INFLUENCE OF SELECTED FACTORS ON THE SAWING CAPACITY OF SAWMILLS IN THE CZECH REPUBLIC*

J.Bomba, M. Böhm, P. Šedivka, F. Friess, R. Orálková

Czech University of Life Sciences Prague, Faculty of Forestry and Wood Sciences, Prague, Czech Republic

The paper deals with the influence of selected factors on the sawing capacity of small and medium-sized sawmills with a sawing capacity to 99 999 m^3/year under the conditions of the Czech Republic. One of the objectives was to analyze the current state of production technology and machinery. In total, data was analyzed from 195 sawmills that were divided into five groups according to the volume of processed timber. A production function was created from the ascertained results in order to determine the sawing capacity for small and medium-sized sawmills. It was found out that sawing capacity is mostly affected by the number of employees. The influence of the degree of mechanization and the main sawing technology was evaluated, too.

Wood; sawing; small and medium-sized enterprise

DE GRUYTER OPEN

doi: 10.1515/sab-2016-0025

Received for publication on October 2, 2015

Accepted for publication on August 13, 2016

INTRODUCTION

The timber industry in the Czech Republic has a good raw material base; about 16 million m^3 of wood is harvested every year. Roughly half of this quantity is processed using sawmill technology (Sloup, Pulkrab, 2012; Ministry of Agriculture Report, 2014). Sawmill woodworking has a long tradition in the Czech Republic. The first mechanically driven saws associated with water mills date back to the 11th century (Štěpán, Křivanová, 2000). However, due to the fact that after World War II the Czech Republic joined the countries of the Council for Mutual Economic Assistance (CMEA) and the logging industry was included in the abated industries, this woodworking tradition was somewhat impaired. Further development of this sector in the Czech Republic then proceeded differently when compared to other West European countries (Bomba, 2009).

The capacitive determination of the size of a production sawmill unit does not have a particularly long tradition. Midway through the 20th century, the size was usually expressed using a number of primary machines, i.e. in the Czech Republic primarily frame saws. There were two-frame and four-frame saws, etc. For experts, this expression was more concise, as they were able to more accurately imagine the described operation, rather than just production data, which could be influenced by many various factors. Data on sawing capacity was also not considered essential due to the fact that each log diameter should be processed on a frame saw with the corresponding throughput. The former sawmill stood in line next to each frame saw with the corresponding throughput. At that time, frame saws with different throughputs stood in line next to each other at the sawmills (maximum registered number is 24 machines) (Fronius, 1989), and not all were constantly running. The drive source usually did not allow for concurrent use of all machines that were placed on a common transmission shaft. The turning point came after 1950, when the use of frame saws began to be tracked in the Czech Republic and planned liquidation of so-called ‘excess’ capacities began (Bomba, Friess, 2009).

* Supported by the Internal Grant Agency of the Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Project No. VGA IG 200741230007

Table 1. Capacitive breakdown of saws (Fronius, 1989)

Designation	Annual sawing in m^3 (plm)
Smallest plants	up to 3 000
Small plants	3 000–9 000
Medium-sized plants	9 000–18 000
Large plants	18 000–30 000
Largest plants	30 000–100 000

Table 2. Size breakdown of saws (Mantau, Sörgel, 2006)

Designation	Annual sawing in m^3 (plm)
Smallest plants	up to 1 000
Small plants 1	1 000–4 999
Small plants 2	5 000–19 999
Medium-sized plants	20 000–99 999
Large plants	100 000–499 999
Largest plants	over 500 000

Production capacity (including sawing capacity) means the ability of a production unit to perform under certain conditions. Yet the performance is, in accordance with the theory, defined as the amount of work done per unit of time. From this definition it is clear that production capacity – sawing capacity – is not an isolated phenomenon which could be assessed without specifying the impact of the relevant conditions, and particularly in their context of the productive time factor (Friess, 2006).

In Central Europe, capacitive expression using the volume of timber processed in m^3 is commonly used (in Scandinavia and North America it is mainly lumber production). Individual factors affecting sawing capacity are so specific that they practically place each unit in its original position. In order to evaluate sawing capacity, it is therefore necessary to create certain groups in which, with some simplification, units of approximately the same annual log sawing performance are grouped together. However, individual production plants may be present in the same group, each very different in their technical and technological level, production program or range of effective working time (Šedivka, 2009). In the 1980s, K. Fronius used the capacitive graduation (see Table 1; Fronius, 1989).

Although the cited work is based on very advanced technologies including aggregate sawing technology, the specified capacity benchmarks were quickly overcome on both extreme poles, i.e. both for small capacities and for large units.

In 2004 Mantau and Sörgel started using different breakdowns (see Table 2; Mantau, Sörgel, 2006).

As is evident, an annual sawing capacity of around 100 000 m^3, regarded as the greatest at the end of the 20th century, only represented in the next decade a transition between large and medium-sized sawmills. In a very short time another development brought a further shift in the upper capacity limit, and thus sawmills with annual log sawing of over one million m^3 are not rare (in the Czech Republic there are currently 4 sawmills with the capacity of 1 million m^3).

The upper limit is a more or less understandable shift and is in line with the general trend based on the development of technology. A similar increase in unit capacities has also been seen in other industries. The situation is different, however, with regard to the capacity of small and the smallest sawmills. Small sawmills are in fact not going out of business – quite the opposite – as evidenced by the above mentioned authors when they comment on the situation in the Federal Republic of Germany – there has even been an increase in the share of small capacities in the total volume of processed materials (Pražan, Příkaský, 2007). The reasons for the continuation and development of a large number of small sawmills are in particular the following:

(1) The availability of raw material practically throughout the entire Czech Republic. Forests cover 33% of the territory (Ministry of Agriculture Report, 2014). However, in some areas the forest cover is not strong enough to allow for efficient operation of large sawmills.

(2) A variety of materials. Although mostly monocultural forests can be found in the Czech Republic, local variations do exist and the diversification of tree species is a forestry concept. Large aggregate capacities require standard (unified) raw materials.

(3) The existence of consumers for small sawmill products. The use of wood is experiencing a gradual renaissance, and in addition to the reconstruction and renovation of old buildings, modern builders have begun using the advantageous properties of wood. Since it is not always a matter of large companies, these customers seek reasonably-sized business partners.

(4) The development of techniques and technologies. Renowned manufacturers of sawmill technology accept the prospects of small sawmill business and offer equipment and machinery adapted for the small sawmills.

(5) Small and medium-sized sawmills are typical employers in areas with scarce job opportunities. Rational local authorities therefore generally support their existence and small business usually finds its place in central development programs.

The indisputable advantage is the ability to carry out the piece and small-series production and respond flexibly to specific market requirements. These include the complete fabrication of a roof frame of a house, the production of long range of lumber (up to 12 m) and, last but not least, the processing the raw materials of

Table 3. Structure of the analyzed companies

Group	Sawing capacity (m^3/year)	Number of companies	Group designation
A	up to 1 000	30	smallest sawmills
B	1 000–4 999	80	small sawmills 1
C	5 000–19 999	66	small sawmills 2
D	20 000–49 999	17	medium-sized sawmills
E	50 000–99 999	2	medium-sized sawmills

Table 4. Basic statistical indicators in individual sawmill groups

Statistical indicators	Sawmill groups				
	A	B	C	D	E
x (m^3/year)	254	497	658	845	1347
SD	147	284	291	445	191
v (%)	57.86	57.15	44.14	52.63	14.17
Min.	50	100	225	364	1212
Max.	600	1500	1250	1667	1482

x = average value, SD = standard deviation, v = coefficient of variation, Min. = minimum measured value, Max. = maximum measured value

private owners. The total number of production units engaged in sawmill wood processing is not reliably monitored anywhere in the Czech Republic. Since 2007, various investigations have been underway with the aim of obtaining relevant data for assessing the state of the sawmill industry. Research is carried out not only at the Faculty of Forestry and Wood Technology of the Czech University of Life Sciences Prague, but also by the Association of Woodworking Companies in the Czech Republic (Pražan, 2010). Similar investigations were also carried out, for example, in Germany (University of Hamburg) and in America (Spelter et al., 2007, 2009).

The production capacity and production of saws for southeast Alaska was monitored from 2000 to 2010. Until that time the sawmill sector here was limited due to sales and transfers of the largest sawmills. Between 2001 and 2002 there was a large increase in the production capacity of the local sawmills (Kilborn et al., 2004). Between 2003 and 2004, a decline in production occurred mainly due to the transfer of manufacturing operations to countries with cheap labour (Brackley et al., 2006). The situation in the sawmill industry stabilized in the following years, and sawmill production capacity did not differ significantly. Adversely, log processing increased due to changes in the energy sector (Brackley, Crone, 2009). In subsequent years, the possibility of using wood as biomass in the form of pellets, biofuels, and electricity increased. This opened up new markets for timber of lesser quality and size (Alexander, Parrent, 2010, 2012). In 2009 there was a sharp decline in sawmill production. During the following year, market conditions began to improve thanks to domestic housing construction and exports to Asian countries, in particular China and Korea.

MATERIAL AND METHODS

In view of the fact that there is no current sawmill database in the Czech Republic, it was necessary to carry out an own investigation. The following sources were selected for acquiring information:

- database of companies cooperating with the Czech University of Life Sciences Prague
- Woodworking Industry Employer Association
- theses and dissertations
- periodicals and newspaper advertising
- websites
- database of the Czech Statistical Office
- European Databank Database (EDB)
- own survey

The processing of company databases was followed by an own investigation to acquire information on the machinery equipment and other parameters of each company. To ensure that this survey was objective and that the individual results were comparable, a set of questions (questionnaire) was prepared. The questionnaire contained 19 basic questions, some of which needed to be elaborated via sub-questions. When preparing the questionnaire, we omitted questions about sensitive data that businesses do not publish (in particular economic).

The questions from the questionnaire were conceived as follows:

- Characteristics of the location (name of municipality) where the company is situated.

• Identifying sawing capacity expressed by the volume of processed raw material, number of employees, and number of shifts.
• Characteristics of processed raw material.
• Own machinery equipment was ascertained in the subsequent part of the questionnaire. The subject of interest were the types of machines, their number, manufacturers, and age.
• The types of used tools and their maintenance.
• The level ~~status~~ of mechanization in the company, i.e. the methods of material manipulation at the sawmill, and log manipulation.
• Beside the inputs, also the outputs of the company were asked about, in particular: the type and quantity of produced lumber, affiliate production, lumber preservation, lumber drying.
• The subject of the investigation was also the exploitation of sawmill waste (sawdust, shavings, bark, etc.).
• In accord with the questionnaire subject, we inquired about the expected investments into machinery equipment, as well as about the main issues of the companies.

The questionnaire took place from 2008 to 2010 and was gradually updated in subsequent years. Over 800 companies were contacted in total (which is about 40% of the production capacity of small and medium-sized enterprises in the Czech Republic (qualified estimate). A total of 195 questionnaires were answered.

RESULTS

Based on the acquired information, the companies were divided into 5 groups according to their sawing capacity and labelled A–E (Table 3). The basic statistical indicators of overall sawing capacity are shown in Table 4.

In the second phase, a sawing cut was determined for one employee for each company according to the following sample:

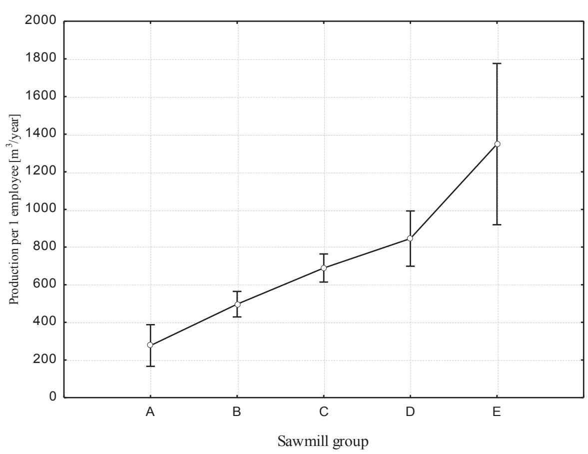

Fig. 1. Course of sawing cut per 1 employee according to sawmill groups

$$P = k/Z \quad (1)$$

where:
P = sawing cut for one employee (m^3/year)
k = sawing capacity (m^3/year)
Z= number of employees

The average sawing cut per 1 employee and other statistical indicators according to the groups of sawmills is shown in Table 4 and Fig 1. It is evident from the figure how the sawing cut changes for employees in individual groups, or that it has an increasing tendency from group A to group E.

The sawing cut per one employee was tested for individual companies via a regression analysis. First linear analysis was applied, which only described the relevant dependence from 28%, and it was therefore necessary to use a non-linear analysis. Exponential course (R^2 = 0.682) proved to be the best way to describe the given characteristic (see Fig. 1), which is given by the equation:

$$P = 1.3132E - 16exp(0.4169(x)) \quad R^2 = 0.682 \quad (2)$$

The sawing capacity per one employee for individual groups of companies is best described by exponential course dependence. This can be explained by the fact that the increasing sawing capacity does not depend only on the number of employees, but also on the level of the technology, degree of mechanization, etc.

Significance of the individual factors affecting sawing capacity is tested in the following analysis.

In the third phase we assessed the impact of the primary machine (primary technology) on sawing capacity. Fig. 2 shows the performance of individual primary machines and all of their possible and used combinations.

It is evident from Fig. 2 that aggregate technology is a wholly different woodworking technology which significantly exceeds through its capacity the possibilities of other primary machines and their combinations. Both aggregate lines from the selection consist of a chipping headrigue and two pairs of ordinary band saws, which from a capacity point of view can be regarded as the less powerful configuration alternative. Aggregate technology in a combination of chipping headrigues, milling machines, and circular saws has much higher capacity options and represents the technology of large and rather high-capacity sawmills. A pair of frame saws in the classic configuration (according to the Scandinavian model) exhibits higher performance than the actual frame saw or horizontal band saw. The performance of the vertical band saw only demonstrably differs from aggregates. Other selections consist of different sets of basic machines, as could be seen in plants; their capacity differences were tested via a detailed statistical analysis.

From the analyses specified above, it was found that sawing capacity is affected in particular by the number of employees, the primary technology and other factors of which the level of mechanization around the primary machine has the greatest influence.

In order to explain the dependence, we used the multiple linear regression method, where the independent variables were the number of employees, the primary technology (primary machine and possible combinations), and the degree of mechanization (mechanization around the primary machine).

From the ascertained results it is possible to determine an equation for calculating sawing capacity in relation to the number of employees (Table 5), the primary technology, and the degree of mechanization, which is as follows:

$$K = -74\,458.9 + 346.2\,(z) + 680.6\,(t) + 2809.1\,(m)$$
$$R^2 = 0.664 \quad (3)$$

where:

K = sawing capacity (m^3/year)

z = number of employees

t = primary machine (sawing technology)

m = level of mechanization around the primary machine

Given the value of the correlation coefficient, we can see a strong dependence of sawing capacity on selected factors, which is described by the given regression function in more than 66%. The strongest factor influencing sawing capacity is the number of employees, and this factor affects the given dependence in almost 54% (according to standardized (beta) regression coefficient). Attention must be drawn to the fact that the number of employees includes shift operations. The second strongest factor can be considered the degree of mechanization; its weight is almost 23%. The third most important factor is the primary technology (primary machine) with a total weight of just over 20%. According to this model it is possible to determine the theoretical sawing capacity for sawmills with an annual sawing capacity up to 99 999 m^3 of timber per year. The situation will be different for larger sawmills, the strength of the number of employee factor will gradually be reduced and the influence of primary technology – aggregate will increase.

It should be noted that in an effort to increase sawing capacity it is not possible to increase only one influencing factor, but individual factors should be adapted reasonably in a balanced way. There are many other factors that affect sawing capacity. Each factor has a low weight and can vary considerably at individual companies, and this generally cannot be taken into account in this test.

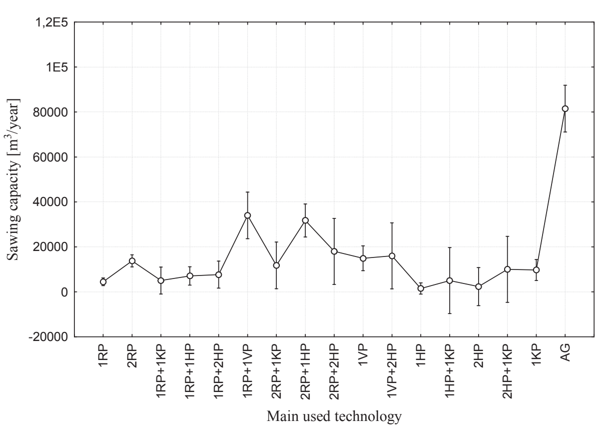

Fig. 2. Sawing capacity of individual primary technologies

1RP = 1 frame saw; 2RP = 2 frame saws; 1RP+1KP = 1 frame saw + 1 circular saw; 1RP+1HP = 1 frame saw + 1 horizontal band saw; 1RP+2HP = 1 frame saw + 2 horizontal band saws; 1RP+1VP = 1 frame saw + 1 vertical band saw; 2RP+1KP = 2 frame saws + 1 circular saw; 2RP+1HP = 2 frame saws + 1 horizontal band saw; 2RP+2HP = 2 frame saws + 2 horizontal band saws; 1VP = 1 vertical band saw; 1VP+2HP = 1 vertical band saw + 2 horizontal band saws; 1HP = 1 horizontal band saw; 1HP+1KP = 1 horizontal band saw + 1 circular saw; 2HP = 2 horizontal band saws; 2HP+1KP = 2 horizontal band saws + 1 circular saw; 1KP = 1 circular saw; AG = aggregate line

DISCUSSION

In this research, small and medium-sized sawmills in the Czech Republic have been analyzed and input data for determining production function were ascertained. Sawing capacity per one employee was calculated and sawing cut function was determined for each sawmill of the sawmill groups. First, linear regression was determined, but it only described the dependence by 28%. Increasing the sawing cut therefore does not depend only on the number of employees, but also on other factors, such as degree of mechanization, technology used, etc. It corresponds with the results of the study by Mantau, Sörgel (2006). In our study the best results were achieved only during the exponential course of a regression curve. The studies of Pauli et al. (2003) and Pražan (2010) focused on the comparison of sawing capacity per worker's salary and did not determine the degree of mechanization and technology used.

In the second stage of the results evaluation we investigated the sawing capacity dependence on the selected factors. It turned out that the number of employees (54%) has the greatest influence on sawing capacity, followed by the degree of mechanization (23%), and then primary machine (20%). According to Bouchard, Colet (2004), the capacity is also affected by many other factors. In our research the capacity affects sawing cut function by 33%. At the end of this section we created an equation for calculating the capacity of a sawmill which applies to sawmills with a capacity of up to 99 999 m^3 logs per year.

Although the experimental expression of factors affecting sawing capacity cannot be considered ab-

Table 5. Sawing cut per one employee – statistical indicators

Statistical indicators	Sawmill groups				
	A	B	C	D	E
x (m^3/year)	254	497	658	845	1347
SD	147	284	291	445	191
v (%)	57.86	57.15	44.14	52.63	14.17
Min.	50	100	225	364	1212
Max.	600	1500	1250	1667	1482

x = average value, SD = standard deviation, v = coefficient of variation, Min. = minimum measured value, Max. = maximum measured value

solutely valid for all types of sawmills, it does have quite a high explanatory ability. The objective of this evaluation was also to further demonstrate the complexity of the interrelationships between using production technology and the various factors that affect sawing capacity.

CONCLUSION

Finally, with this research estimated the type of production function depending of sawing capacity per one employee. The sawing cut function for each sawmill of the 5 sawmill groups was determined. It has been found out that increasing of the sawing cut does not depend only on the number of employees, but also on other factors, such as the degree of mechanization, technology used, etc.

In connection with the sawing capacity of sawmills, we often encounter opinions regarding the total redundancy of sawmill capacity in the Czech Republic as a harmful phenomenon, negatively affecting relationships between the forestry industry and wood processing sectors. To this we can only add that the full utilization of sawmills capacity was never achieved in the Czech Republic or anywhere else, and as mentioned above, it has never been an individual or comprehensive business plan. Due to the limiting conditions, the maximum target capacity cannot be determined, and its optimal size changes, especially in view of economic (i.e. especially conjunctural) situation.

If considerable quantities of quality sawmill logs (about 5 million m^3 – Ministry of Agriculture Report (2014)) are exported from this country, the capacities within this area can hardly be considered superfluous.

REFERENCES

Alexander SJ, Parrent DJ (2010): Estimating sawmill processing capacity for Tongass timber: 2007 and 2008 update. Research Note PNW-RN-565. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland.

Alexander SJ, Parrent DJ (2012): Estimating sawmill processing capacity for Tongass timber: 2009 and 2010 update. Research Note PNW-RN-568. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland.

Bomba J (2009): Analysing the machine and technological equipment at small and medium-size sawmills in the Czech Republic. Dissertation, Czech University of Life Sciences Prague. (in Czech)

Bomba J, Friess F (2009): The development of sawmilling in the Czech lands. Lesnická práce, 89, 32–33. (in Czech)

Bouchard Y, Colet P (2004): Machine vision guides lumber cutting. Laser Focus World, 40, 111–114.

Brackley AM; Crone LK (2009). Estimating sawmill processing capacity for

Tongass timber: 2005 and 2006 update. Res. Note PNW-RN-561. Portland, OR:

U.S. Department of Agriculture, Forest Service, Pacific Northwest Research

Station. 15 p.

Brackley MA, Parrent JD, Rojas DT (2006): Estimating sawmill processing capacity for Tongass timber: 2003 and 2004 update. Research Note PNW-RN-553. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland.

Friess F (2006): Size of the operation and firm policy in sawmill production. Czech University of Life Sciences Prague, Prague. (in Czech)

Fronius K (1989): The Rundholzplatz: Works and installations in sawmill. Volume 1. DRW-Verlag, Stuttgart. (in German)

Kilborn KA, Parrent DJ, Housley RD (2004): Estimating sawmill processing capacity for Tongass timber. Research Note PNW-RN-545. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland.

Lippmann R (1921): Establishment, equipment and operation of sawmills. JENA GmbH, 136 p.

Mantau U, Sörgel CH (2006): Structural changes in sawmill industry. University of Hamburg, Centre for Wood Science, Hamburg. (in German)

Ministry of Agriculture Report (2014): Report on the state of forests and forestry in the Czech Republic in 2013. Ministry of Agriculture of the Czech Republic, Prague.

Pauli B, Weidner U, Burkhardt A (2003): Situation and future of the Swiss sawmill industry, results of a comprehensive structural and potential analysis. Jaakko Pöyry Consulting, 49 p.

Pražan P (2010): Alternative factor analysis of development in small and medium sawmill production in the Czech Republic. Dissertation, Czech University of Life Sciences Prague. (in Czech)

Pražan P, Příkaský F (2007): Status and development of the sawmill industry in Central Europe and Czech Republic focusing on small and medium-sized enteprises. Conference Sawmill industry in Central Europe and Czech Republic. Collection of expert contributions from a national seminar, Brno, Czech Republic, 21–30. (in Czech)

Šedivka P (2009): Estimation of technical efficiency in production technologies of Czech sawmills. Drvna Industrija, 60, 197–207.

Sloup R, Pulkrab K (2012): Potential intensity of management. Zprávy lesnického výzkumu, 56, 75–85. (in Czech)

Spelter H, McKeever D, Alderman M (2007): Profile 2007: softwood sawmills in the United States and Canada. Research Paper FPL-RP-637. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison.

Spelter, H. and Toth, D. (2009). The North American wood pellet sector. Research Paper RP-FPL-656.USDA Forest Service, Forest Products Laboratory, Madison, WI. 21 p.

Štěpán L, Křivanová M (2000): Production and life of millers and hatchet men in Bohemia. Argo, Prague. (in Czech)

Corresponding Author:

Ing. Jan B o m b a , Ph.D.,Czech University of Life Sciences Prague, Faculty of Forestry and Wood Sciences, Department of Wood Products and Wood Construction,, Kamýcká 129, 165 21 Prague 6-Suchdol, Czech Republic, phone: +420 224 383 411,
e-mail: bomba@fld.czu.cz