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Technology used in furniture and sawmill micro-sized enterprises in terms of machine attributes

Yener Top[a], Hakan Adanur[b], Mehmet Öz[c]
[a] University of Gumushane, Baglarbasi, 29100, Gumushane, Turkey
yenertop@gumushane.edu.tr
[b] Karadeniz Technical University, Arsin, 61900, Trabzon, Turkey
adanurhakan@gmail.com
[c] University of Gumushane, Baglarbasi, 29100, Gumushane, Turkey
mehmetoz@gumushane.edu.tr

Abstract. The wood products industry is an industry having a typically low level of technology. The size of an entity is also an important factor in terms of technology level. Generally, the tech level at larger entities is higher, and they may even have their own research and development departments. However, small- and medium-size enterprises (SMEs) in both developed and emerging economies are more numerous and represent an essential part of production and employment. For these reasons, we studied machines being used in micro-sized furniture and sawmills entities in terms of type, age, and place where their machines were produced. A face-to-face questionnaire method was used to gather data. It was found that average machine ages varied according to machine type and the mean number of machines in the enterprises was 3.4. The most frequently owned machine was a table saw in furniture manufacturing and vertical band saws with log carriages in sawmills. There were weak, positive linear correlations between enterprise age and machine age for milling machines, planers, band saws, and sliding table saws.

Keywords: forest products, machinery, technological level, micro-sized enterprises.

1 INTRODUCTION

Wood has a key place in the development of civilization. It was used for fuel and as a building raw material for many centuries (Perlin, 1991 cited by (Teischinger, 2010)). The over use of wood resulted in resource scarcity, and this new reality changed the technologies used in wood processing.

Manufacturers reassess the technology used in their production in a competitive environment nowadays. Customer-driven markets, flexible product design, and product quality requirements have caused small enterprises looking for ways to improve their actual productivity and competitiveness (Rishel & Burns, 1997). Yu et al. (2011) stated that advanced manufacturing technology provides dramatic benefits to firms adopting such technologies in terms of improving labor productivity, product quality, reliable production, production flexibility, profitability, and plant performance, as well as reduced manufacturing costs (Yu, Shen, & Lewark, 2011). Lourens and Jonker (2013) stated that their study confirmed a significant association between competitiveness and technology; their results indicated that the higher the technology level, the more significant the benefits to the business (Lourens & Jonker, 2013).

Firms in the wood products industry have some attributes that are very labor intensive. Small- and medium-sized enterprises, key for increasing a country's economy, such as employment and production (Robb & Xie, 2003), are often regarded as "low-tech" or, at best, "medium-low-tech" (Hirsch-Kreinsen, 2008). Laurens and Jonker (2013) also stated that furniture manufacturing had the capacity to provide jobs and foreign earnings, despite being a generally low-technology industry (Lourens & Jonker, 2013). In contrast, larger firms are generally self-sufficient in terms of research and development.

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They often have well-equipped research departments (Woolgar, Vaux, Gomes, Ezingeard, & Grieve, 1998).

The Organization for Economic Co-operation and Development (OECD) categorizes industries as follows: high-tech sectors (research and development (R&D) intensity > 5%), medium-high-tech sectors (R&D intensity of 3–5%), and medium-low-tech and low tech (R&D intensity < 3%). Thus, the wood and furniture industries are considered to be low-tech and medium-low-tech (LMT) (Hirsch-Kreinsen, 2008).

Sawmilling and furniture manufacturing belong to the primary and secondary wood-processing sectors, respectively. Technology used in both sectors has improved considerably over past decades. Improved sawmill technology has higher throughput, greater accuracy, laser-assisted measuring devices, and computer controls. It was common to see men pushing timber through circular saws by hand years ago (Anonym, 1991); worker decisions in such 'traditional' sawmilling used to determine the processing, which directly affected quality and yield (Conners, Kline, Araman, & Drayer, 1997; Sales, 2001). However, today, with the development of sensors to detect defects, form, and irregularities, it is possible to gather qualitative and quantitative data regarding the input materials. With new techniques, these data can be analyzed before cutting patterns are optimized (Sales, 2001).

Conners et al. (1997) reported that vision technology, such as laser ranging and cameras, has been used to measure the dimensions of logs and lumber. While these technologies have been useful in improving productivity, they still have deficits regarding evaluation of the surface, geometry, and internal features of wood, such as knots, splits, warp, wane, voids, and decay. However, machines using ultrasound, microwaves, nuclear, and X-ray technologies can overcome these problems (Conners, Kline, Araman, & Drayer, 1997).

In secondary processing sectors, including furniture manufacturing, technology has also changed in recent years; today, modern machines can process wood materials faster and more accurately than ever before (Anonym, 1991). In surface machining, high-speed machines can give a surface quality similar to that produced by sanding. As a result of developments in the use of diamonds and ceramics, multi-axial machining systems can carry out multiple operations simultaneously (Sales, 2001).

The objectives of this study were (1) to identify the types, numbers, and ages of machines used in the wood products industry sectors in Trabzon, (2) to estimate the technology level of this industry using information regarding machine age, and (3) to assess any correlation between machine age and the foundation year of enterprises.

2 MATERIALS AND METHODS

2.1 Materials

Enterprises of micro-size and founded in Trabzon were selected as research subjects. The selected enterprises operate in the primary and secondary manufacturing sector, two subsectors of the wood products industry. Sawmills and the furniture sector are divisions 16 and 31, respectively, in the International Standard Industrial Classification of All Economic Activities (ISIC Rev. 4) (United Nations, 2016).

Micro-sized enterprises are important in terms of employment and production in developing countries just as in developed ones. Indeed, micro-scale enterprises constitute the majority of the manufacturing sector. They are involved in craft production and used, in large part, in low levels of technology. In the sawmill and furniture sectors, micro-sized enterprises represent 97% and 96.5%, respectively, of all enterprises (Türkiye İstatistik Kurumu, 2002). That is, only 3% and 3.5% of Turkish sawmills and furniture enterprises are not micro-sized. The ratios of micro-sized enterprises to all enterprises in

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Trabzon province were 98.6% and 97.9% for sawmills and the furniture sector, respectively (Türkiye İstatistik Kurumu, 2002). Thus, the ratios of micro-sized wood processing enterprises were even higher than in Turkey generally.

2.2 Methods

A formal, standardized questionnaire was designed and researchers used it at the enterprises through personal face-to-face interviews. As the size (N) of the Trabzon wood processing sector was known, it was used to compute the sample size (n) required to represent N, with the following equation:

$$n=[N\times t2\times p\times q] / [(N-1)\times D2+t2\times p\times q] \text{ (Arikan, 2011; Kilic, 2012).} \quad (1)$$

According to this Equation (1), the n required to represent the main population was 120. This sample size was divided into two: 50 for sawmills and 70 for furniture manufacturing enterprises.

The questionnaire concerned the demographic structure of the enterprise, types of machines, the years when the machines were bought, and whether the machines were imported. This study was conducted in mid-2015. To analyze the data, SPSS software was used (ver. 19.0), (IBM Corp., 2010). Correlation analyses were performed to assess whether there was a linear association between machine and enterprise age. The Spearman correlation method was used, because it does not require that there be a linear correlation between variables or that the sample has a normal distribution.

3 RESULTS

The machines used by the enterprises in the furniture and the sawmill industries for manufacturing are provided in Table 1. From this table, it can be seen that some machines were used only in the sawmill or furniture sector, whereas others were used in both. The mean number of machines per enterprise was 3.4 in total: 3.02 in sawmills and 3.7 in the furniture sector. The sawmill and furniture manufacturing businesses examined used 13 and 16 different types of machine, respectively. Regarding the frequency of the machines (>19) used by the subsectors, it can be seen that four and six machines were mostly used in sawmills and the furniture sector, respectively.

Table 1. Machines owned and their frequency according to subsectors

Type of machine	Field of activity		Total
	Sawmill	Furniture	
Band saw with log carriage	26	5	31
Automatic band saw with log carriage	19	0	19
Powder suction machine	0	4	4
Computer numeric control (CNC)	0	4	4
Hole machine	0	1	1
Milling	7	39	46
Thickness machine	11	30	41
Edge-banding machine	1	26	27
Compressor	0	1	1
Wood-splitting machine	16	0	16
Groove machine	1	1	2
Planer	22	49	71
Press	1	4	5
Band saw (80 cm)	10	27	37
Wood-turning machine	2	0	2
Sliding table saw	27	64	91
Sanding machine	0	3	3
Chain-drilling machine	0	2	2
Hinge location-opening machine	0	1	1

Side-making machine	8	0	8
Total	151	261	412

Table 2 shows the ages of the machines owned by the enterprises regardless of sector. The mean ages of computer numeric control (CNC), edge-banding, powder suction, and hinge location-opening machines were lower than the others. Thus, it can be concluded that the use of these machines or technologies is relatively new in the wood-processing industries in Trabzon. Another conclusion from Table 2 is that the use of sliding table saws, planers, and thickness and milling machines are common, but CNC, hole, groove, and wood-turning machines are not common.

Table 2. Ages and purchase years of machines owned by the businesses

	Type of machines	N	Years		Ages		Mean (age)	Standard Deviation	Variance
			Min.	Max.	Min.	Max.			
1	Automatic band saw with log carriage	19	1985	2014	1	30	11.00	9.339	87.222
2	Band saw with log carriage	31	1967	2014	1	48	25.26	9.856	97.131
3	CNC	4	2010	2013	2	5	3.25	1.258	1.583
4	Hole machine	1	2000	2000	15	15	15.00	.	.
5	Milling	46	1975	2011	4	40	17.57	8.578	73.585
6	Thickness machine	41	1965	2010	5	50	24.49	12.386	153.406
7	Edge-banding machine	27	2000	2014	1	15	6.41	4.060	16.481
8	Compressor	1	2003	2003	12	12	12.00	.	.
9	Wood-splitting machine	16	1985	2012	3	30	14.75	7.603	57.800
10	Groove machine	2	2000	2005	10	15	12.50	3.536	12.500
11	Planer	71	1965	2010	5	50	22.44	11.756	138.192
12	Press	5	1977	2013	2	38	16.60	15.291	233.800
13	Band saw (80 cm)	37	1965	2015	0	50	24.16	10.128	102.584
14	Hinge location-opening machine	1	2014	2014	1	1	1.00	.	.
15	Wood-turning machine	2	1995	2000	15	20	17.50	3.536	12.500
16	Powder suction machine	4	2010	2013	2	5	3.50	1.732	3.000
17	Side-making machine	8	1985	2012	3	30	11.38	9.319	86.839
18	Sliding table saw	91	1965	2015	0	50	15.36	11.216	125.789
19	Sanding machine	3	1979	2000	15	36	24.67	10.599	112.333
20	Chain-drilling machine	2	2005	2014	1	10	5.50	6.364	40.500
	Total	412							

The average enterprise ages ranged from 1 to 65 years, with a mean of 22.98 (standard deviation (SD): 15.5) overall. According to subsector, the mean enterprise ages were 20.94 years for the sawmills and 25.82 years for the furniture enterprises. Table 3 shows other statistics related to enterprise age.

Table 3. Statistics related to enterprise age

	N	Range	Min.	Max.	Sum	Mean	Std. Error	Std. Deviation	Variance
All enterprises	117	65	0	65	2689	22.98	1.436	15.537	241.413
Enterprises related to furniture	68	65	0	65	1424	20.94	1.719	14.175	200.922
Enterprises related to timber	49	60	2	62	1265	25.82	2.428	16.996	288.861

When the ages of the 412 machines in the data set were examined, the number of machines more than 23 years, or more than the mean machine age, was 123; these older machines accounted for 30%, based on the total number of machines. The level of machines older than 30 years was 9.95%. This means that the enterprises supplied some parts for their machines from second-hand machine markets. When comparing the

machine ages, e.g., milling machines, with the foundation year of enterprises that have milling machines, it was found that the ages of 16 milling machines were older than the enterprises where the 16 machines were being used. Thus, 36.4% of all milling machines had been purchased as second-hand machines during the foundation of the enterprises. Values related to enterprise and milling machine age are provided in Table 4.

Table 4. Comparison of milling machine and enterprise ages

Number	Age		Number	Age	
	Enterprises	Milling Machine		Enterprises	Milling Machine
1	45	40	23	16	15
2	14	10	24	25	20
3	26	20	25	15	20
4	4	4	26	26	16
5	35	10	27	55	15
6	21	15	28	58	5
7	6	10	29	8	15
8	20	8	30	23	23
9	8	20	31	11	13
10	37	30	32	18	9
11	34	30	33	17	17
12	37	35	34	13	20
13	6	6	35	15	8
14	1	10	36	20	10
15	14	20	37	15	30
16	65	20	38	15	30
17	5	6	39	30	20
18	23	15	40	25	25
19	1	10	41	16	30
20	35	30	42	14	20
21	35	8	43	12	15
22	2	15	44	25	20

A correlation analysis was used to assess any association between the foundation years of the enterprises and the times when the machines were bought for each type of machine. When we analyzed 20 machine types, a positive and statistically significant linear correlation was determined for milling, thickness, planer, band saw (80 cm), and sliding table saw machines. No significant correlation was found between the years when the other machines were bought and the years when the enterprises were founded ($p > 0.05$, H_o accepted).

Correlation coefficients between the ages of the enterprises and the machines mentioned above were weak and positive ($r = 0.26–0.49$). That is, as the age of the machines increased, the ages of the enterprises increased. Table 5 shows the machines for which there were correlations between machine and enterprise ages.

Table 5. Correlation analyses enterprises and machine ages.

			Foundation years	Milling
Spearman's rho	Foundation years	Correlation Coefficient	1.000	0.380*
		Sig. (2-tailed)	.	0.011
	Milling	Correlation Coefficient	0.380*	1.000
		Sig. (2-tailed)	0.011	.
*. Significant at the 0.05 level (2-tailed). b. Listwise N = 44				
			Foundation years	Thickness Machine
Spearman's rho	Foundation years	Correlation Coefficient	1.000	0.496**
		Sig. (2-tailed)	.	0.001
	Thickness Machine	Correlation Coefficient	0. 496**	1.000
		Sig. (2-tailed)	0.001	.

**. Significant at the 0.01 level (2-tailed). b. Listwise N = 40

			Foundation years	Planer
Spearman's rho	Foundation years	Correlation Coefficient	1.000	0.495**
		Sig. (2-tailed)	.	< 0.001
	Planer	Correlation Coefficient	0.495**	1.000
		Sig. (2-tailed)	< 0.001	.

**. Significant at the 0.01 level (2-tailed). b. Listwise N = 69

			Foundation years	Band Saw (80 cm)
Spearman's rho	Foundation years	Correlation Coefficient	1.000	0.467**
		Sig. (2-tailed)	.	0.004
	Band Saw (80 cm)	Correlation Coefficient	0.467**	1.000
		Sig. (2-tailed)	0.004	.

**. Significant at the 0.01 level (2-tailed). b. Listwise N = 36

			Foundation years	Sliding Table Saw
Spearman's rho	Foundation years	Correlation Coefficient	1.000	0.315**
		Sig. (2-tailed)	.	0.003
	Sliding Table Saw	Correlation Coefficient	0.315**	1.000
		Sig. (2-tailed)	0.003	.

**. Significant at the 0.01 level (2-tailed). b. Listwise N = 88

We found that only two of 412 machines were imported. Thus, the ratio of imported machines was 0.48%.

4 DISCUSSION

The wood and the furniture industries, like the manufacturing of metal and plastic products, are considered to be LMT industries. This should not be taken to mean that these sectors are unimportant. On the contrary, LMT industries have an important role at the national level for employment in both developed and developing countries (Hirsch-Kreinsen, 2008).

Conners et al. (1997) reported that vision technology had been used in the wood products industry, although no information on the size of the enterprises selected for their study in the early 1980s was provided; however, in our study, no enterprise examined used this technology (Conners, Kline, Araman, & Drayer, 1997). Moreover, no enterprise examined pushed sections of timber through circular saws by hand (Anonym, 1991), as they did 50 years ago.

Robb and Xie (2003) in their study on the Chinese furniture industry found that the average age of the machines was 7.1 (range, 1–30) years. However, their study included 72 enterprises and only two of the 72 employed fewer than 50 employees (Robb & Xie, 2003). In our study, we found that the ages of the machines used in the wood products industry in Trabzon ranged from 1 to 65 years and machine ages averaged 20.94 years. Thus, the mean machine age was about three times higher than in the Chinese study.

Tuncel and Burdurlu (2002) reported that using computer technology decreased the make-ready time in large measure; conversely, it caused problems in finding appropriately qualified employees and increased wages. However, the reduced employee numbers caused a decrease in costs overall (Tuncel & Burdurlu, 2002). In our study, there were four enterprises using computer technology, all operating in the furniture subsector. Furthermore, their purchasing years ranged from 2010 to 2013 (Table 2). Thus, the use of this technology in micro-sized enterprises in the wood products industry is recent.

Weidenbeck and Parsons (2010) reported that many mid-size firms in the value-added wood products industry were using CNC and computer-aided design (CAD) technologies; even small manufacturers recognized the benefits and accessibility of these technologies. They also found out that there was a relationship between technology utilization and firm size, in which CNC and CAD were used by large and medium firms more frequently than small firms (<15 employees) (Wiedenbeck & Parsons, 2010). In our study, it was found

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that the level of CNC in the wood products industry in Trabzon was 0.97% of all machines used.

Elva and Marku (2014) found that large enterprises, employing 50–80 workers, used advanced technology; medium enterprises, employing 10–15 workers, used some modern machines; and small enterprises, employing 2–4 workers, used two or three wood-related machines in the wood industry in Albania (Elva & Marku, 2014). The mean number of machines used in each enterprise in Trabzon corresponded with the results of Elva and Marku.

Kodzi et al. (2007) reported that the types of machines and equipment being used changed not only between different sectors but also between the enterprises operating in the same sector but on a different scale (Kodzi, Gazo, & Vlosky, 2007). In our study, we found that different machine types were used according to the subsector. For example, it is characteristic to use an edge-banding machine in furniture manufacturing and an automatic band saw with a log carriage in sawmills (Table 1). Kodzi et al. (2007) concluded that most of the enterprises producing furniture and cabinets frequently used table saws, routers, belt sanders, and band saws (Kodzi, Gazo, & Vlosky, 2007). We also found that these machines were the most frequently used machines in furniture manufacturing, except the belt sander. The reason for this may be the material used for furniture products; because most of the furniture manufacturing enterprises in Trabzon used fiber or particle board-covered melamine, they do not need a sander. Kodzi et al. (2007) reported that enterprises producing furniture and cabinets used 20 different machines and that enterprises producing lumber, veneer, and plywood used 10 different machines (Kodzi, Gazo, & Vlosky, 2007). The furniture and sawmill enterprises in Trabzon used 16 and 13 different machines types, respectively.

The weak and positive correlations between enterprise and machine ages for milling, thickness, planer, band saw (80 cm), and sliding table saw machines showed that the enterprises typically bought these machines during the foundation phase. However, the weakness of the trend and the milling machines being older than the enterprises also indicated that these machines were often bought from secondary machine markets. Given that a characteristic attribute of micro-sized enterprises is their financial weakness, it is not surprising that there is a tendency to purchase second-hand machines. It also may be that the tendency to buy second-hand machines hinders the introduction of new technologies through new machines. In the literature, there is no study on second-hand machine use in the wood products industry. Thus, it was not possible to compare our study with others in this regard.

The Malaysian forest products industry, the tenth biggest exporter in the world in 2008, imported 83% of technology and machines from Germany, Italy, and Taiwan (Ratnasingnam, et al., 2013). Boon-Kwee and Thiruchelvam (2011) reported that of the machines used by the industry, more than 95%, were imported and there were modified machines by industry, such as presses, table saws, bench drills, band saws, and jump saws (Boon-Kwee & Thiruchelvam, 2011). We found that only 0.5% of the machines used by the furniture and sawmill industry were imported. Thus, the enterprises in Trabzon are not dependent on foreign sources for machines.

5 CONCLUSIONS

Most of micro-sized wood products industry enterprises in Trabzon are still using old-fashioned or traditional manufacturing technology, not CNC equipment. Their level of technology is low in the context of average machinery age. Some types of machines used in production change according to subsector. Furthermore, some machines are used very often, but some rarely.

The types of machines used in enterprises for furniture manufacturing were distributed over a wider range, and in both furniture and sawmill subsectors, the average

number of machines owned by enterprises in Trabzon was 3.4. The average age of the machines was about 23 years.

An important result of our study is that the use of second-hand machines was common in the furniture and sawmill industries. Weak, positive linear correlations were found between the ages of the enterprises and machines only for milling, thickness, planer, band saw (80 cm), and sliding table saw machines. In addition, the number of the machines that were older than the enterprises accounted for about one-third of all machines owned by all of the enterprises examined. The great majority of the machines used by the subsectors in Trabzon were from Turkish machine producers. Reasons motivating enterprises to buy second-hand machines require further research.

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