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Differences in round wood measurements using electronic 2D and 3D systems and standard manual method

Razlike u mjerenju oblog drva elektroničkim 2D i 3D sustavima i standardnom ručnom metodom

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ABSTRACT • *This paper describes the use of electronic scanning systems for round wood in the Czech Republic. It analyses the two most wide-spread systems (2D and 3D), compares the values of diameters and volumes measured by these systems with the results of measurements using the Huber method and evaluates differences. The volume of the logs determined by the 2D system was 0.4 – 0.5% higher than the volume determined by manual comparative measurement. The deviation is in the range of possible measuring accuracy. The log volume determined by the 3D system was 2.5 – 5.5% lower than by careful manual measurement. The log volumes stated in the delivery bills are very rough and they cannot be used to assess the accuracy of electronic measurement systems. The study briefly outlines the present state and trends of the electronic reception of logs in the Czech Republic.*

Key words: *log yards, round wood, electronic measurement systems, reception, volume calculation*

SAŽETAK • *U radu se opisuje uporaba elektroničkih sustava za mjerenje oblog drva u Republici Češkoj. Analiziraju se dva najčešće rabljena sustava za mjerenje (2D i 3D), uspoređuju se vrijednosti promjera i obujma mjerene tim sustavima s rezultatima mjerenja standardnom Huberovom metodom te se određuju razlike. Obujam oblog drva dobiven mjerenjem elektroničkim sustavom 2D bio je za 0,4 – 0,5 % veći od obujma dobivenog usporednim mjerenjem ručnom metodom. Razlike su u rasponu realno mogućih pogrešaka pri mjerenju. Obujam oblog drva dobiven mjerenjem elektroničkim sustavom 3D bio je za 2,5 – 5,5% manji od rezultata dobivenih pažljivim ručnim mjerenjem. Podaci za obujam trupaca koji se nalaze na dostavnicama samo su približni podaci i ne mogu se koristiti za ocjenu točnosti elektroničkog mjerenja. Autor u radu iznosi i podatke o sadašnjem stanju te o trendovima uporabe elektroničkog mjerenja oblog drva u Republici Češkoj.*

Ključne riječi: *stovarište trupaca, elektronički mjerni sustavi, prijam oblog drva, izračun obujma*

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1 INTRODUCTION
1. UVOD

Electronic devices for scanning the diameter and length of logs are the routine part of cross-cutting and sorting lines in sawmills. A considerable part of cross-cutting/sorting carriages is also equipped with these systems. In the Czech Republic, two systems are particularly used for the electronic reception of raw material in sawmills, viz. a system scanning a log diameter in two directions perpendicular to each other (2D) or a system scanning many points of the girth curve, which can be used for the evaluation of a diameter in nearly any direction (3D). Thus, different methods of scanning and data processing lead to different results of measured dimensions (mainly diameter) and volume, which can raise doubts among suppliers and processors of raw material regarding the precision of measurements. These doubts are supported by the fact that in the Czech Republic, there is no legislative norm that would determine the requirements for technical parameters of scanning devices, methods of processing the measured data and methods of calculating the logs volume.

The aim of this paper is to define the most used methods of electronic scanning of saw logs dimensions in the Czech Republic, to compare the electronically measured values of log dimensions and volume with results of measurements carried out using the Huber method, to evaluate differences and to find possibilities to establish a simple relation (conversion) between the results of an electronic measurement and a standard manual method. The values given in this paper arise from our previous studies in the field of round timber measurement (Janák, 2004; Janák, 2005) and our work is a contribution to foreign comparative measurements, lucidly summarized by Hauffe and Müller (2002).

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

The following procedures were used to achieve the required objective:

a) Determining the most used types of electronic measurements, defining operational methods of scanning, and evaluating dimensions and volumes of logs. The initial survey of users is compiled according to data of manufactures of scanning and control systems on supplies and installations of the devices within the CR. Data on the actual distribution of the systems and ways of their use are obtained using the questionnaire form addressed to users of devices. Types of devices and methods of their use are categorised according to questionnaire surveys returned by users.

b) Electronic measurements for the purpose of comparison

   To reduce potential errors, the measurement is carried out 1 time before barking, i.e. overbark and 3 times after barking, i.e. underbark (1 passage with barking, other 2 passages with open knives – it is impossible to pass the barker otherwise).

c) Comparative measurements related to the results obtained

   The diameter measurement is carried out in unbarked logs using a calliper at the log top, in the centre of the log length and at the butt end 2 times perpendicular to each other with an accuracy of 1 mm. The log length is measured by a tape with an accuracy of 1 cm. The measurement is carried out 2 times separately by two groups of workers, the second group measures the diameters after turning the log by 45°. In addition to this, the bark thickness is measured accurate to mm. The mid-diameter is determined as a mean value of both measurements (from four values) given in mm. The double bark thickness is subtracted from the value of the mid diameter over bark. The obtained value of the diameter under bark in mm is converted to cm in such a way that mm are not taken into consideration. The calculation of volume is consistent with an electronic measurement procedure.

d) Definition of the range of measurements

   The range of measurements is selected for 95% interval of reliability accurate to 1% (in assessing individual logs approximately 0.0025 m^3, in assessing supplies approximately 0.3 m^3). It corresponds to the selection of at least 400 logs (supplies) for one method of electronic reception.

e) The calculation of deviations between the electronic and manual comparative measurement (mid diameter, length, volume of individual logs and volume of individual supplies, expression of absolute values and relatively in %).

f) Determination of dependences between the volume of logs determined by electronic devices and results of manual comparative measurement.

g) Preliminary determination of dependences between the volume of supplies determined by electronic devices and on the basis of results of manual comparative measurement. Determination of statistically significant dependences would require carrying out manual measurements of at least 400 supplies of logs, which would largely exceed the possibilities of the study.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Using electronic measurement of logs in the Czech Republic
3.1. Uporaba elektroničkog mjerenja oblog drva u Republici Češkoj

In total, about 90–95 stable devices for scanning the diameter and length of logs have been installed in the Czech Republic. This number does not include scanning devices installed on cross-cutting/sorting carriages. Out of this number, there were about 70 new installations; the remaining devices were renewed. At the turn of 2005/06, about 40-45 of these devices were in operation at cross-cutting lines. These data were obtained through a questionnaire survey of users and suppliers of measuring devices. Detailed information was provided by 26 users. Both centralized log conversion

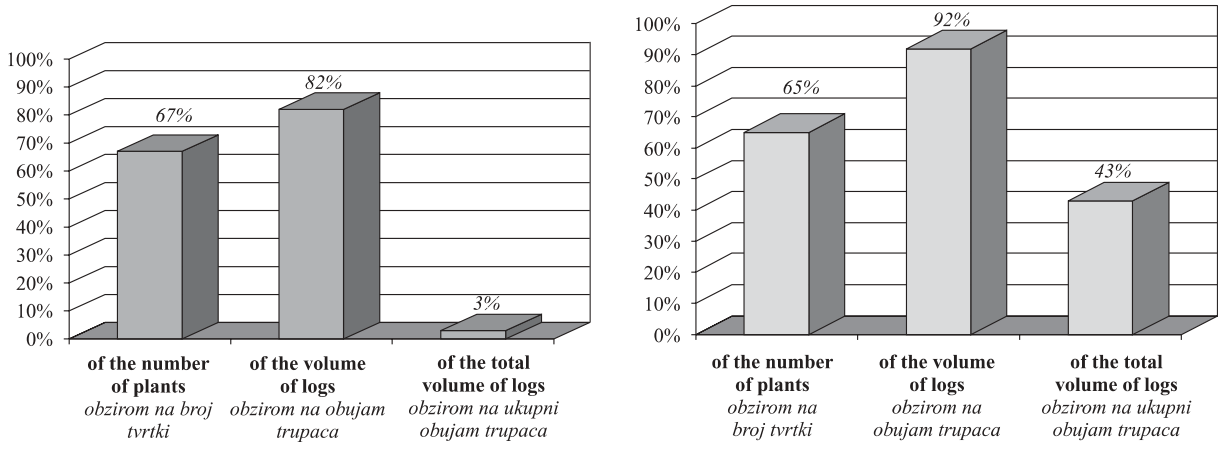


Figure 1 Using the electronic measurement of raw material for reception a) with suppliers, b) with processors
Slika 1. Uporaba elektroničkog mjerenja oblog drva a) kod dobavljača, b) kod prerađivača drva

depots (log suppliers) and sawmills (log processors) were the systems users.

Out of the total number of plants, which are equipped with electronic scanning devices of any type, both suppliers (67%) and processors (65%) use their devices roughly to the same extent for the electronic reception of a raw material. The ratio of volumes also gives comparable values of using electronic devices. Out of the total volume of electronically measured logs, 82% is measured with suppliers and 92% with processors (Fig. 1). A higher percentage obtained by comparison of volumes means that on both sides, mainly large plants are equipped with the electronic systems of measurement. Out of the total volume of saw logs supplied and received in the Czech Republic for domestic processing (6.69 mil. m^3, i.e. not only electronically measured), the volume of electronically supplied logs (228 000 m^3) represents only 3%, while the volume of electronically received logs (3 024 000 m^3) represents 43%. This disproportion is caused by a few large sawmills (Paskov, Plana, Pteni, Zdirec), whose huge volume production has no equivalent on the side of suppliers.

3.2 Methods of electronic measurement of dimensions
3.2. Metode elektroničkog mjerenja dimenzija oblog drva

Using various methods of scanning (1D-2D-3D) for the purpose of electronic reception of logs at yards of raw material, suppliers are unambiguously dominated by 2D measurements (100%). At yards of log processors, the situation is less unambiguous. Out of 11 mills, which use the measurement for the electronic reception of raw material (taken as 100 %), none of them uses 1D measurement, eight (624 000 m^3) use 2D measurement and three (2 400 000 m^3) have 3D measurement at their disposal. The ratio of individual types of measurement in the electronic reception of logs according to the number of mills and the volume of received and processed raw material is given in the following diagram in Fig.3.

Processors, who use the results of electronic measurements for the reception of raw material, measure

Figure 2 Visual quality evaluation during electronic reception of logs
Slika 2. Vizualna ocjena kvalitete tijekom elektroničkog prijma oblog drva

the raw material both over bark (o.b.) and under bark (u.b.) roughly in the same number of cases. The measurement of log dimensions after barking is typical of mills with substantially higher volumes of production. The volume of raw material measured for needs of reception u.b. is, therefore, 12 times higher than the volume of raw material measured o.b.

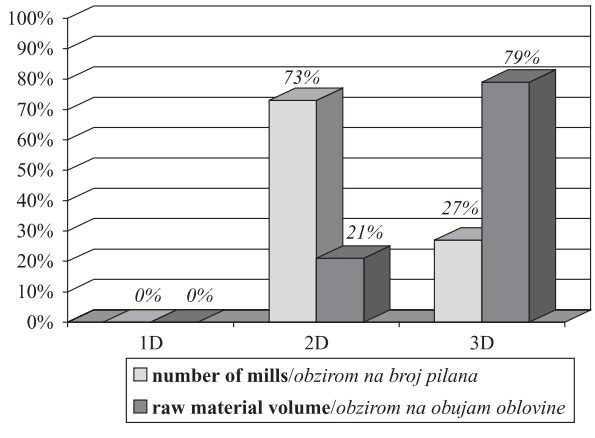
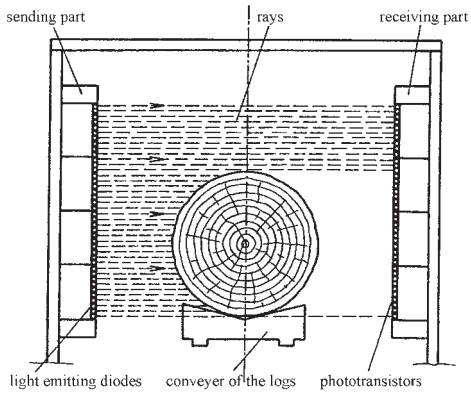
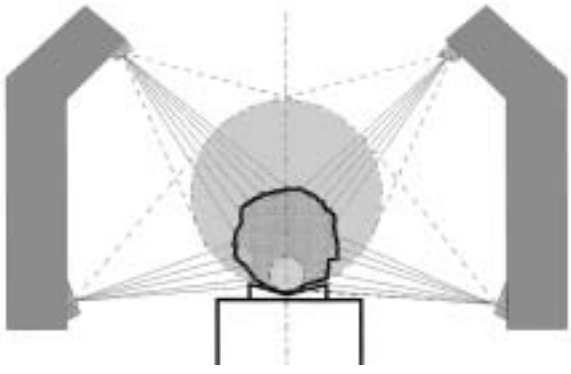


Figure 3 Using particular methods of measurement for the electronic reception of raw material with processors
Slika 3. Primjena određene metode mjerenja pri elektroničkom prijmu oblog drva



a) b)

Figure 4 2D log diameter scanner a) principle and b) in run behind the metal detector
Slika 4. 2D skener promjera trupaca: a) načelo rada i b) u radu, postavljen iza detektora metala



a) b)

Figure 5 a) Points, scanned on the surface of the „light cross section“ by 3D system, b) 3D Log diameter scanner
Slika 5. a) Točke skenirane na površini “svjetlosnoga poprečnog presjeka” sustavom 3D, b) 3D skener promjera trupaca

Thus, two methods of electronic measurement of log dimensions were selected to compare the electronic and traditional measurement of timber dimensions:

Scanning two diameters perpendicular to each other (2D) is carried out in barked logs. Directions of scanning are 45° with regard to the horizontal plane. The results of scanning consist of values of two diameters perpendicular to each other taken in one place and given in mm. For further processing, measurements are selected (as well as in the previous case) in 10 cm intervals. To determine a mid-diameter, the diameters are selected from all these pairs, which were taken in the range of 20 cm relative to the log centre (2 places of measurement). An arithmetic mean is calculated of each diameter pair given in mm, a smaller diameter of these values, obtained in this way, is selected and the value is expressed in whole cm in such a way that mm are not taken into account. This value is considered to be a mid-diameter. The volume of logs is given and calculated as in the previous case. The same principles apply to a nominal length, allowance and shifting or rejection of logs from the reception.

Scanning the whole surface curve (3D) is also carried out after barking the logs. The result of scanning consists of the position of 16 points on the log surface scanned in one moment accurate to mm, which create the shape of the surface curve in the given place, i.e. “cross section” (fig. 5). For further processing, measurements are selected in the interval of 10 cm along the whole length of a measured log. From each of the selected surface curves, a value is calculated of the lowest diameter in the place of measurement and the value of a diameter perpendicular to it. For determining the mid diameter, the pairs are selected of all these pairs, which are scanned in the range of 20 cm, relative to the log centre (2 points of measurement). Values of diameters are given in cm, mm are not taken into account.

An arithmetical mean is calculated of each diameter pair given in cm, a smaller value is selected from values obtained in this way and the value is given again in whole cm, not taking into account mm. This value is regarded as a mid diameter. The log volume is calculated as the volume of a cylinder, whose diameter is the value of a mid diameter and the cylinder length is the nominal length of a log. The volume is expressed in m^3 accurate to 2 decimal places. The nominal length is graduated by 1 m long sections having to include an allowance of 1.5%. If the allowance is shorter, the length is allocated to the log which is a degree shorter. If it is not possible (the log is of the shortest demanded length), the log is discarded from reception.

3.3 Measurement deviations
3.3. Razlike u rezultatima mjerenja

Generally, it is possible to state that departures evaluated in all measurements are relatively balanced,

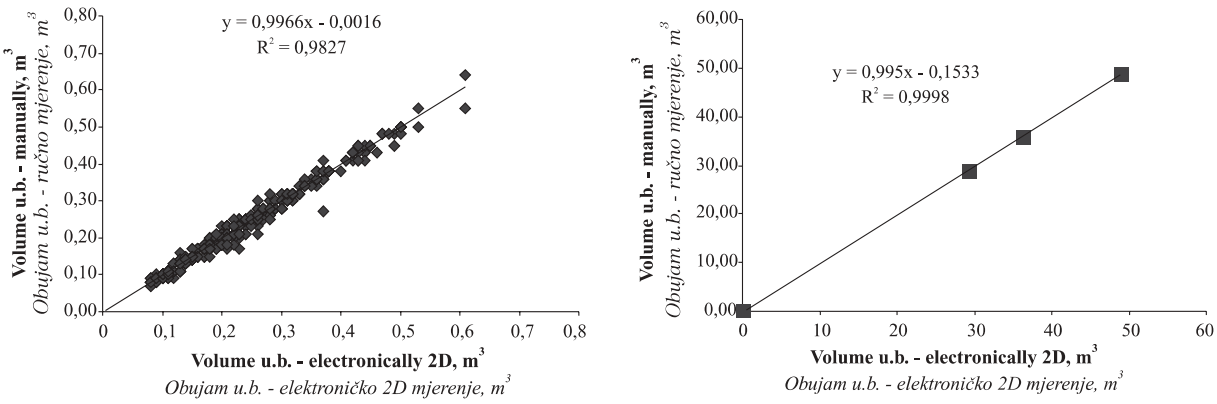


Figure 6 Relationship between the volume of raw material obtained using the 2D electronic system (horizontal *x*-axis) and the volume determined according to results of the manual comparable measurement (vertical *y*-axis), a) according to the log volume, b) according to the volume of supplies

Slika 6. Korelacija između obujma oblog drva dobivenog elektroničkim sustavom 2D (*x*-os) i obujma određenoga prema rezultatima usporednoga ručnog mjerenja (*y*-os): a) prema obujmu svakog trupca, b) prema ukupnom obujmu svakog dobavljača sirovine

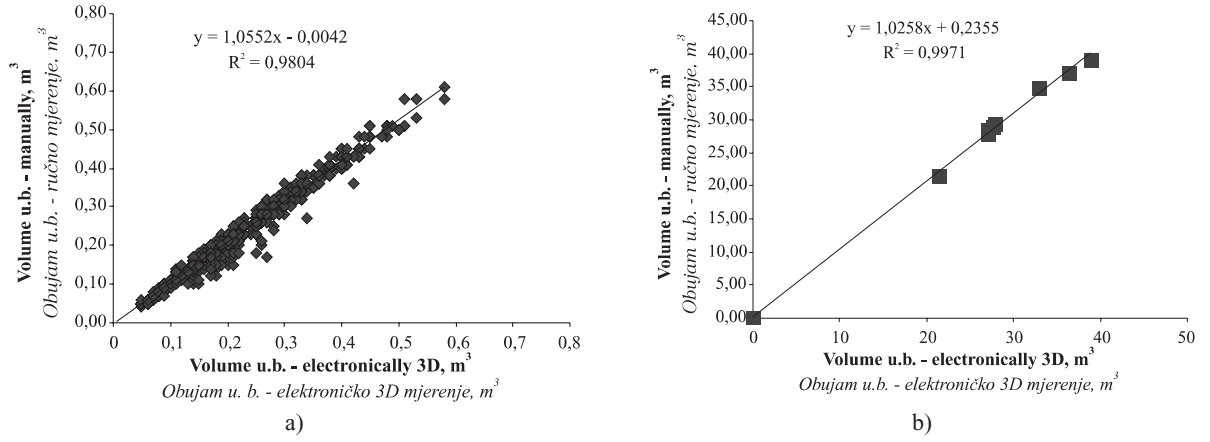


Figure 7 Relationship between the volume of raw material obtained using the 3D electronic system (horizontal *x*-axis) and volume determined according to the results of manual comparable measurement (vertical *y*-axis), a) according to the volume of logs, b) according to the volume of supplies

Slika 7. Korelacija između obujma oblog drva dobivenog elektroničkim sustavom 3D (*x*-os) i obujma određenog prema rezultatima usporednoga ručnog mjerenja (*y*-os): a) prema obujmu svakog trupca, b) prema ukupnom obujmu svakog dobavljača sirovine

the number and size of extreme values is low and, thus, their effect is also low.

Deviations of log dimensions and volumes using the 2D system were evaluated in three supplies with the total number of 512 logs. The diameter is slightly higher using the electronic system of measurement. Values of volumes are, therefore, slightly overestimated.

Deviations of log dimensions and volumes in scanning using the 3D system are evaluated in eight supplies with the total number of 1155 logs. The diameter is slightly lower using the electronic system of measurement. Values of volumes are, therefore, slightly underestimated.

The variance of values of the results of electronic measurements in 2D and 3D systems allows creating relatively reliable regression dependence. The relationship is evaluated by two methods, viz. from values of individual logs and from values of whole supplies. It is determined separately for 2D and 3D systems.

2D system of measurement (Fig. 6):

– according to the volume of individual logs

$y = 0.9966x - 0.0016$; $R^2 = 0.9827$

– according to the volume of whole supplies

$y = 0.9950x - 0.1533$; $R^2 = 0.9998$

where: y = volume u.b. in manual measurement

x = volume u.b. in electronic measurement

Relationships between the volume of raw material given by the 2D system and volume obtained in manual measurement evaluated according to the volume of logs and according to the volume of supplies are in a very good agreement. Both methods of evaluation give nearly the same deviation: electronic measurement gives a value 0.4 to 0.5% higher than manual comparative measurement.

3D system of measurement (Fig.7):

– according to the volume of individual logs

$y = 1.0552x - 0.0042$; $R^2 = 0.9804$

– according to the volume of whole supplies

$y = 1.0258x + 0.2355$; $R^2 = 0.9971$

Relationships between the volume of raw material given by the 3D system and volume obtained in manual measurement evaluated according to the volume of logs and according to the volume of supplies differ in

Figure 8 Supervisory hand measuring and quality evaluation of logs. The results of this measuring were used as comparative for this study.
Slika 8. Provedba ručnog mjerenja dimenzija i ocjene kvalitete trupaca (rezultati tog mjerenja poslužili su za usporedbu s elektroničkim mjerenjem u ovom radu)

some measure. In the evaluation according to the volume of individual logs electronic measurement gives values about 5.5% lower than manual comparative measurements, and in the evaluation according to supplies the value of electronic measurement is about 2.6% lower.

The distribution of values creating the basis for regression relations is relatively balanced and suitable for the expression of a linear dependence. However, it should be mentioned that it was determined under conditions of two mills for 3D measurements and under conditions of one mill for 2D measurements. Thus, it is not possible to recommend its excessive generalization without taking into consideration conditions of operation where it is to be used.

3.4 Conditions and prospects of electronic measurement
3.4. Današnji uvjeti i trendovi primjene elektroničkog mjerenja

At present only 2D and 3D systems should be considered for the electronic reception of saw logs. 1D systems show lower accuracy of the results of measurement. In the Czech Republic, they are not used for the electronic reception of raw material and there is no prospect for their use in this field of operation.

Electronic measurements for needs of reception are used by both consumers and suppliers of raw material. Due to substantially broader range of processed raw material, substantially lower average outputs of plants of raw material suppliers and increasing logging by means of harvesters, it is not possible to anticipate a marked increase in the electronic reception in centralized log conversion depots of raw material suppliers. On the other hand, it is necessary to take into account an increase in the proportion of electronically measured raw material in logging operations carried out by harvesters.

Electronic reception by yards of sawmills will be increased and it can also be considered by yards equipped with cross-cutting/sorting carriages with an output of 15 000 – 20 000 m^3 per year. Their equipment with 2D scanning systems is almost a condition for this purpose. The use of 3D systems cannot be assumed in sawmills of medium or small capacity (roughly < 150 000 m^3 of the annual volume of processed logs) in the near future.

The majority of modern sorting systems in large sawmills calculates the diameter of logs as a minimum value in the place of measurement, and gives measurement values in whole cm not taking into account mm (no mathematical rounding) calculating the volume of logs in m^3 accurate to 2 decimal places. All points mentioned above result in the decrease of the calculated volume of raw material. Thus, the expansion (or at least stress on the expansion) of these systems can also be expected in the future.

2D systems with a scanning frame inclined by 45° with respect to a horizontal plane give the resultant value of a mid-diameter quite comparable with a careful manual measurement. Resulting values of the volume of logs are then virtually identical with results of the Huber method (differences about 0.4 to 0.5%). 2D systems scanning the log diameter both in horizontal and vertical direction show on average higher differences between values of both scanned diameters (it is caused by flattening the logs and their "flat" position on a conveyer). In evaluating the log diameter as a mean value these systems show comparable results with the previous ones. In determining a minimum value, values of diameters and volumes shown by these systems are lower.

In searching the minimum value of a diameter, 3D systems are not limited to preset directions of scanning. Despite the virtually identical algorithm of further data processing the resultant value of a mid diameter is lower than by careful manual measurement. Thus, the resultant values of log volumes are lower differences and namely 2.5 - 5.5%.

Data on delivery notes are mostly incomplete and their departures from manual comparable measurements are often multiples of departures of electronic systems. Therefore, it is not possible to use these delivery notes to assess the accuracy of electronic measuring systems or to demonstrate actual differences between electronic and manual measurements.

4 CONCLUSION
4. ZAKLJUČAK

Electronic reception of raw material represents the system of operations to determine dimensions, volumes and quality of individual logs and whole supplies. Differences in the implementation of these operations together with other effects (raw material shape, growth and production defects, condition of transport lines) result in different results of measurements. Even relatively small values of these differences expressed in % (0.5 – 3.5%) represent relatively high financial differences. At the annual output of 100 000 m^3 processed raw material and differences between results of the traditional and electronic measurement amounting to 1% (which is a good agreement), this difference means 1000 m^3 logs. At the average price of saw timber of € 62/m^3 (spruce, quality class III A, B; the 1st half-year of 2006) this difference represents € 62 000 per year.

It is impossible to eliminate these differences even theoretically. Through the practicable procedure of measurement it is not even possible to reach accurate results (e.g. the value of a diameter or volume) but only to come to an interval where results can range at high probability. The accuracy and homogeneity of results are virtually given (to a great extent) by a convention, i.e. rules which have to include the definition of particular quantities, methods of their measurement, evaluation of results and accepting a certain difference between operational and check measurements. At present, discussions on an agreement of this type are in progress in the Czech Republic. Their objective is to create a legally obligatory or at least recommended regulation, which will determine the method and conditions of electronic reception. However, considerable number of existing and used devices of different design will require the preparation of "conversion" coefficients or relations, which will make possible to compare results of these devices for the period of their expected service life (transition period) even after the acceptance of rules mentioned above. It is assumed that differences, which could originate by a slightly different definition of dimensions or the quality of assortments, can also be compensated by a price.

Electronic reception of raw material carried out by any method is a benefit from the viewpoint of outputs achieved, productivity of labour and accuracy of determining dimensions and quality of received logs. The acceptance of this opinion by the majority of suppliers and processors of saw logs in the Czech Republic and works associated with the preparation of rules for the electronic reception of logs are the basic contribution hat has been achieved so far.

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