# Examination of Industry 4.0 Awareness, Perceptions, and Actions of Employees in Furniture and Board Businesses

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## Abstract

Industry 4.0 (I 4.0) is a major transformation in manufacturing that is driven by the use of digital technologies. Furniture and board businesses are one of the subsectors of the forest products sector that can benefit from I 4.0. In this study, a survey was administered to 206 employees working in furniture and board businesses to understand their awareness of I 4.0, their perceptions regarding its obstacles and potential benefits and practices. The most widely recognized I 4.0 technology by employees is digital connectivity. Employees also see the potential for I 4.0 to help them implement new business models. However, the main obstacles to implementing I 4.0 are a lack of skilled workers and high costs. Employees of furniture businesses are less aware of I 4.0 than are employees of board businesses. Additionally, only a small percentage of businesses in both sectors have an I 4.0 or smart manufacturing strategy. The results of this study suggest that furniture and board businesses need to do more to raise awareness of I 4.0 and to develop strategies for implementing it. By doing so, they can improve their productivity and competitiveness in the global marketplace. This study was conducted on a relatively small sample in a limited area, so the generalizability of the results is low.


Sustainable development is a very broad concept that has become popular and integrated into daily life. In the report titled "Our Common Future" published by the United Nations World Commission on Environment and Development in 1987, the concept of sustainable development was defined for the first time as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987).

Sustainable development is a process of change in which resources are increased, the direction of investments is determined, the development of technology is focused on, and the work of different institutions is harmonized, thus increasing the potential to fulfill human needs and desires. According to Manioudis and Meramveliotakis (2022), it is the right mix of economy and technology that enables us to envision a world where economic growth is sustainable.

Economic development has close connections with the promotion of the division of labor and the mechanization of the production process. At the same time, today it has become necessary to use innovative technologies that increase the capacity of the environment and compensate for the negative impact on the environment. The spread of Industry 4.0 (I 4.0) technologies emerges as an underlying force for increasing productivity, which is the basis of economic development. I 4.0 is built on advances in hardware, software and the storage, processing and transfer of data and has enabled the enablement of new digital production systems (Müller et al. 2019, Culot et al. 2020).

Unlike the previous three revolutions, I 4.0 does not represent a single technology but a combination of technologies, and is based on gaining maximum benefit from innovations in technological transformations (Jäger and Lerch 2020). In addition to accommodating human–human and human–machine interaction, I 4.0 is also a digital transformation process that paves the way for machines to interact with one another (Karamustafa et al. 2022). This digital transformation has enabled businesses with a low-value asset structure to achieve high market value (Ergün and Özcan 2022). With I 4.0, financial resources, which once provided the competitive advantage in traditional production, have been replaced by intellectual capital (Ozan Kesbiç 2020). Technologies related to I 4.0 are localization and identification of objects, sensor technology,

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Forest Prod. J. 74(1):1–9.
doi:10.13073/FPJ-D-23-00056

machine-to-machine communication, human–machine interaction, big data (BD) and cloud computing (CC), advanced analytics, and artificial intelligence (AI) (Bartodziej 2017).

One sector where I 4.0 has significant potential is that of forest products (Molinaro and Orzes 2022). The forestry and forest products industry sectors consist of all cutting and weeding activities (including cutting sites, trees to be cut, the harvesting process, and roadside transportation lines), transport and storage activities (involving the transport of logs, biomass, or intermediate products from the forests to the industrial facilities), and the processing and production activities of the desired end product (Scholz et al. 2018, Zhang et al. 2020).

I 4.0 technologies can improve all processes, from a deeper understanding of the characteristics of a forest to the correct management of raw materials and the provision of higher quality products (Teischinger 2017). In addition, the large amount of data produced in the process, starting from the wood supply chain and continuing through the manufacturing of lumber–furniture–board–paper, can be used to improve the sector (Zhang et al. 2020). Similarly, by optimizing processes with new technologies, a cyber–physical environment can be created that increases efficiency (Chang and Chen 2017). It is also recommended that, in line with the 2030 Agenda for Sustainable Development promoting the sustainable use of natural resources, investments should be made to develop I 4.0 technologies for use in the sustainable production and consumption of forest products (Molinaro and Orzes 2022). The economic potential of I 4.0 in the forestry sector is relatively low compared with other sectors (a 15% increase in gross value added), but it is thought that new digital solutions could provide versatility to the sector (Bauer et al. 2014).

Wood is a raw material that can be processed into different valuable products, and every cubic meter should be used prudently. Therefore, efficient and integrated technologies should be used and waste should be greatly minimized (Molinos 2011, 2013), and optimization of the sawing and manufacturing processes is an important need in the forest products sector (Wieruszewski et al. 2023). Its aim is to improve productivity by using AI to correlate the acoustic emission data of the sawing process with sawing power and waviness (Nasir et al. 2019), and by developing AI and machine safety techniques in industrial chemical processes (Ragab et al. 2018) and automated feeding (Cunha et al. 2015). Rossit et al. (2019) have reported that BD and data mining technologies can be used to improve the performance of the process prediction model. Saxena et al. (2020) have shown that the implementation of I 4.0 additive manufacturing technologies improved cost and quality. In simulations, Alam et al. (2014) found that as the certainty of information on wood quality increases, the gross profit of a business can be increased by up to 50 percent. Moktadir et al. (2018) stated that AI, which consists of a wide variety of machine-learning algorithms that learn automatically through experience, can be used in businesses to analyze and process BD. In a study conducted based on structured interviews with managers of furniture companies in the Czech Republic in 2021 and 2022, participants reported that the I 4.0 application directly contributed to an increase in operational efficiency by 30 to 50 percent, a decrease in communication flow, errors, and repetitive operations, and therefore the realization of sustainable production (Červený et al. 2022).

On the other hand, research shows that until recently there was limited awareness and use of the term I 4.0 in the forestry sector (Legg et al. 2021). Müller et al. (2019) reports that many businesses continue to conduct their manufacturing processes manually, and that they are not fully aware of the potential offered by automation in the sector (Landscheidt and Kans 2019). In a provincial-level study evaluating businesses manufacturing forest products in Türkiye (Turkey), close to half of the businesses were of the opinion that they were sufficient for the I 4.0 (Hatipoğlu and Tunacan 2020), and a little more than half of the large-scale secondary forest products manufacturers in the United States indicated that they had a strategic vision for digitalization (Buehlmann and Forth 2020). The world's forest products sector is no stranger to I 4.0 and it is a current and important subject for research. The potential of I 4.0 for the forestry and forest products sector in Türkiye has not been adequately discussed and very few examples of applications have been provided documenting how I 4.0 might impact these sectors in the future. Accordingly, the aim of this study is to examine the I 4.0 awareness, perceptions, and actions of employees in businesses that manufacture furniture and boards.

## Materials and Methods

### Type of research

A descriptive analytical approach was used in this study.

### Participants

The study population consists of approximately 7,500 employees working in 17 institutionalized businesses with more than 300 employees, located in 6 provinces in Türkiye. The sample size was calculated as 209 people with a 95 percent confidence level and a 7 percent acceptable error rate. The study sample consisted of 206 people who were selected by the purposive sampling method (those who work in sectors in which technological processes are used in the businesses where the study was conducted) and who agreed to participate in the study.

### Instrumentation

A 19-item questionnaire, which included socio-demographic information of the employees and their perspectives on I 4.0 applications, was used in the study. Data were collected in face-to-face interviews conducted between March and July 2023. The questionnaire was based on one developed by Legg et al. (2021) for identifying I 4.0 applications in the forest products industry. The survey items were translated into Turkish by two faculty members (from the Department of Engineering Sciences) who speak both Turkish and English. The translators and the researcher worked together and came to a common opinion regarding Turkish expressions. The survey form was applied to a total of 13 people working in the furniture and board industry, outside the scope of the sample, to evaluate its understandability. At this stage, the answer format was changed to yes or no because the rating items were found to be unusable. Some questions were removed because they were deemed inappropriate, and changes were made to the options of some

Table 1.—Characteristics of survey participants and businesses at which they worked.

| Variable | Frequency | % |
|---|---|---|
| Age | | |
| ≤25 | 10 | 4.9 |
| 26–35 | 106 | 51.5 |
| 36–45 | 58 | 28.2 |
| ≥46 | 32 | 15.5 |
| Gender | | |
| Female | 74 | 35.9 |
| Male | 132 | 64.1 |
| Education | | |
| Primary or Secondary school | 2 | 1.0 |
| High school | 56 | 27.2 |
| Associate degree | 18 | 8.7 |
| Undergraduate–Graduate | 130 | 63.1 |
| Position and/or title in the business | | |
| Manager | 43 | 20.9 |
| Engineer or Chief or Shift supervisor | 63 | 30.6 |
| Master or Foreman | 26 | 12.6 |
| Worker | 74 | 35.9 |
| Length of employment in the business | | |
| ≤1 yr | 44 | 21.4 |
| 1–3 yr | 34 | 16.5 |
| 4–6 yr | 40 | 19.4 |
| 7–10 yr | 32 | 15.5 |
| >10 yr | 56 | 27.2 |
| The main activity of the business | | |
| Furniture | 98 | 47.6 |
| Board | 108 | 52.4 |

questions. The edited version of the survey was back-translated into English by another language expert. The original and back-translated versions were compared by the researcher and a decision was made regarding the items. The terms “smart manufacturing” and “Industry 4.0” were intentionally not used until the final question of the questionnaire because the researcher expected that some respondents might not be familiar with these terms, and did not want this to deter respondents from completing the questionnaire. The test–retest reliability of the survey was evaluated with 34 employees. Accordingly, the test–retest reliability was found to be 0.91 and this result was considered sufficient.

## Data analysis

The data were evaluated using the IBM SPSS 22.0 statistical package program. Categorical variables were calculated with numbers and percentages. The chi-square test and Fisher’s exact test and Cramér’s V were used to compare the perspectives of the employees regarding I 4.0 applications and the distribution of I 4.0 features in their businesses according to the specific properties of the sample. $P < 0.05$ was considered statistically significant.

## Ethical issues

For the study to be conducted, written permission was obtained from the Scientific Research and Publication Ethics Committee of a state university (Date: 15.03.2023, Decision No: 02-2023/04). Prior to the interviews, the business managers were informed about the structure of the study and, acting in line with the principle of voluntariness, written consent was obtained from the participating employees.

## Limitations

The most important limitations of this study were that the sampling was made from furniture and board businesses in six provinces in Türkiye and sample size was small. Numbers of men and women in the sample are not equal, which is a natural consequence of the male-dominated structure of this sector in Türkiye.

# Results

Characteristics of the survey participants and businesses are presented in Table 1. The mean age of the 206 employees was 35.86 ± 8.26 years, of which 52 percent were between the ages of 26 to 35 years, 64 percent were male, 63 percent had undergraduate or graduate degrees, and 65 percent were from people working in senior roles (managers, engineer/chief/shift supervisor, and master/foremen). Of the participants, 27 percent had been working at the establishment for 10 or more years and 52 percent were employees of a board manufacturing business.

Figure 1 and Table 2 show participants’ awareness (knowledge) of various technologies, how these technologies contribute to the business, and the factors that prevent

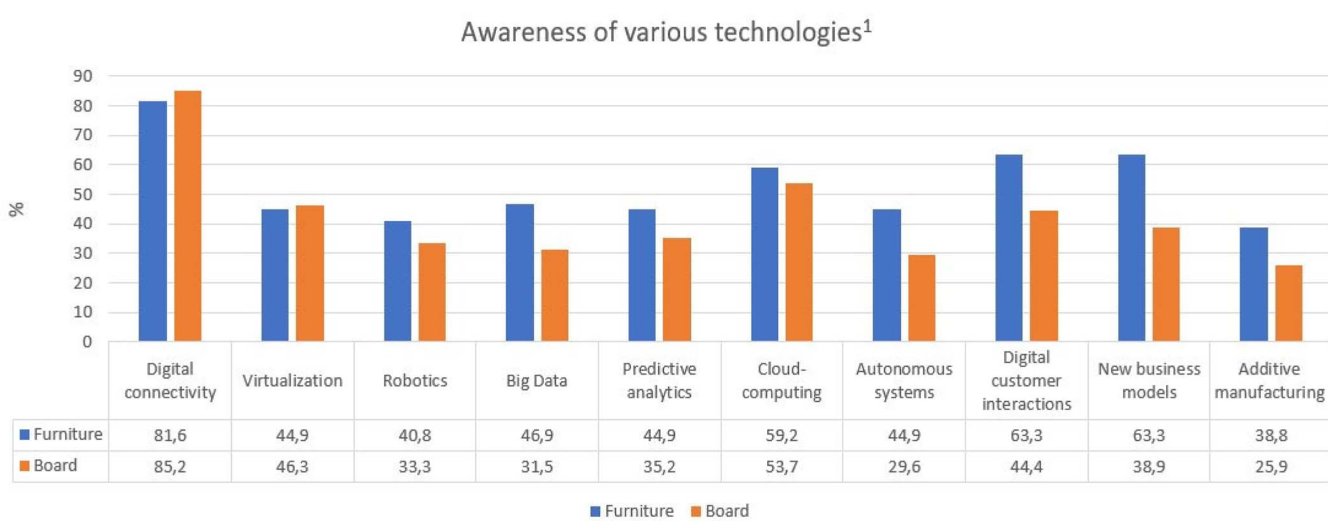


Figure 1.—Survey participants’ awareness of various technologies. [1]More than one option selected.

*Table 2.—Contribution of technologies to furniture and board businesses, and the obstacles to adopting these technologies, according to surveyed employees.* n* *number of responses.*

| Variable | Furniture | | Board | | Statistics[a] |
|---|---|---|---|---|---|
| | $n$* | % | $n$* | % | $\chi^2$; **V**; $P$ |
| Contributions of technology to the business[b] | | | | | |
| Complexity of production | 50 | 51.0 | 50 | 46.3 | 0.459; 0.047; 0.498 |
| Reducing consumption | 44 | 44.9 | 46 | 42.6 | 0.111; 0.023; 0.739 |
| Providing mass customization | 58 | 59.2 | 50 | 46.3 | 3.421; 0.129; 0.064 |
| Implementing new business models | 70 | 71.4 | 68 | 63.0 | 1.665; 0.090; 0.197 |
| Increasing flexibility | 58 | 59.2 | 52 | 48.1 | 2.514; 0.110; 0.113 |
| Implementing machine learning models | 58 | 59.2 | 66 | 61.1 | 0.080; 0.020; 0.778 |
| Minimizing errors in supply chain | 56 | 57.1 | 54 | 50.0 | 1.053; 0.072; 0.305 |
| Improving quality of final product | 66 | 67.3 | 58 | 53.7 | **3.991; 0.139; 0.046** |
| Globalization of future markets | 64 | 65.3 | 54 | 50.0 | **4.919; 0.155; 0.027** |
| Obstacles to using new production technologies[b] | | | | | |
| Lack of skilled workers | 62 | 63.3 | 50 | 46.3 | **5.963; 0.170; 0.015** |
| No roadmap for implementation | 52 | 53.1 | 34 | 31.5 | **9.839; 0.219; 0.002** |
| High cost | 56 | 57.1 | 52 | 48.1 | 1.667; 0.090; 0.197 |
| Lack of manufacturing sensors | 22 | 22.4 | 2 | 1.9 | **21.176; 0.321; 0.000** |
| Pending questions about privacy | 8 | 8.2 | 12 | 11.1 | 0.509; 0.050; 0.475 |
| Unclear financial benefits | 46 | 46.9 | 30 | 27.8 | **8.102; 0.198; 0.004** |
| Current facilities out-of-date | 32 | 32.7 | 44 | 40.7 | 1.443; 0.084; 0.230 |
| Lack of knowledge of service providers | 30 | 30.6 | 18 | 16.7 | **5.591; 0.165; 0.018** |
| Lack of knowledge of technologies | 62 | 63.3 | 52 | 48.1 | **4.751; 0.152; 0.029** |

[a] $\chi^2$: Chi-square test; V: Cramér's V test; $P < 0.05$: statistically significant values in bold font.
[b] More than one option selected.

the implementation of new production technologies, as distributed according to employment at furniture and board businesses. Employees reported that knowledge of BD (47%), autonomous systems (45%), digital customer interactions (63%), new business models (63%), and additive manufacturing (39%) technologies were greater in those working in board than in furniture businesses (Figure 1). Employees working in furniture businesses emphasized the role of technologies in improving the quality of the final product (67%) and the globalization of future markets (65%) as contributing significantly more to the business than did employees of board businesses. Employees working in furniture businesses perceived the lack of skilled workers (63%), lack of a roadmap for implementation (53%), lack of manufacturing sensors (22%), unclear financial benefits (47%), lack of knowledge of service providers (31%), and lack of knowledge of technologies (63%) as more significant barriers to the use of new production technologies than did those employees working in board businesses (Table 2; $P < 0.05$).

Figure 2 illustrates the expertise reported by survey participants in different types of technologies and technological processes used in their businesses. Expertise in data analysis (31%) and data visualization (39%) was reported as significantly higher in furniture business employees, whereas expertise in robotics (6%) and automation (37%) was significantly higher in board business employees ($P < 0.05$).

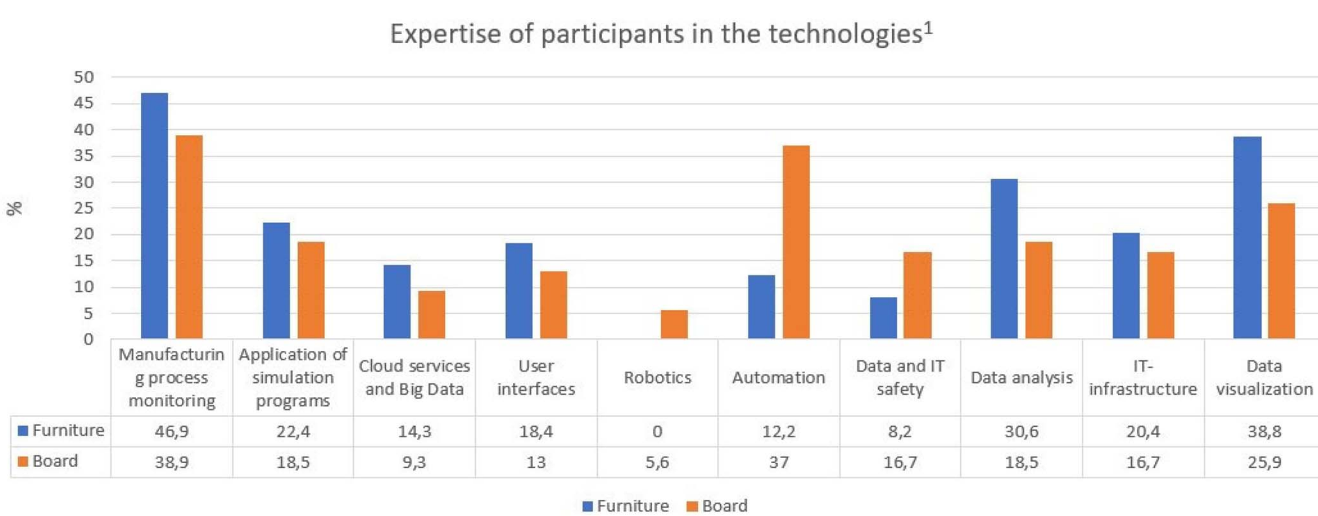


*Figure 2.—Expertise of survey participants in various technologies.* [1]*More than one option selected.*

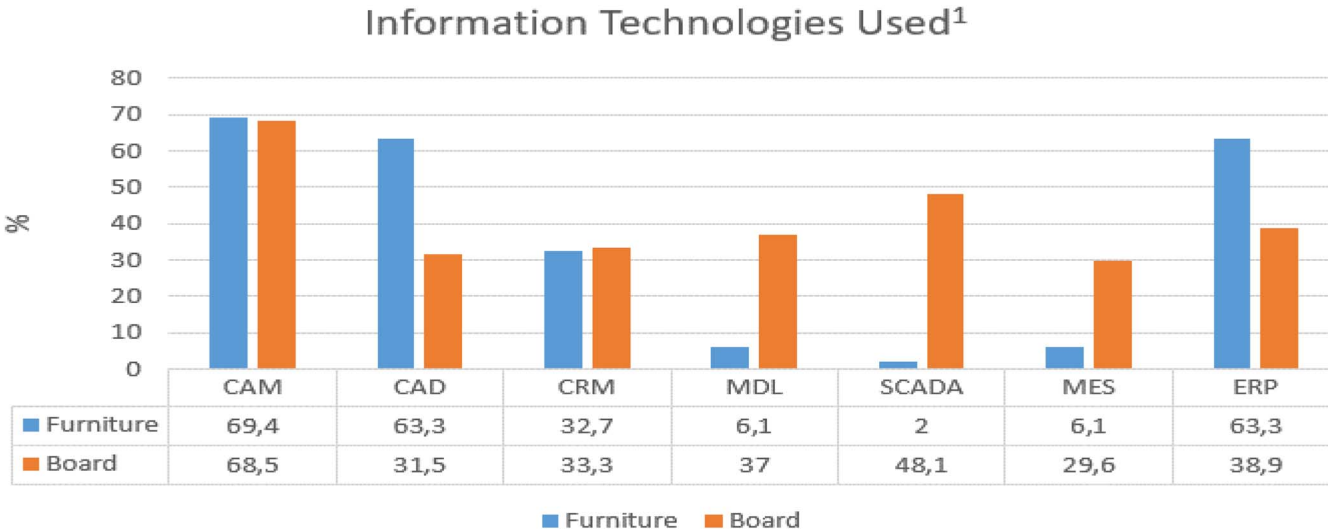


*Figure 3.—Information technologies used by survey participants. [1]More than one option selected. CAM: Computer Aided Manufacturing; CAD: Computer Aided Design; CRM: Customer Relationship Management; MDL: Machine Data Logging Systems; SCADA: Supervisory Control and Data Acquisition; MES: Manufacturing Execution System; ERP: Enterprise Resource Planning.*

Figure 3 shows the distribution of information technologies (IT) used by the participants in the furniture and board businesses. The use of computer aided design (CAD; 63%) and enterprise resource planning (ERP; 63%) was significantly higher among those working in the furniture business, whereas the use of machine data logging systems (MDL; 37%), supervisory control and data acquisition (SCADA; 48%), and manufacturing execution system (MES; 30%) was significantly higher among those in the board business ($P < 0.05$).

A higher percentage of employees working in board businesses than in furniture businesses stated that machine data are collected and analyzed in a system to improve production performance (87%), training is given to employees on the technologies used (39%), a pay-per-use model is employed (44%), and that their business has a smart manufacturing or industry 4.0 strategy (28%). A higher percentage of employees of furniture businesses than in board businesses stated that their businesses are planning to invest in new production technologies or techniques within the next 3 years (67%; $P < 0.05$; Table 3).

Employees in furniture businesses stated that they do not use robots in production but that their use would be beneficial (69%), whereas employees in board businesses reported a higher rate of automated guided vehicle use (39%). Those working in the furniture business indicated that they use wood fingerprints (14%) and photo IDs (14%) more often to identify and/or track materials and/or products in their businesses, whereas employees in the board business reported using barcodes (89%) more often ($P < 0.05$; Table 3).

## Discussion

The results of this study have enabled an understanding of the potential of I 4.0 and given insights into how I 4.0 technologies will impact production from the perspectives of employees working in furniture and board businesses in the forest products sector. The majority of the participants are young adults, male, with higher education and in executive positions. The technology most widely known among furniture and board business employees is digital connectivity. The second-most-known technologies among furniture business employees are digital customer interactions and new business models, but among board business employees it is CC. The rate of familiarity with I 4.0 technologies among employees of furniture and board businesses is between 39 to 82 percent and 26 to 85 percent, respectively. In general, awareness of various technologies is higher among employees in furniture businesses than among those in board businesses. Board businesses are generally smaller and less complex than furniture businesses.

Legg et al. (2021), workers in the US primary wood products industry are more aware of digital connectivity, CC, and new business models than they are of other I 4.0 technologies. Both digital connectivity and CC provide uninterrupted access to data and prevent errors and misunderstandings (Beimborn and Joachim 2011, Castellina 2018). In this respect, these technologies can stand out in terms of decreasing time and cost, and increasing process performance in furniture and board businesses.

In this study, employees of both subsectors emphasized the contribution of various I 4.0 technologies to the implementation of new business models. Employees stated that offering more options to customers and producing furniture and boards to order are the new business models that I 4.0 could support. Although they cannot directly define it conceptually, this general perspective is interpreted as mass customization and on-demand production (MCOP). Businesses can offer customers a wide range of options to customize their furniture and board products such as countertops and cabinets (e.g., choosing the size, color, and material of the pieces). Furniture and board businesses can also produce to order. MCOP can help businesses increase the efficiency of the production process and reduce inventory costs and waste. In the furniture and board industry in Türkiye, businesses becoming more agile and sensitive to customer demands will increase their competitiveness. Employees of furniture businesses reported that improving the quality of the final product was the second biggest contribution of I 4.0 technologies;

*Table 3.—The technologies and technological processes currently used in furniture and board businesses, as reported by surveyed employees. n* number of responses.*

| Variable | Furniture | | Board | | Statistics[a] |
|---|---|---|---|---|---|
| | *n** | % | *n** | % | $\chi^2$; V; *P* |
| Does the business collect/analyze machine data in a system for production performance? | | | | | |
| Yes (e.g., for providing data to management, for real-time production) | 54 | 55.1 | 94 | 87.0 | **25.904; 0.355; 0.000** |
| Does the business use any form of virtual or augmented reality? | | | | | |
| Yes | 10 | 10.2 | 10 | 9.3 | 0.052; 0.016; 0.819 |
| What types of robots are being integrated into your production?[b] | | | | | |
| None, but would be useful | 68 | 69.4 | 28 | 25.9 | **39.000; 0.435; 0.000** |
| None, we do not need any | 10 | 10.2 | 6 | 5.6 | 1.550; .0.087; 0.213 |
| Automated Guided Vehicles | 10 | 10.2 | 42 | 38.9 | **22.403; 0.330; 0.000** |
| Cooperative robots | 12 | 12.2 | 10 | 9.3 | 0.480; 0.048; 0.488 |
| Substituting robots | 4 | 4.1 | 12 | 11.1 | 3.544; 0.131; 0.071 |
| Are employees working in such areas as robotics, automation, etc. being given training? | | | | | |
| Yes | 22 | 22.4 | 42 | 38.9 | **10.325; 0.224; 0.006** |
| No | 54 | 55.1 | 56 | 51.9 | |
| Planned for the future | 22 | 22.4 | 10 | 9.3 | |
| How does your business identify/track materials/products?[b] | | | | | |
| UV tag | 4 | 4.1 | 10 | 9.3 | 2.174; 0.103; 0.172 |
| Wood fingerprint | 14 | 14.3 | 6 | 5.6 | **4.467; 0.147; 0.035** |
| Photo ID | 14 | 14.3 | 0 | 0 | **16.554; 0.283; 0.000** |
| RFID | 2 | 2.0 | 2 | 1.9 | 0.01; 0.007; 1.000 |
| Barcode | 64 | 65.3 | 96 | 88.9 | **16.475; 0.283; 0.000** |
| Does your business receive remote servicing/maintenance? | | | | | |
| Yes | 76 | 77.6 | 78 | 72.2 | 0.773; 0.061; 0.379 |
| Does your business employ a pay-per-use model (renting machines/products)? | | | | | |
| Yes | 26 | 26.5 | 48 | 44.4 | **7.163; 0.186; 0.007** |
| Is your business planning on investing in new production technologies/techniques within the next 3 years? | | | | | |
| Yes, it is | 66 | 67.3 | 58 | 53.7 | **3.991; 0.139; 0.046** |
| Does your business have a smart manufacturing or industry 4.0 strategy? | | | | | |
| Yes | 16 | 16.3 | 30 | 27.8 | **3.885; 0.137; 0.049** |

[a] $\chi^2$: Chi-square test; V: Cramér's V test; $P < 0.05$: statistically significant values in bold font.
[b] More than one option selected.

whereas, employees of board businesses listed the second biggest contribution as implementing machine learning models. As in this study, Legg et al. (2021) found that improving the quality of the final product was the most frequently reported benefit; however, in contrast to their study, the participants of this study perceived the support of technologies in providing mass customization and globalization of future markets more positively. In general, in this study, opinions of the employees in both subsectors regarding the contribution of various technologies to their businesses are similar; close to half, and at increasing rates, agree that technologies will contribute to their businesses in a variety of ways. These positive perceptions of employees will be reinforced if more concrete contributions are seen in their businesses. Therefore, it is important to monitor the short and long-term results of an I 4.0 technology implemented.

In this study, furniture business employees cited lack of skilled workers and lack of knowledge of technologies, and board business employees cited high costs and lack of knowledge of technologies, as being the main factors preventing implementation of new production technologies. High technology costs and lack of skilled workers have also been highlighted in other studies as the main obstacles to implementation of I 4.0 in the forest products sector (Ratnasingam et al. 2019, Kropivšek and Grošelj 2020, Buehlmann and Forth 2020, Legg et al. 2021, Kırklıkçı 2023). Businesses need to invest in training and education for their employees on various I 4.0 technologies. Businesses can partner with educational institutions to develop and deliver I 4.0 training programs. This will help to ensure that there is a pipeline of skilled workers available to the industry. Businesses can make I 4.0 jobs more attractive by offering competitive salaries and benefits as well as opportunities for career development. They can also highlight the positive impact that I 4.0 could have on employees' work–life balance. Lack of manufacturing sensors and pending or unanswered questions about privacy were the factors considered by participants to be minor barriers to technology use. Employees' focus on costs of the technologies leads us to conclude that employees are unaware of the cost-reducing effects of the technologies and that they therefore have negative preconceptions. Indeed, the cost-reducing effects of different the internet of things (IoT) solutions and BD have been reported in the forest products industry (Hämäläinen and Inkinen 2017, Pödör et al. 2017). The uncertainty of the financial benefits of investing in new technology can be a barrier to investment. This barrier can be eliminated by providing appropriate training to the responsible specialists and management. Businesses can focus primarily on low-cost, high-impact technologies. Cloud-based I 4.0 solutions can help businesses reduce upfront implementation costs. Businesses can implement I 4.0 technologies gradually, starting with the most important technologies. This will help businesses spread costs and minimize disruption to their operations.

This study also demonstrates that the surveyed employees report expertise in a variety of technologies. From a total of 10 specializations, robotics was reported at the lowest rate of expertise by employees in both subsectors. Expertise in manufacturing process monitoring is the most reported among employees of both subsectors. In second place is data visualization among furniture business employees, and automation among board business employees. According to Legg et al. (2021), manufacturing process monitoring and data analysis are the areas where experts have the highest level of expertise. Robotics and data visualization, on the other hand, are the areas where experts have the lowest level of expertise. In this study, although the level of awareness of employees about robotics was not low and their businesses had sufficient capacity to integrate robots into production (approximately 48% on average in both subsectors), they have been unable to specialize in this area. In general, in terms of expertise, it cannot be said that the employees consider themselves to be unqualified regarding technologies. However, this finding contradicts the fact that lack of skilled workers and lack of knowledge of technologies have been reported among the factors hindering the use of technologies. On the other hand, surveyed employees were not given in-service training on the use of technologies (robotics, automation, etc.). The reluctance of most businesses to plan any such training in the future is also evident. The fact that many I 4.0 applications require significant changes in work organization and production processes and pose risks that may cause temporary malfunctions or loss of product quality makes business managers hesitant to adopt them (McKinsey Digital 2015). Business managers should not hesitate to integrate these technologies into some business processes, taking into account the I 4.0 expertise of their employees. Additionally, employees' self-confidence regarding I 4.0 technologies should be increased through in-service training activities.

Although IT used by the furniture and board businesses differs according to the characteristics of the companies, the one most frequently used in both subsectors is computer aided manufacturing (CAM). The second most frequently used IT are computer aided design (CAD) and enterprise resource planning (ERP) by furniture businesses and supervisory control and data acquisition (SCADA) by board businesses. Legg et al. (2021) reported that the highest usage in IT was CAD with 48 percent, and that 30 percent of employees did not use an IT system of any kind. These IT systems integrate all basic processes of furniture and board businesses such as accounting, production, sales, and human resources. IT is often used to automate these processes and increase efficiency. The fact that businesses have IT systems in their infrastructure will provide them with an advantage in the transition to I 4.0. However, as supported by the results of this study, other research states that the majority of operations in the forest products sector are lacking in functional cyber-physical systems (CPS), IT network infrastructure, and data management capabilities (Ratnasingam et al. 2019).

Employees sampled in this study generally do not use robotics in production. Employees of furniture businesses reported that cooperative robots were used more, whereas employees of board businesses reported the use of automated guided vehicles (AVGs). In both subsectors, close to half of the employees (48%) think that using robots in production would be beneficial. Legg et al. (2021) noted that a little more than half of the participants indicated that using robotics in production would be beneficial, whereas a quarter of them stated that they do not need robots. Particularly in the furniture subsector, the benefits of the use of autonomous and collaborative robots have been pointed out (Ghobakhloo 2018, Molinaro and Orzes 2022). Businesses should transition to the use of robots to relieve operators and improve quality and safety in physically demanding tasks such as cutting and production (e.g., wood board loading and carrying, nailing pallets, etc.).

In both subsectors, barcoding is the most common method (by a wide margin) for identifying and/or tracking materials and/or products. This is followed in second place by wood fingerprints and photo IDs among furniture business employees, whereas the preference is for UV Tags among board business employees. Overall, use of methods other than barcoding is very low. In Legg et al. (2021), barcoding was the primary material and/or product tracking method with (61%).

Employees of board businesses (87%) reported a higher rate of machine data collection and/or analysis in a system for production performance purposes than did employees of furniture businesses. In both subsectors, use of any form of virtual or augmented reality is fairly low. Nearly half (44%) of the employees in board businesses stated that a pay-per-use model was employed to access technologies. Employees in furniture businesses (67%) reported that their business intends to invest in new technologies within the next 3 years at a higher rate than did employees in the board business. Research has indicated that in the absence of employees who are knowledgeable about technology, businesses may abandon plans to adopt new technology because of the fear that they will not succeed in operation and maintenance of it (Legg et al. 2021). The final question asked of the participants was whether or not their businesses had smart manufacturing or an I 4.0 strategy. Employees working in board businesses (28%) reported a higher rate of smart manufacturing and I 4.0 strategy implementation than did those working in furniture businesses. This finding appears to be quite low considering the responses to the questions in the preceding sections pertaining to awareness of various technologies, benefits of using technologies, hindering factors, expertise, and the technological infrastructure and processes in their businesses.

The fact that this study was conducted in a limited geographical scope in Türkiye limits the generalizability of the findings to furniture and board sectors across the country. The industry may vary across different regions, potentially leading to skewed results. A small sample size increases the margin of error, reducing the likelihood that the results will accurately represent the entire population of furniture and board businesses in Türkiye. Larger samples would provide more reliable and statistically significant results. With non-probability sampling, selection bias can occur, leading to skewed results that may not be generalizable to the broader population. A male-dominated sample may also lead to biased interpretation of data, such as overlooking or misinterpreting issues related to female employees.

## Conclusions

The most important limitations of this study were that the sampling was made from furniture and board businesses in six provinces in Türkiye and the sample size was small. The fact that the numbers of men and women in the sample were not equal is a natural consequence of the male-dominated structure of this sector in Türkiye. Results of this study indicate that these businesses have been unable to make a connection between current technologies and I 4.0 and that they conduct their production processes with an I 3.0-level infrastructure and mindset. The main barriers to adopting new technologies are the lack of a skilled workforce and concerns about costs. As automation and digitalization become essential for maintaining competitiveness, it is necessary for the forest products sector in Türkiye, particularly the furniture and board businesses, to gain speed. Otherwise, they face losing their competitive power in the global market. The market currently lacks a skilled workforce, so a more sustainable approach would be to upgrade the training of existing employees regarding I 4.0. Businesses could consider conducting a self-assessment prior to investing in I 4.0. Based on such a current situation analysis, it is important for businesses that wish to move to I 4.0 to develop a roadmap for their future technology strategy and to establish the necessary IT without delay. I 4.0 technologies can also help to make furniture and board manufacturing more sustainable. IoT sensors can be used to monitor energy consumption and identify opportunities to reduce waste, while AI can be used to optimize the cutting process to minimize material waste.

It is important that all stakeholders, including government, industry associations, and businesses, work together to achieve I 4.0 compliance for furniture and board businesses. Government and industry associations can play a role in educating furniture and board businesses on I 4.0, providing technical support, and promoting success stories. Additionally, the government may offer financial incentives to help furniture and board businesses invest in I 4.0 technologies. This may include tax deductions, grants, or loans.

More empirical research is needed to determine the impact of I 4.0 technologies on environmental, social, and economic sustainability performance in the forest products sector. The results of these researches will not only help forest products businesses increase their I 4.0 investments but will also contribute to ensuring sustainability.

## Acknowledgments

I thank Professor Eric Hansen for permission to use the questionnaire they developed in this study.

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