furniture manufacturers for transiting towards Industry 4.0.

EXPERIMENTAL

Methodology

Target respondents

The study was conducted *via* a questionnaire-based survey sent to 800 furniture manufacturers in Peninsular Malaysia, which accounted for almost 92% of all furniture manufacturing operation in the country (Ratnasingam *et al*. 2018). The response rate from the potential respondents was 39%, or 312 respondents. The respondent furniture factories were identified and selected from the membership database of Malaysian Furniture Council (MFC), and those selected were either large or medium sized manufacturers, who were more akin to adopt automation technologies.

Questionnaire-based survey

A four-part questionnaire was designed to gather the required information. The questionnaire was prepared after discussions with industry experts, academics, analysts from trade bodies, and contractors, who have been involved in promoting automated technologies and are familiar with the Industry 4.0 concepts. The questionnaire was

prepared by referring to previous studies (MPC 2018; Ratnasingam *et al*. 2018) to ensure that the questions in the study were relevant and could meet the study objectives.

The first part of the questionnaire compiled data on the background of the respondent factory, such as position of the respondent in the factory, factory-size, number of workers employed, type of products, target market, and years in operation.

The second part of the questionnaire required the respondents to reveal the number of automated machines used as a % of the overall number of machines. The work stations with the highest extent of automated technologies used were identified and ranked in a descending order. The respondents were also asked to identify the automated technologies presently used in their factories (if any).

The third part of the questionnaire evaluated the factors that influenced the respondent's decision to apply automated technologies in the particular work stations identified in the second part of the questionnaire. A total of 29 motivations for applying of automated technologies were included in the study, which included increased output, on-time delivery, reduced down-time, shortened manufacturing cycle-time, reduced unit cost, higher investment, higher return-on-investment (ROI), reduced workforce, higher productivity, limited skilled workers, lack of information communication technologies (ICT), lack of production-networking data, consistent quality, product diversity, improved quality, smaller batch-size, standardized components, reduced waste, less pollutants, improved ergonomics, improved safety and health factors, improved workers welfare, higher manufacturing standard, ISO 9001 compliant, ISO 14001 compliant, ISO 18001 compliant, low-wage workers', no clear policy directions on automation and Industry 4.0, and lack of incentives. These motivations were rated on the basis of the Likert's five-point rating scale, from 1 (strongly unimportant) to 5 (strongly important).

The fourth part of the survey required the respondents to evaluate their readiness to adopt Industry 4.0 within their organization and also identify the main challenges faced.

Data collection

The questionnaire was initially pre-tested among 25 randomly selected furniture manufacturers in the Sungai Buloh area, in Selangor, Malaysia in December 2018. After obtaining the responses and comments from the respondents, the questionnaire was modified accordingly to ensure clarity and ease of implementation. The revised questionnaires were distributed to the 800 furniture manufacturers with the assistance of the Malaysian Furniture Council. After three weeks, a follow-up reminder was made through telephone to all the potential respondents, and at the end of the fifth week, a total of 312 furniture manufacturers (39% of the sample population) had returned their completed questionnaires in the self-addressed and stamped envelope provided.

Data analysis

The data from the questionnaires were compiled and tabulated using Microsoft Excel software (Microsoft, version 2010, Las Vegas, NV, USA) to facilitate analysis. The analysis of data was conducted using the Statistical Package for the Social Sciences (SPSS; IBM, version 25, New York, NY, USA). The extent of automation presently used, its use in specific work stations, the effects of motivations on the preferential application of automated technologies in furniture manufacturing, and the readiness of furniture manufacturers to adopt Industry 4.0 were analyzed. The comparison mean between the test factors was performed using the non-parametric statistical method of the Kruskal-Wallis test, as the data in this study was ordinal (Ho 2006). This test was required to validate the

use of factor analysis and to establish the important motivations that determined the application of automated technologies in furniture manufacturing. Factor analysis was then carried out on the 29 motivations for applying automated technologies to simplify them into smaller groups of several factors, which determined their extent of influence on furniture manufacturing, as suggested by Landscheidt and Kans (2016).

RESULTS AND DISCUSSION

The results of this study are presented in five parts: (1) the extent of automation in furniture manufacturing, (2) preferred application of automated technologies in furniture manufacturing, (3) the motivations for automated technologies that determines its application among furniture manufacturers, (4) a factor analysis of the motivations for automated technologies in furniture manufacturing, and (5) the readiness of furniture manufacturers to adopt Industry 4.0.

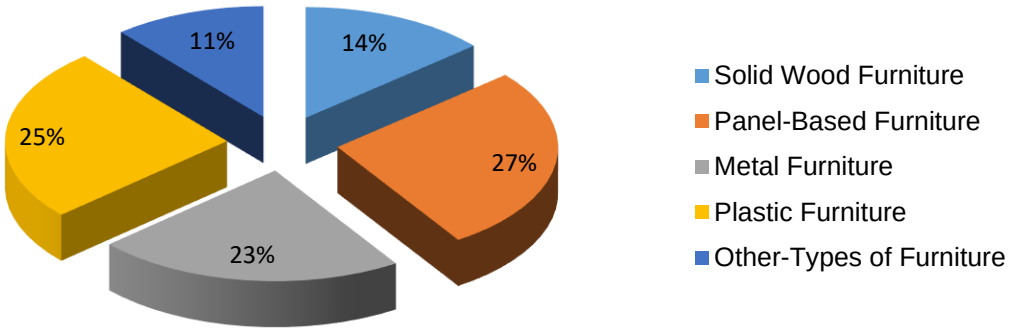


Fig. 3. Extent of automation in the furniture manufacturing industry

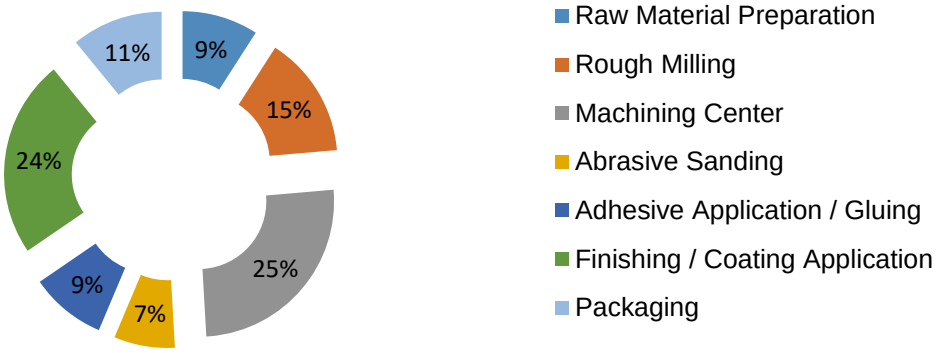


Fig. 4. Application of automated technologies in the manufacturing processes of furniture

The results from the study revealed that the present application of automation in the Malaysian furniture manufacturing industry is focused primarily on panel-based furniture manufacturing rather than solid-wood or other types of furniture products (Figs. 3 and 4). This preference among panel-based furniture manufacturers to apply a higher

degree of automated technologies in the manufacturing facility is driven by the need for consistent quality, lower unit cost, standardized components, and compliance to various standards (Bahrin *et al.* 2016). Ng (2011) revealed that panel-based furniture manufacturing applied a higher level of automation compared to solid-wood furniture manufacturing, primarily due to the standardized components and raw materials used.

In terms of the application of automated technologies in furniture manufacturing, the machining centers were ranked first, while the abrasive sanding operation was ranked the last (Fig. 5). The development in manufacturing technologies, such as robotics, sensor technologies, automated sorter, in-line defects detection systems, automatic spray finishing system, and computer numerical control (CNC) workstations, have paved the way for greater automation in some furniture manufacturing operations to be more receptive to automation compared to the others. The choice of automated technologies presently used by furniture manufacturers is shown in Fig. 6. Several characteristics are at play in each of the manufacturing operations, which predetermined its adaptability to automated technologies, as shown in Table 2.

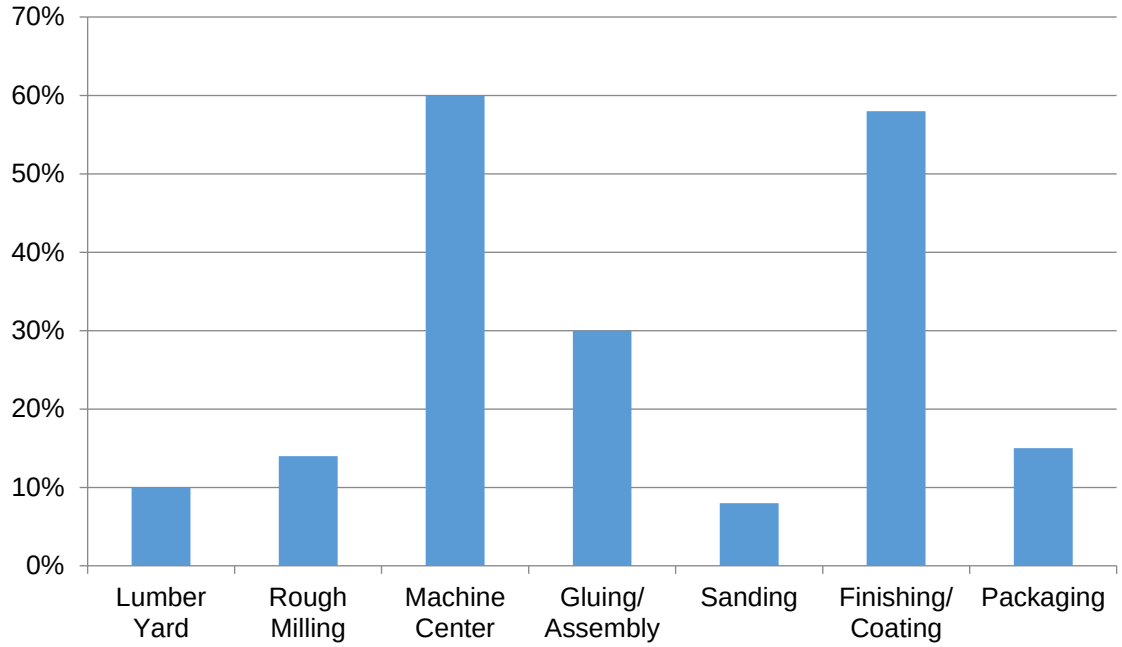


Fig. 5. Application of automation in the various stages of furniture manufacturing

Table 2. Factors Encouraging the Use of Automated Technologies in Furniture Manufacturing Operations

Manufacturing Processes	Factors Encouraging the Use of Automated Technologies
Rough Milling	Capacity, Just-in-Time, Consistent Quality, High Productivity
Machining Centers	Lack of Skilled Workers, Low Cost, Improved, and Consistent Quality, High Number of Workers
Abrasive Sanding	Increased Productivity, Capacity, Consistent Quality, High Number of Workers, Low Cost, Reduce Pollutants
Gluing & Assembly	Just-In-Time, Consistent Quality, Capacity
Surface Coating	Improved Quality, Higher Standards, Reduce Pollutants, High Productivity, Lack of Skilled Workers, Reduce Number of Workers
Packaging	Capacity, Low Cost, Consistent Quality

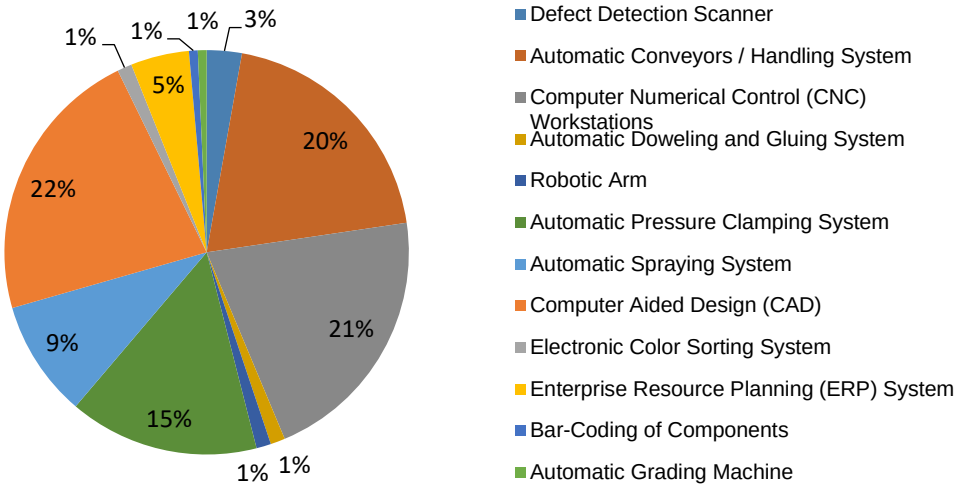


Fig. 6. Specific automated technologies used in the Malaysian furniture industry

The results of the analysis of the 29 motivations for applying automated technologies that encouraged its use among furniture manufacturers were then evaluated. Table 3 presents the mean ranking of the effects automated technologies have on furniture manufacturing. It also includes the determinant factors for the use of automated technologies by the solid-wood and panel-based furniture manufacturers. It was apparent that the lower unit cost, higher output, consistent quality, standardized components, and higher productivity encouraged furniture manufacturers to adopt automated technologies in furniture factories. On the other hand, the main obstacles for applying automation among furniture manufacturers were the high investment cost, lack of skilled workers, lack of incentives, lack of production-networking data, and the presently low workers' wages, which conflated the motivations to explore such technologies. In the final analysis though, the predisposing criterion for the investing in automated technologies was the derived economic benefits, which befits the cost-sensitive furniture manufacturing industry in Malaysia.

However, these findings were contrary to other reports on the motivations that influenced the use of automated technologies in the furniture manufacturing industry. Ng and Kanagasundaram (2017) reported that automated technologies were the most appropriate means of manufacturing furniture in high-wage economies, where the high labor cost is often off-set by the investments in automated technologies, which also provides a shorter period for the return on investment (ROI) due to its higher output rate. In Japan, for instance, the application of automated technologies is more pervasive throughout the furniture manufacturing industry, even among small enterprises, due to the high cost of labor and strict environmental regulations (Thoben *et al*. 2017). The high precision work culture of quality and consistency characteristic of the Japanese workforce necessitates the use of automated technologies, which in many instances eliminate human errors that may impair the overall product quality and customer expectations. A similar finding was also echoed by a study conducted on the furniture industry in Singapore (Ratnasingam *et al*. (2012), where the more stringent labor laws encouraged the application of automated technologies, not only to comply with the requirements, but also to create a much more conducive working environment.

Table 3. Mean Importance Rating of Motivation and Determinant Factors for Automated Technologies in Furniture Manufacturing

No.	*Motivation*	*Mean*	*Chi-sq*	*P-value*	*Determinant Factors*	
					Mean for Solid Wood Furniture	*Mean for Panel-Based Furniture*
1	Increased Output	12.1	1.036	0.041	**4.1**	**4.4**
2	On-Time Delivery	13.3			3.8	3.8
3	Reduced Down-Time	12.4			3.7	3.9
4	Shorter Manufacturing Cycle-Time	12.6			3.8	3.9
5	Reduced Unit Cost	13.6	0.928	0.038	**4.1**	**4.4**
6	Higher Investment	13.1			1.8	2.7
7	Higher Return on Investment (ROI)	14.3			3.1	3.6
8	Reduced Number of Workers	12.1	0.814	0.059	3.9	3.9
9	Higher Productivity	12.4			**4.0**	**4.4**
10	Lack of Skilled Workers	13.1			3.3	3.9
11	Lack of ICT Competency	13.6			3.7	3.8
12	Lack of Production-Network Data	13.5			3.5	3.8
13	Consistent Quality	12.3	0.911	0.047	**4.0**	**4.3**
14	Product Diversity	11.9			**4.4**	**4.1**
15	Improved Quality	12.5			3.8	3.5
16	Smaller Batch Size	13.1			3.4	3.8
17	Standardized components	13.1			**4.0**	**4.3**
18	Reduced Waste	16.6	0.663	0.317	2.9	3.1
19	Less Pollutants	17.4			2.6	3.0
20	Improved Ergonomics	16.2			2.9	2.7
21	Improved Safety and Health Conditions	16.8			3.1	3.3
22	Lack of incentives	12.3	0.814	0.067	3.1	3.5
23	No Clear Policy Direction	14.7			3.8	3.6
24	Low Workers' Wage	12.6			3.4	3.1
25	Improved Workers Welfare	12.5	0.708	0.544	2.8	3.1
26	Higher Manufacturing Standards	12.1			3.9	**4.4**
27	ISO 9001 Compliance	13.3			3.3	3.6
28	ISO 14001 Compliance	13.6			3.1	3.5
29	ISO 18001 Compliance	13.1			3.2	3.5

Ratnasingam *et al*. (2018) reported that the prevailing low-wage economy of the furniture manufacturing industry in many parts of Asia explains the reluctance of many furniture manufacturers to adopt automated technologies. The report implied that lack of stringent environmental regulations and the poor attitude towards workers welfare and their health and safety explains the low adoption of automated technologies in the furniture

manufacturing industry. Other studies have reported that the benefits of applying automated technologies in furniture manufacturing outweighs its initial high investment, and with a higher productivity levels gained, the returns from such investments can be shortened significantly (Bahrin *et al*. 2016; Wang *et al.* 2017).

Table 3 reveals that the lower unit cost, higher output, consistent quality, standardized components, and higher manufacturing standards are the main reasons for furniture manufacturers to adopt automated technologies both among solid wood and panel-based furniture manufacturers. A statistical analysis was conducted to determine whether the seven factors had any significant effect on the type of furniture manufactured and its preference to adopt automated technologies.

The Kruskal-Wallis statistical analysis was conducted to determine the significant difference in the motivations that influenced the application of automated technologies in panel-based furniture and solid-wood furniture. The results of the analysis shown in Table 3 revealed that only the factors of lower unit cost, standardized components, higher manufacturing standards, higher output, and increased productivity were important determinants in the more pervasive use of automated technologies in panels-based furniture manufacturing. This result is also similar to the preliminary study by MFC (2017), which reported that panel-based furniture manufacturers applied more automated technologies compared to other furniture type manufacturers, and it is primarily attributed to their standardized components and the need for higher productivity and lower unit cost due to the nature of the products manufactured. In this context, the main concerns for furniture manufacturers in Malaysia in deciding to adopt automated technologies are the cost involved and the potential economic gains.

Factor Analysis of Motivations that Affected the Use of Automated Technologies in Furniture Manufacturing

According to Ho (2006), it is assumed that in a factor analysis all the motivations in the study are somewhat correlated, and the extent of the correlation among the motivations can be evaluated by the Kaiser-Meyer-Olkin method. The analysis conducted in this study revealed that the correlation among variables in this study had a value of 0.313, which reflects a weak correlation between the motivations. Upon conducting the Bartlett's test of sphericity on the correlation matrix a value of 91.44 was obtained, with a level of significance (p value) of less than 0.001. Therefore, the correlation matrix indicated significant correlation among some of the motivations in the study, and suggested that the factor analysis could be used for this study.

The factor analysis grouped the 29 motivations into seven factors, as follows: (1) production capacity, (2) cost, (3) human capital, (4) product characteristics, (5) work environment, (6) government policy, and (7) market demand, that influenced the manufacturer's decision to use these technologies. The variance of the seven factors against the total variance observed among the various motivations is shown in Table 4.

The application of automated technologies in furniture manufacturing in Malaysia was dependent on increasing production capacity, the cost involved, government policy, and the product characteristics. The motivations related to human capital, work environment, and market demand have a lesser effect on the decision making by furniture manufacturers to adopt automated technologies. This result supports the claims by the Woodworking Machinery Suppliers Association (WMSA) of Malaysia that the Malaysian furniture industry is very cost-sensitive, and any boost to adopt automated technologies could be realized through more stringent regulatory framework and provision of incentives

(Ratnasingam *et al*. 2018). Despite the advertisements and promotional campaigns by the relevant authorities, the use of automated technologies in the furniture manufacturing industry is very much at an early stage, and therefore, no rapid increase use in automation technologies could be realized in the short and medium term.

Table 4. Seven Factor Solutions from the Factor Analysis of the Motivation for Automated Technologies in Furniture Manufacturing

No.	Factors	Motivation	Mean for Solid Wood Furniture	Mean for Panel-Based Furniture	Total Variance
1	Capacity	Increased Output	**4.1**	**4.4**	22.5%
2		On-Time Delivery	3.8	3.8	
3		Reduced Down-Time	3.7	3.9	
4		Shorter Manufacturing Cycle-Time	3.8	3.9	
5	Cost	Reduced Unit Cost	**4.1**	**4.4**	19.1%
6		Higher Investment	1.8	2.7	
7		Higher Return on Investment (ROI)	3.1	3.6	
8	Human Capital	Reduced Number of Workers	3.9	3.9	8.1%
9		Higher Productivity	**4.0**	**4.4**	
10		Lack of Skilled Workers	3.3	3.9	
11		Lack of ICT Competency	3.7	3.8	
12		Lack of Production-Network Data	3.5	3.8	
13	Product Attributes	Consistent Quality	**4.0**	**4.3**	17.1%
14		Product Diversity	**4.6**	**4.1**	
15		Improved Quality	3.8	3.5	
16		Smaller Batch Size	3.4	3.8	
17		Standardized components	**4.0**	**4.4**	
18	Work Environment	Reduced Waste	2.9	3.1	6.9%
19		Less Pollutants	2.6	3.0	
20		Improved Ergonomics	2.9	2.7	
21		Improved Safety and Health Conditions	3.1	3.3	
22	Government Policy	Lack of incentives	**4.3**	**4.5**	15.4%
23		No Clear Policy Direction	3.8	3.6	
24		Low Minimum Wage	3.4	3.1	
25	Market Demand	Improved Workers Welfare	2.8	3.1	6.7%
26		Higher Manufacturing Standards	**4.0**	**4.4**	
27		ISO 9001 Compliance	3.3	3.6	
28		ISO 14001 Compliance	3.1	3.5	
29		ISO 18001 Compliance	3.2	3.5	

Note: Figures in bold represent the highest ranking attributes that are important for each application

Consequently, this study emphasizes the fact that the Malaysian furniture industry has relatively low diffusion of Industry 3.0, which as a precursor to the fourth industrial revolution, and that this may seriously hamper the efforts to shift towards Industry 4.0. The results from the survey of this study, also revealed that the readiness to adopt Industry 4.0 in furniture manufacturing is relatively low, as almost 96% of the respondents were wary of the high initial investment involved, their lack of information technology networking infrastructure, and data management within their manufacturing facility. This sentiment was also expressed in the earlier study by Ratnasingam (2015), who found that the higher initial investments required tend to discourage many furniture manufacturers from exploring the benefits of automation. Furniture manufacturers and other wood products manufacturers in Malaysia are contended with the fact that their low-cost foreign

workforce could more or less offset any benefits that could be possibility offered by automation, and the desire to explore Industry 4.0 is limited and may not be realized in the short to medium term (Bahrin *et al.* 2016).

Implications for the Industry

The results of this study, the first of its kind on this subject in the country, have far-reaching implications on the successful adoption of automated technologies in the labor-intensive furniture manufacturing industry in Malaysia, in line with the government's aspiration to shift towards greater automation in the overall manufacturing sector and its desire to embrace the concept of Industry 4.0 (MITI 2018). Contrary to previous thoughts among policymakers, automation is more appealing to panel-based furniture manufacturers as opposed to solid-wood furniture manufacturers. In this context, the push for automation within the furniture industry should be more focused on this sub-sector, as it may be more successful due to the need for standardized components, higher output, lower unit cost, and type of materials used. Policymakers must also recognize that the adoption of automation within the furniture industry is predetermined by factors such as increasing production capacity, investment cost, product characteristics, and government policy. However, other factors related to the work environment, human capital, and market demand have marginal influence on furniture manufacturers to automate, which inevitably reflects the current low-wage economy prevalent within the industry. The results underscore the need for incentives and clear policy direction, if this aspiration of increased use of automated technologies is to be realized sooner rather than later.

Against the findings of this study, the prevailing low-wage economy in the furniture manufacturing industry does not augur well for the adoption of automated technologies, and the perceived limited benefits to be gained from the application of automation is inhibiting the diffusion of Industry 3.0 within the Malaysian furniture industry. This in turn, negatively impacts the readiness of the furniture industry towards Industry 4.0, and its adoption is improbable in the near to medium term.

In this context, a further study on the possibility of leap-frogging and implementing Industry 4.0 systems in furniture companies that have not even embraced Industry 3.0 fully is highly recommended. Such a study may provide useful insights for the successful implementation of national Industry 4.0 policy framework, within the context of the furniture industry.

CONCLUSIONS

1. The extent of automation application within Malaysia's furniture manufacturing industry is presently highest in the machining and finishing/coating operations.
2. Computer numerical control (CNC), computer aided design (CAD), sorting systems, and automatic spraying technologies were the automated technologies most prominently used in the furniture manufacturing industry.
3. The panel-based furniture industry is more automated compared to other types of furniture manufacturing due to its need for standardized components, higher capacity, and lower unit cost.

4. The factor analysis revealed that automation is driven primarily by higher production capacity, cost, product characteristics, and government policy, which inevitably underscores the cost-sensitive nature of the industry.
5. Generally, the diffusion of automated technologies and information and computer technologies (also referred to as Industry 3.0) within the Malaysian furniture industry is limited, and therefore the probability and readiness among furniture manufacturers for implementing Industry 4.0 is relatively low.

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