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# Sadržaj
# Contents



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*Leon Oblak, Matej Jošt*[1]

# Methodology for Studying the Ecological Quality of Furniture

## Metodologija proučavanja ekološke kvalitete namještaja

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**ABSTRACT** • *Decisions for environment-friendly production and environmentally acceptable products are becoming a necessity and one of very important objectives of timber companies next to already existing economic criteria. Individual products and their manufacture have different influences on the pollution of the environment. Therefore it is necessary to determine the ecological quality of individual products, which means analyzing their ecological suitability during their life cycle. In our research we developed the methodology for establishing the ecological quality of furniture, based on three scientific methods: the method of life cycle analysis, ABC analysis, modified for our case, and the multi-criteria decision-making method. We analyzed the ecological quality of three kitchens of a well-known manufacturer. The results of the research are the basis for developing an optimal business strategy from the viewpoint of determining a production assortment. The used methodology is also suitable for studying other furniture products and for accepting optimal environmentally acceptable decisions in wood companies.*

***Key words:*** *wood company, furniture, ecological quality, methodology, decision-making*

**SAŽETAK** • *Odabir ekološke proizvodnje i ekološki prihvatljivih proizvoda, osim već postojećih ekonomskih kriterija, postaju nužnost i jedan od vrlo važnih ciljeva drvnoprerađivačkih tvrtki. Pojedini proizvodi i njihova proizvodnja imaju različite utjecaje na onečišćenje okoliša. Stoga je potrebno utvrditi ekološku kvalitetu pojedinih proizvoda, što znači analizirati njihove ekološke pogodnosti tijekom njihova životnog ciklusa. U ovom je istraživanju utemeljena metodologija utvrđivanja ekološke kvalitete namještaja, koja se temelji na tri znanstvene metode: metodi životnog ciklusa proizvoda, ABC analizi koja je modificirana za tu metodologiju i na metodi multikriterijskog odlučivanja. Analizirana je ekološka kvaliteta triju kuhinja poznatog proizvođača. Rezultati istraživanja osnova su za izgradnju optimalne poslovne strategije sa stajališta određivanja proizvodnog asortimana. Metodologija kojom smo se koristili također je pogodna za proučavanje ostalih vrsta namještaja i za donošenje optimalnih ekološki prihvatljivih odluka u drvnim poduzećima.*

***Ključne riječi:*** *drvnoindustrijsko poduzeće, namještaj, ekološka kvaliteta, metodologija, odlučivanje*

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## 1 INTRODUCTION
1. UVOD

Global market, which requires and encourages constant progress, is more and more demanding when it comes to environment protection regulation. Also the market of financial capital, which is more and more favorable towards environmental projects, demands for a restructuration of wood industry in accordance with environmental needs. Many authors (Paluš and Matova, 2009; Kaputa and Šupin, 2010; Kuzman *et al*., 2010) have dealt with these problems.

Ecological awareness of manufacturers is nowadays an important competitive advantage, which the company can acquire in foreign or home markets (Oblak and Tratnik, 1997). Wood industry basically processes environment friendly natural material – wood, but the technological procedures, materials, use of products and their disposal are ecologically challenging. Therefore, ecological quality of the products in individual phases of their life cycle must be determined from their conception, use of resources, production, use, until the disposal of "used" products (Winter *et al*., 1993).

The objective of our research was to determine the ecological quality of three kitchens from a well-known manufacturer. On the basis of the results, the company could adopt a long-term strategy, where one of the most important goals would be to develop and produce products from environment friendly materials, with low use of all kinds of energy and with low emissions of harmful matters into earth, water and air.

## 2 METHODS AND MATERIALS
2. METODE I MATERIJALI

Ecological problems are so complex that they need to be solved systematically (Oblak and Kropivšek, 1997). For this purpose we used three scientific-research methods in the research:
- the method of life cycle analysis,
- modified ABC analysis and
- the multi-criteria decision-making method.

Despite the fact that there are various methods for studying the ecological quality of products, we decided for an innovative approach and with the combination of the above methods we developed a methodology that later showed to be very suitable for decision-making in wood companies, aimed at making environment friendly decisions.

### 2.1 The method of life cycle analysis
2.1. Metoda životnog ciklusa proizvoda

The method of life cycle analysis is a methodological framework for estimating and assessing the environmental impacts attributable to the life cycle of a product, such as climate change, stratospheric ozone depletion, tropospheric ozone (smog) creation, eutrophication, acidification, toxicological stress on human health and ecosystems, depletion of resources, water use, land use, noise and others.

With the method of life cycle analysis we tried to demonstrate a complete image of possible interactions of production processes with environment. The method helps us to understand long-term consequences of human activity in the environment and in decision-making, when opportunities are sought for improving the ecological behavior (Košir, 1999).

This method is used for evaluating the burdening of the environment, connected with manufacturing of products or services, by establishing how much energy and materials are required according to the type and quantity, which types and quantities of waste and of emissions into environment are produced and what are the possible consequences for the environment (Richter, 1995).

The evaluations include the whole life cycle of the product, together with planning, acquiring raw materials and energy, production, transport and distribution, packaging, use, maintenance, possible recycling and final disposal. This is, therefore, a complex analysis of all factors that can influence the environment; and hence the effects of the emissions are evaluated on the basis of:
- harmful effects on people, animals, plants or ecosystem or other objects, such as buildings or ozone layer
- duration of effects (long life cycle of harmful substances in the environment)
- tendency for spreading or dispersion
- piling up, which is tightly connected with the duration of the effect and can cause elevated local concentrations
- synergic effects with other substances or products produced in the environment

### 2.2 ABC analysis
2.2. ABC analiza

When establishing a system of environment protection, a great deal of ecological parameters is met in the company. This demands a large scope of work, but also causes lack of clarity over the whole action. Thorough following and analysis of all ecological parameters would also cause high expenses, surely not in proportion with the results that can be expected from it. It is, therefore, necessary to determine the critical ecological parameters and prioritize them in the procedure (Oblak *et al.*, 1998).

This can be achieved by ABC analysis. It is a very widely applied method that was used for many years only for economic studies, but in this research we modified it also for solving environmental problems in companies. The method is based on Parrett's principle of cause-consequence interdependence, which says that approximately 20% of causes is responsible for approximately 80% of consequences or effects. If this is applied to the environmental field, this means that 20% of ecological parameters cause 80% of ecological problems in the companies (Ljubič, 2000).

With this method, all ecologic parameters are categorized in three typical groups. Group A is for 5-10% of ecological parameters that are responsible for the major share (70-80%) of environment pollution, group C consists of the major share of less important ecological parameters (60-70%) that cause only a minor, less important pollution share (5-10%), while the middle group B consist of 20-30% of ecological parameters that influence the pollution with a 10-25% share (Oblak and Podlesnik, 2005).

For the needs of our research, the method was slightly modified by adding two intermediate groups AB and BC. Thus, groups A and AB will contain the effects on the environment that demand immediate action, groups B and BC will contain the noticeable effects to be resolved in middle terms, and group C will contain the effects that are of secondary importance and do not cause any significant damage to the environment.

### 2.3 The multi-criteria decision-making method
### 2.3. Metoda multikriterijskog odlučivanja

The method of multi-criteria decision-making is used for resolving demanding decision-making problems. The essence of this method is to break the decision-making problem to smaller units and treat them separately. The variants are deconstructed to individual parameters and evaluated separately. By merging these evaluations a final grade is obtained, which is the basis for selection of most suitable variant (Rajkovič and Bohanec, 1995).

Definition of the problem is followed by determination and implementation of the list of criteria considered important. For the needs of the model, the criteria must be hierarchically organized while considering inter-dependences and content connections. This way a tree of criteria is obtained. A measuring scale and estimating value is attributed to each criterion, which can be used for evaluation. With the help of a program package for decision-making support, the utility functions and decision-making (if-then) rules are defined. On the basis of these functions the computer determines the best of all the variants, which are previously described by the values of basic criteria (Jereb *et al.*, 2003)

For a decision-making model, it is necessary to establish a decision-making group, in which experts for the fields involved should be included, as this is the only way to assure greater reliability of the decision-making model. The members of the group participate in defining the objectives and demands as well as in setting criteria and decision-making rules, and in the final phase they also help with evaluation and deciding on optimal variant (Novak, 2006).

## 3 RESULTS AND DISCUSSION
## 3. REZULTATI I RASPRAVA

A wood company that produces kitchens was included in the research. After agreement with professional cooperators, we selected three kitchens from their production program. The kitchens differ significantly in the selection of used materials and type of manufacture. For all three kitchens, we analyzed the typical composition: one high sideboard, three low sideboards and two hanging cabinets.

In the first part of the analysis of ecological quality of the kitchens, we used the method of life cycle

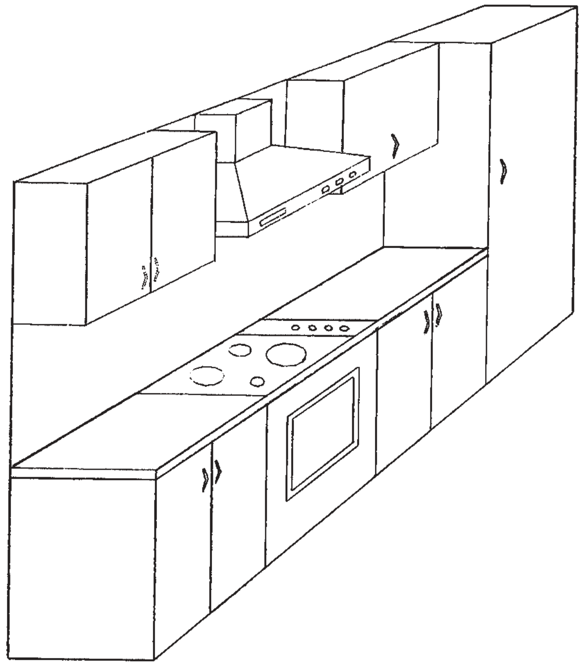

**Figure 1** Drawing of studied elements in the kitchens
**Slika 1.** Skica elemenata promatranih kuhinja

analysis. When the life cycle of the products is estimated, the current condition in the company must be analyzed first. In this analysis it is necessary to establish the quantities of raw materials, materials, energy and other substances entering the production process, and the quantities of production emissions into water, air and soil.

We acquired the information on some most important parameters that influence the evaluation of ecological suitability of individual kitchens in the company and this is the subject of this research. Where the data could not be defined in numbers, we used expert evaluations. From the acquired data, a basis of input information was created for the evaluation of ecological quality of the three kitchens during their life cycle. The data are presented in Table 1 and Table 2.

In Table 1 and Table 2, the sign »-« means that a certain substance is not used or consumed for this product, and sign »?« means that no information could be obtained for a certain ecological parameter.

In the second part of the analysis of ecological quality of kitchens, the ABC analysis was used. The analysis was modified for the research needs by introducing two additional classes (AB and BC) next to three classical ones (A, B and C). For individual ecological parameters, an expert inter-disciplinary group, formed especially for this assignment, determined the weight or so-called ponders. For raw materials, materials, energies and other substances that make part of the production products, the focus was on the additional materials, such as mastic, bark-liquor, varnishes, glues, solvents, foils and grinding paper. For emissions that are generated in the production process and go into soil, water and air, the most weight was given to waste waters, which present a big problem in wood industry due to the above mentioned materials.

**Table 1** Input information for the analysis of ecological quality of kitchens: Quantity of raw materials, energy and other substances entering the production process
**Tablica 1.** Unos podataka za analizu ekološke kvalitete kuhinja: količina sirovina, energije i drugih tvari koje ulaze u proizvodni proces

| | | | | **Kitchens** / *Kuhinje* | | |
|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 |
| wood / *drvo* | massive / *cjelovito drvo* | | $m^3$ | 0.0003 | 0.0042 | 0.0029 |
| | particleboards / *iverice* | | $m^3$ | 0.4379 | 0.2416 | 0.3327 |
| | veneer / *furnir* | | $m^3$ | 0.0032 | - | - |
| | fibreboard / *vlaknatice* | | $m^3$ | 0.0187 | 0.0435 | 0.0298 |
| | cardboard / *karton* | | kg | 20.37 | 42.59 | 31.12 |
| metal / *metal* | hardware / *hardver* | | g | 1433 | 5835 | 4779 |
| | screws / *vijci* | | g | 256 | 212 | 686 |
| synthetic materials *sintetički materijali* | polymeric materials / *polimerni materijali* | | kg | 1.42 | 1.80 | 2.62 |
| | glass / *staklo* | | kg | 1.57 | 1.60 | 1.35 |
| additional materials *pomoćni materijali* | mastic / *smola* | | kg | 0.012 | 0.087 | 0.032 |
| | bark-liquor / *kora drva u tekućem stanju* | | kg | 0.23 | 0 | 0.05 |
| | varnish / *lak* | | kg | 0.07 | 4.93 | 2.12 |
| | glue / *ljepilo* | | kg | 0.43 | 0.22 | 0.32 |
| | solvents / *otapala* | | kg | 0.12 | 0.20 | 0.10 |
| | foils / *folije* | | $m^3$ | 0.16 | 1.91 | 1.82 |
| | grinding paper / *brusni papir* | | m | 1.4 | 2.2 | 2.8 |
| packaging / *pakiranje* | cardboard / *karton* | | kg | 0.60 | 0.69 | 0.74 |
| | wood / *drvo* | | kg | 0.33 | 2.90 | 1.71 |
| | synthetic materials / *sintetički materijali* | | kg | 0.23 | 1.09 | 1.66 |
| energy / *energija* | electric energy / *električna energija* | | kWh | 53.6 | 59.9 | 65.2 |
| | heating energy / *toplinska energija* | oil / *ulje* | l | - | - | - |
| | | gas / *plin* | $m^3$ | - | - | - |
| | | wood / *drvo* | $m^3$ | 0.187 | 0.139 | 0.202 |

The six members of interdisciplinary expert group placed the ecological parameters into groups A, AB, B, BC and C. They considered the permitted limit values for the ecological parameters specified by applicable regulations and standards. For other ecological parameters decisions were based on intuition. Intuition can help decision makers, especially when they deal with non-standard situations or in expedient decision making.

The evaluations of modified ABC analysis are shown in Table 3.

The third part of the analysis involved the implementation of multi-criteria decision-making model. In our case, the considered variants were three kitchens. First it was necessary to determine the criteria for decisions and implement a decision-making tree. In the structure of the tree, we included all ecological parameters from Table 3. This way we obtained a decision-making tree, presented in Figure 2.

The modified groups that we used for ABC analysis were also used for estimating the values. Then decision-making (if-then) rules were established. The developed model was inserted into the computer program DEXi, where the solution was obtained as presented in Figure 3.

The results show that in final evaluation the kitchens were given different values. From the aspect of ecological quality, "kitchen 1" is the most suitable and on the basis of the research results it can be graded as ecologically acceptable. It is followed by "kitchen 3", which is ecologically questionable, and "kitchen 2" got the worst results and was estimated as ecologically problematic.

On the basis of the obtained results, the company can reconsider the use of certain materials and raw materials and the general assortment of products in the future. A strategic decision would be to stop producing "kitchen 2" and modify the procedures for making "kitchen 3" in order to improve its ecological quality.

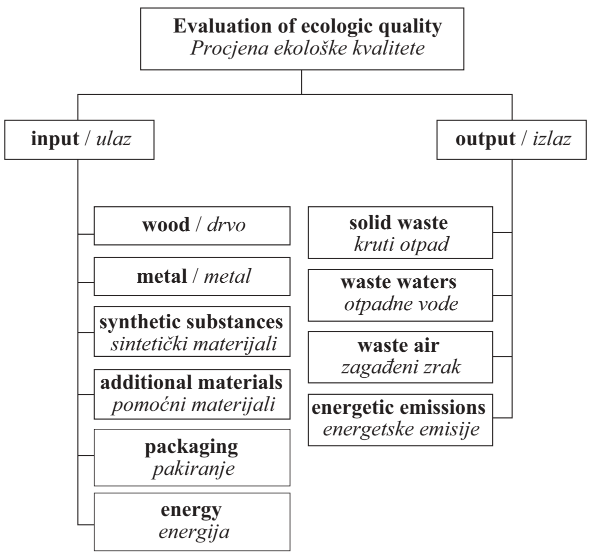


**Figure 2** Decision-making tree for multiple criteria decision-making
**Slika 2.** Drvo odlučivanja pri multikriterijskom odlučivanju

**Table 2** Input information for the analysis of ecological quality of kitchens: Quantities of production emissions into water, soil and air
**Tablica 2.** Unos podataka za analizu ekološke kvalitete kuhinja: količina emisija koje izlaze iz procesa proizvodnje i koje ulaze u vodu, tlo i zrak

| | | | **Kitchens / *Kuhinje*** | | |
|---|---|---|---|---|---|
| | | | 1 | 2 | 3 |
| solid waste / *kruti otpad* | | $m^3$ | 0.18 | 0.03 | 0.09 |
| waste waters / *otpadne vode* | sanitary / *sanitarne* | $m^3$ | 0.07 | 0.09 | 0.10 |
| | industrial / *industrijske* | $m^3$ | 0.08 | 0.12 | 0.07 |
| waste air / *onečišćeni zrak* | $CO_2$ | mg/h | ? | ? | ? |
| | CO | $mg/m^3$ | 489 | 600 | 560 |
| | $SO_2$ | $mg/m^3$ | ? | ? | ? |
| | $NO_x$ | $mg/m^3$ | 95 | 120 | 250 |
| | HC | g | 290 | 420 | 320 |
| | steam / *para* | $mg/m^3$ | 15 | 20 | 15 |
| energy emissions / *energetske emisije* | noise / *buka* | dB | 44 | 53 | 45 |
| | waste heat / *izgubljena toplina* | MW | 1.0 | 0.7 | 0.4 |

**Table 3** ABC analysis of three kitchens from the aspect of their ecological quality
**Tablica 3.** ABC analiza triju kuhinja sa stajališta njihove ekološke kakvoće

| **Ecological parameters** / *Ekološki parametri* | **Ponder** % | **Kitchens** / *Kuhinje* 1 | 2 | 3 |
|---|---|---|---|---|
| Quantity of raw materials, materials, energy and other substances that enter into the production process / *Količina sirovina, energije i drugih tvari koje ulaze u proizvodni proces* | 50 | | | |
| wood / *drvo* | 3 | BC* | B | B |
| metal / *metal* | 3 | C | B | B |
| synthetic substances / *sintetički materijali* | 12 | BC | B | AB |
| additional materials / *pomoćni materijali* | 20 | BC | AB | B |
| packaging / *pakiranje* | 2 | C | B | BC |
| energy / *energija* | 10 | C | C | C |
| Quantities of production emissions into water, soil and air *Količina emisija, koje izlaze iz procesa proizvodnje i ulaze u vodu, tlo i zrak* | 50 | | | |
| solid waste / *kruti otpad* | 5 | BC | C | C |
| waste waters / *otpadne vode* | 20 | B | AB | B |
| waste air / *onečišćeni zrak* | 15 | B | AB | AB |
| energy emissions / *energetske emisije* | 10 | C | BC | C |

*The meaning of class marks in Table is as follows: A – ecologically unacceptable, AB – ecologically problematic, B – ecologically questionable, BC – ecologically acceptable, C – ecologically irreproachable, / *Oznake u tablici označavaju: A – ekološki neprihvatljivo, AB – ekološki problematično, B – ekološki upitno, BC – ekološki prihvatljivo, C – ekološki besprijekorno.*


**Figure 3** Results of research on ecological quality of three kitchens
**Slika 3.** Rezultati istraživanja ekološke kvalitete triju kuhinja

## 4 CONCLUSION
## 4. ZAKLJUČAK

In the research, we analyzed the ecological quality of three kitchens from a well known manufacturer. We implemented a methodology based on three scientific methods: the method of life cycle analysis, ABC analysis, modified for our case, and the multi- decision-making method. The results of the research have shown that, for the same manufacturer, there are great differences from the aspect of ecological quality in their production and sales program. The three studied kitchens are burdening the environment very differently during their life cycle. The company can profit from the results of this research and use them in order to improve their competitive advantages on the demanding global market.

On the basis of the results of studying the ecological quality of timber products, the products or groups of products that meet the environmental requirements should be marked with a suitable ecological label in the future. This way the customers would know that such a product is more environment friendly in comparison with other products, which can be one of the decisive criteria for selection and purchase for ecologically aware customers.

The used methodology presents an innovative approach to solving ecological problems in companies and is a basis for adopting optimal strategic decisions, connected with ecological quality of the products. In our case, it was used for the evaluation of kitchens, but it is also suitable for the analysis of other products.

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# Formaldehyde Emission from Wood-Based Panels Bonded with Different Formaldehyde-Based Resins

## Emisija formaldehida iz drvnih ploča s različitim ljepilima na bazi formaldehida

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**ABSTRACT •** *In this study, the formaldehyde emission (FE) from different types of particleboard, medium density fiberboard (MDF), and plywood products supplied from a commercial plant in the Czech Republic were evaluated by gas analysis (EN 717-2) and European small chamber (EN 717-1) methods. The significant effects of manufacturing variables (board type and thickness) as well as different types of formaldehyde-based resins on FE measured by gas analysis were obtained. When the E1 type adhesives were employed, a wide variation in the quantity of free formaldehyde was observed among the three product types. The FE values of plywood samples measured by gas analysis were lower than those of the particleboard and MDF samples. The correlation between the two methods for the particleboard and MDF were good ($R^2$ = 0.82 and 0.76, respectively) and however for plywood ($R^2$ = 0.52) it was not convincing. FE specified in EN 717-2 was comparable with the EN 717-1 values for the same board type and thickness as well as the resin type and below the E1-emission class.*

***Keywords:*** *formaldehyde emission, formaldehyde-based resins, wood-based panels, chamber method, gas analysis method.*

**SAŽETAK •** *U radu se analizira emisija formaldehida (FE) iz različitih tipova ploča iverica, ploča vlaknatica srednje gustoće (MDF) i furnirskih ploča nabavljenih od komercijalnih proizvođača u Republici Češkoj. Emisija formaldehida određena je primjenom dviju metoda – analize plinova (EN 717-2) i male europske komore (EN 717-1). Istraživanja su pokazala signifikantan utjecaj proizvodnih parametara ploča (vrste i debljine ploča) i vrste upotrijebljenoga formaldehidnog ljepila na emisiju formaldehida mjerenu metodom analize plinova. Analizom uzoraka za koje je upotrijebljen E1 tip ljepila dobiven je širok raspon vrijednosti količine slobodnog formaldehida za tri vrste proizvoda. Vrijednosti FE furnirskih ploča niže su od vrijednosti uzoraka ploča iverica i MDF ploča. Korelacija rezultata dobivenih dvjema različitim metodama dobra je za ploče iverice i MDF ploče ($R^2$ = 0,82 i*

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*0,76), međutim, za furnirske ploče korelacija nije uvjerljiva ($R^2$ = 0,52). FE vrijednosti dobivene metodom prema normi EN 717-2 usporedive su s vrijednostima dobivenim metodom prema normi EN 717-1 za istu vrstu ploče i jednake debljine te za istu vrstu ljepila i razinu emisije formaldehida nižu od razreda E1.*

**Ključne riječi:** *emisija formaldehida, ljepila na bazi formaldehida, drvne ploče, metoda komore, metoda analize plinova*

## 1 INTRODUCTION
## 1. UVOD

In 1992, the California Air Resources Board (CARB, 1992) identified formaldehyde as a toxic air contaminant based primarily on the determination that it was a human carcinogen with no known safe level of exposure. The International Agency for Research on Cancer (IARC, 2004) conducted an evaluation of formaldehyde and concluded that there is sufficient evidence that formaldehyde causes nasopharyngeal cancer in humans (*i.e.,* in the region of the throat behind the nose). Formaldehyde is a well known allergen that causes contact dermatitis. Formaldehyde can be free on the material or bonded in different ways to the chemical structure. Free formaldehyde, including bonded formaldehyde, can be released under different analytical conditions.

Wood-based panels such as plywood, medium density fiberboard (MDF) and particleboard and the resins used like urea-formaldehyde (UF), melamine-modified urea formaldehyde (MUF), and phenol-formaldehyde (PF) are the main sources for FE. The present importance of such problematic results arises from the fact that formaldehyde was the first among the six chemical substances considered as industrial hazards (Tanabe, 2008). In 2001, the CARB initiated the development of a regulation to reduce public exposure to formaldehyde. The CARB regulation, effective January 1, 2009, placed limits on formaldehyde emission (FE) from wood-based panels.

Aminoplastic resins, especially UF-resins, are the main binders used in the industry of wood-based panels. UF-resins are fast curing resins and of uncontested good performance. However, boards bonded with UF-resins are, in general, of limited moisture resistance and emit detectable amounts of formaldehyde (Roffael *et al.,* 2010). Furthermore, concern about the emission of formaldehyde from particleboards and weakening glue bond caused by hydrolytic degradation of UF polymers have stimulated efforts to develop improved and/or new adhesives based on UF resins.

The MUF resins with reduced melamine content levels have been developed to improve durability and moisture resistance properties. These low-melamine content UF resins have been relatively popular in Europe and in the Asia-Pacific region (Parker and Crews, 1999) for many years.

Phenolic-based compounds also tend to be more chemically stable and less susceptible to hydrolysis than UF. Both of these characteristics are beneficial to PF resin. This is one of the reasons why PF resins are considered waterproof, while UF is not (Dunky, 2005). PF resin has generally been the resin chosen by the manufacture of exterior grade structural panels.

There are many factors affecting the FE of wood panel products. For example, many variables such as temperature, relative humidity, air exchange rate, loading ratio, etc. could affect the FE measurements of wood-based panel products (Myers and Nagaoka, 1981; Myers, 1985).

Actually, many different attempts have been made to compare the FE or to establish correlations between methods. Sundin *et al.* (1987) compared four different methods of testing the FE of particleboards, and found good relationships between the methods with correlation coefficients greater than 0.9. Risholm-Sundman *et al.* (2007) reported that the variations between the measured results were due to specific differences in test conditions. Bulian *et al.* (2003) also reported that the lack of certified reference material made it difficult to establish an inter-calibration between test methods.

The amount of free formaldehyde observed in the chamber under conditions that simulated mobile loadings of wood product, air change rate, temperature, and humidity relate to real wood formaldehyde levels (Que and Furuno, 2007).

Recently, continuous methods have also been proposed for assessing the formaldehyde release during production in the factories (Engström, 2007, 2008). In Europe, mainly three laboratory methods for the determination of formaldehyde release have been standardized and namely: 1) Extraction method called the perforator method (EN 120, 1993), 2) FE by gas analysis method (EN 717-2, 1994) and 3) FE by the flask method (EN 717-3, 1996). Apart from these methods, the FE of the boards can be measured using the European chamber technique (EN 717-1, 2004), which is considered to be the reference method.

Among the above-mentioned laboratory methods, gas analysis technique gained wide acceptance for assessing the emission of formaldehyde from wood-based panels. The European gas analysis method is CARB-approved quality control test method (Ruffing *et al.,* 2010).

This study aimed to determine the effects of some manufacturing factors on the emission of formaldehyde from different types of particleboard, MDF and plywood panels. The effects of board type and thickness were investigated, as well as the effect of resin adhesive type. The relationship between the European small-chamber and gas analysis values were also reported.

## 2 MATERIALS AND METHODS
## 2. MATERIJALI I METODE

### 2.1 Sample collection
### 2.1. Skupljanje uzoraka

Wood-based panels used in this study were particleboard, MDF and plywood, with thickness of 12 mm (T12), 16 mm (T16) and 18 mm (T18), supplied from commercial plants in the Czech Republic. Samples of particleboards (500 mm × 500 mm) were cut at the mill from three full-sized boards (2840 × 1830, 2750 × 1830 and 2810 × 1810 mm) from each thickness type of uncoated (P2), laminated (PL) and veneered (PV) particleboards, respectively. In addition, the uncoated MDF (MDF) samples were cut from 2750 × 1840 mm boards for each thickness. The laminated MDF (MDFL) samples were taken from the boards with dimension 2750 × 1840 mm for T16 and T18 and from 2440 × 1220 mm for T12, respectively; and these boards were laminated with high-pressure laminate.

The uncoated plywood samples used in interior application (PLY) were cut from each of the three panels with dimensions 250 × 125 cm of T12, T16, and T18. These panels were produced from beech veneers. Samples of plywood with T12 and T18 used in construction applications (PLYs) were cut from panels with dimensions 125 × 250 cm and produced from birch veneer and with T16 panels they were produced from poplar veneer. The sampling was done in accordance with standards EN 312 (2003), EN 622–1 (2003), and EN 13986 (2002). These standards were designed for testing the requirements of wood-based panels.

All the samples were delivered to the laboratory of Timber Research and Development Institute in Prague, Czech Republic. The delivered samples were wrapped with polyethylene film prior to being cut into test specimens in order to measure the FE with EN 717-1 and EN 717-2.

The plywood samples are conditioned for 4 weeks at 20 °C and 65 % RH before measuring the FE by EN 717-2 according to German Federal Health Office (BGA, 1977). Particleboards and MDF samples were analyzed directly after opening the polyethylene film and sealing the edges (Risholm-Sundman *et al.,* 2007).

The different types of particleboard and MDF were produced for many different purposes, especially for the manufacture of furniture and interior equipment. MDF is produced from spruce wood fiber, bonded together with MUF resin. The three types of particleboard panels used in this study were bonded with a high quality wholesome UF resin and produced from spruce particles. The veneered particleboards are made from the European oak decorative veneer, which is pressed onto the board on both sides. PLY panels were bonded with MUF resin adhesive and PLYs panels were bonded with PF resin. The numbers of different types of particleboard, MDF and plywood samples for gas analysis and European small-chamber tests were determined according to board thickness (Table 1).

### 2.2 Free formaldehyde test methods
### 2.2. Metode određivanja emisije formaldehida

To determine the FE, the European small-chamber and gas analysis methods were employed as specified in the standards EN 717-1 (2004) and EN 717-2 (1994), respectively.

#### 2.2.1 Gas analysis method (EN 717-2)
#### 2.2.1. Metoda analize plinova (EN 717-2)

In the gas analysis method, a test piece of 400 mm × 50 mm × board thickness was placed in a 4-litre cylindrical chamber with controlled temperature (60 ± 0.5 °C), relative humidity (RH ≤ 3%), airflow (60 ± 3 l/h) and pressure. Air was continuously passed through the chamber at 1L/min over the test piece, whose edge was sealed with self-adhesive aluminum tape before testing. The determinations were made in duplicate using two different pieces and actual formaldehyde value was the average of two pieces after 4 hours expressed in mg HCHO/m$^2$·h. These determinations were repeated, as samples were available, for better homogeneity of the results. The E1-emission class for all types of wood-based panels is ≤ 3.5 mg/m$^2$·h.

#### 2.2.2 Small-chamber method (EN 717-1)
#### 2.2.2. Metoda male komore (EN 717-1)

In the European small-chamber method, two test pieces (0.2 m × 0.28 m × board thickness) were cut from 500 mm × 500 mm samples for each wood product with a total area of 0.225 m$^2$ for free formaldehyde measurement by chamber method (0.225 m$^3$ in volume). The samples were not conditioned before the test. The loading factor was 1 m$^2$/m$^3$, so that the edges were partly sealed (1.5 m open edge/m²), where the edges of two pieces were sealed with aluminum foil to obtain a constant ratio of the length ($U$) of the open (unsealed) edges to the surface area ($A$), so that $U/A$ = 1.5 m/m$^2$. The temperature was held at 23 ± 0.5 °C and the RH at 45 ± 3 %. Formaldehyde released from the test pieces mixes with the air in the chamber, and a specified volume of air is drawn from the chamber twice a day. Sampling is periodically continued until the formaldehyde concentration in the chamber has reached a steady-state. The result of the test is given after 2-4 weeks as the

**Table 1** Number of specimens used for gas analysis and small chamber tests
**Tablica 1.** Broj uzoraka upotrijebljenih za metodu analize plinova i test male komore

| **Wood-based panels** *Drvne ploče* | | **Particleboards** *Ploče iverice* | | | **Fiberboards** *Ploče vlaknatice* | | **Plywoods** *Furnirske ploče* | |
|---|---|---|---|---|---|---|---|---|
| board type / *tip ploče* | | P2 | PL | PV | MDF | MDFL | PLY | PLYs |
| Thickness, mm / *debljina, mm* | | 12-18 | 12-18 | 12-18 | 12-18 | 12-18 | 12-18 | 12-18 |
| Number of samples *broj uzoraka* | EN 717-2 | 36 | 22 | 24 | 28 | 26 | 20 | 22 |
| | EN 717-1 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |

steady-state emission value (mg/m$^3$) or ppm. The E1-emission class for all types of wood-based panels is ≤ 0.1 ppm (0.12 mg/m$^3$ of air).

The formaldehyde amount in the water from both methods was determined photometrically by acetylacetone spectrophotometric analysis. This technique, as described by Nash (1953), is widely applied and is a standard procedure for the specific analysis of free formaldehyde. The determination is based on the Hantzsch reaction, in which aqueous formaldehyde reacts with ammonium ions and acetylacetone to yield diacetyldihydrolutidine (DDL).

### 2.3 Statistical Analyses
### 2.3. Statističke analize

In order to achieve the study aims; the formaldehyde values measured by gas analysis method were statistically analyzed. Analysis of variance (ANOVA) with different repetitions was used to test for significant difference of factors and levels. When the ANOVA indicated a significant difference among factors and levels, a comparison of the means was done employing a Duncan's multiple-range test (1954) at 0.05 level of probability. Formaldehyde values are reported as least square means (LS Means) with 95 % confidence intervals (95 % CI). Linear correlations were applied to the gas analysis versus European small chamber values using the CORR option. Analyses were performed by SAS version 8.2 (2001) Statistical Analysis System software.

## 3 RESULTS AND DISCUSSION
## 3. REZULTATI I RASPRAVA

### 3.1 Gas analysis values
### 3.1. Vrijednosti dobivene metodom analize plinova

The values of FE measured by gas analysis were very significantly affected by board type ($P < 0.001$), board thickness ($P < 0.001$) and the interactions between them ($P < 0.001$) for almost all wood-based panels types used in this study (Table 2). For MDF boards, the interaction between them had a significant effect ($P < 0.05$).

The overall comparisons between the means of FE from different types of wood-based panels bonded with different formaldehyde-based resin are presented in Table 3. The FE of particleboard was the highest in PV T18 and PV T16 (2.52 and 1.68 mg/m$^2$·h, respectively) followed by PV T12 (0.96 mg/m$^2$·h), whereas the PL T12 had the lowest amount of FE (0.23 mg/m$^2$·h). The FE from fiberboards showed a high amount presented in MDF T18 (0.77 mg/m$^2$·h) followed by MDFL T18 (0.61 mg/m$^2$·h). The PLY T18 had a high amount of FE (0.35 mg/m$^2$·h) and the PLYs T12 had the lowest amount of FE (0.11 mg/m$^2$·h) from plywood panels studied. The concentration of FE in PLY (it ranged from 0.16 to 0.35 mg/m$^2$·h) had a higher value than the concentration of FE from PLYs (it ranged from 0.11 to 0.25 mg/m$^2$·h) and this could be explained in the use of different glue types.

All values measured for the different types of wood-based panels used in this study were below the standard limit E1 specified in EN 717-2. Moreover, it has been shown that the applications of laminating over the boards were responsible for decreasing the emission of formaldehyde from the particleboard and MDF, and also for increasing FE due to the increase of the board thickness.

### 3.2 Small-chamber values
### 3.2. Vrijednosti dobivene metodom male komore

For the sake of comparison, the European small-chamber values that were obtained for almost all the boards examined - particleboard, MDF and plywood, are shown in Table 4. For particleboard samples, the formaldehyde values ranged from 0.048 (PL T12) to 0.123 mg/m$^3$ (PV T18) and from 0.042 (MDFL T12) to 0.087 mg/m$^3$ (MDF T18) for the fiberboards. Plywood formaldehyde values also ranged from 0.051-0.066 mg/m$^3$ for PLY and 0.005 to 0.007 for PLYs. In this regard, the emission of formaldehyde from the boards is close to the emission of solid untreated wood (*i.e.,* between 0.008-0.01ppm for spruce wood flakes) (Marutzky and Dix, 2004).

The last study also showed that the veneered particleboards emitted a higher amount of free formal-

**Table 2** Significant levels for the effects of board type within the thickness on overall values of gas analysis of wood-based panels
**Tablica 2**. Razina signifikantnosti utjecaja vrste ploče jednake debljine na vrijednosti dobivene analizom plinova za sve vrste istraživanih ploča

| **Wood-based panels** *Drvne ploče* | **Source of Variation** / *Izvor varijacije* | **Significant level** / *Razina signifikantnosti* | $R^2$ | *CV* |
|---|---|---|---|---|
| Particleboards *ploče iverice* | A | *** | 0.98 | 8.71 |
| | B | *** | | |
| | A × B | *** | | |
| Fiberboards *ploče vlaknatice* | A | *** | 0.97 | 6.58 |
| | B | *** | | |
| | A × B | * | | |
| Plywoods *furnirske ploče* | A | *** | 0.93 | 13.61 |
| | B | *** | | |
| | A × B | ** | | |

(*) $P < 0.05$ (significant/*signifikantno*), (**) $P < 0.01$ (highly significant / *visoko signifikantno*); (***) $P < 0.001$ (very highly significant / *vrlo visoko signifikantno*).
(A) Board type / *vrsta ploče*, (B) Board thickness / *debljina ploče*, (A × B) Interaction between board type and thickness / *interakcija između vrste ploče i debljine ploče*.

**Table 3** Formaldehyde emission of different types of wood-based panels (12–18 mm) measured by gas analysis method (mg/m²·h)
**Tablica 3.** Emisija formaldehida različitih tipova drvnih ploča (12 – 18 mm) mjerena metodom analize plinova (mg/m²·h)

| **Board type** / *Tip ploče* | **Resin type** / *Vrsta ljepila* | **Thickness** / *Debljina* | | |
|---|---|---|---|---|
| | | T12 | T16 | T18 |
| P2 | UF | (0.67± 0.16)* *f* | (0.63 ± 0.09) *fg* | (1.68 ± 0.02) *b* |
| PV | | (0.96± 0.02) *d* | (1.19 ± 0.02) *c* | (2.52 ± 0.02) *a* |
| PL | | (0.23± 0.02) *klm* | (0.54 ± 0.08) *gh* | (0.84 ± 0.03) *e* |
| MDF | MUF | (0.38 ± 0.03) *ij* | (0.47 ± 0.05) *hi* | (0.77 ± 0.03) *e* |
| MDFL | | (0.29 ± 0.02) *jk* | (0.32 ± 0.01) *jk* | (0.61 ± 0.01) *fg* |
| PLY | MUF | (0.16 ± 0.01) *lmn* | (0.37 ± 0.01) *ij* | (0.35 ± 0.06) *j* |
| PLYs | PF | (0.11 ± 0.01) *n* | (0.25 ± 0.01) *kl* | (0.15 ± 0.01) *mn* |

(*) Values (mean ± SD) / *vrijednosti (srednja vrijednost ± standardna devijacija)*.
Different letters represent statistical differences between the averages of the values. Means with the same letter are not significantly different at 0.05 level of probability according to Duncan's multiple test. / *Različita slova označavaju statistički signifikantnu razliku između srednjih vrijednosti. Srednje vrijednosti s istim slovom nisu statistički signifikantno različite na razini signifikantnosti 0,05 prema Duncanovu testu.*

**Table 4** Formaldehyde emission of wood product (12–18 mm) measured by chamber method (ppm)
**Tablica 4.** Emisija formaldehida iz različitih tipova drvnih ploča (12 – 18 mm) mjerena metodom komore (ppm)

| **Wood-based panels** *Drvne ploče* | **Board type** *Tip ploče* | **Thickness, mm** *Debljina, mm* | | |
|---|---|---|---|---|
| | | T12 | T16 | T18 |
| Particleboards *ploče iverice* | P2 | 0.074 | 0.076 | 0.083 |
| | PV | 0.082 | 0.087 | 0.123 |
| | PL | 0.048 | 0.049 | 0.079 |
| Fiberboards *ploče vlaknatice* | MDF | 0.050 | 0.077 | 0.087 |
| | MDFL | 0.042 | 0.052 | 0.065 |
| Plywoods *furnirske ploče* | PLY | 0.051 | 0.063 | 0.066 |
| | PLYs | 0.005 | 0.006 | 0.007 |

dehyde than the uncoated and laminated boards. Moreover, the plywood panels used in construction had the lowest FE concentration. All the values of the tested wood-based panels measured by EN 717-1 and EN 717-2 were below the E1-class emission.

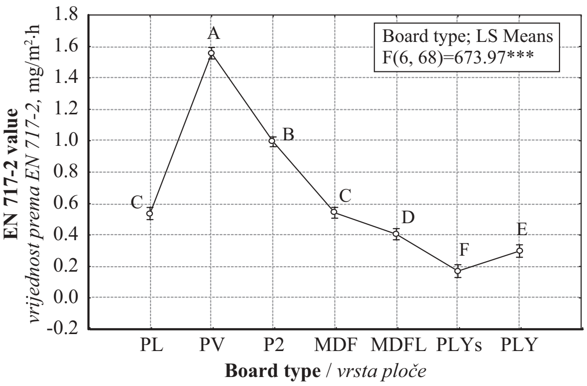
The FE values of plywood samples measured by the gas analysis method were lower than those of the particleboard and MDF samples. Our results were in agreements with Park *et al.,* 2010, who found that the emission of formaldehyde from plywood samples measured by the 1-m³ chamber method was lower than those of particleboard and MDF samples. Furthermore, the boards-E1, had approximately the same value for each method. This shows that for the same kind of material, the methods show similar results.

### 3.3 Effect of different types of formaldehyde-based resins
### 3.3. Utjecaj različitih tipova formaldehidnih ljepila

By introducing the above experimental data of the FE measured by gas analysis and corresponding effects of some manufacturing variables following a similar procedure as described above, it was found that the types of resins had a high effect on the FE.

As can be seen in Figure 1, a high amount of FE measured by gas analysis method was observed from PV/UF followed by P2/UF. Mean values showed that the MDF/MUF emitted free formaldehyde with values equal to PL/UF, while the MDFL/MUF had a lower amount of FE than particleboards, and the plywood values from PLYs/PF had the lowest amount of FE. In addition, these results were comparable with the chamber values for the same board type and thickness as well as the resin type. It is important to point out here that such low free formaldehyde values may be emitted from the wood itself. At such low levels of free FE, the boards are considered formaldehyde free.

The differences between the formaldehyde values emitted from different types of wood-based panels due to different formaldehyde-based resins can be explained as follows: the reaction of urea with formaldehyde first produces hydroxylmethyolated urea that then condenses to yield methylene and dimethylene ether bridged urea




PL: Laminated particleboard / *lamelirana iverica* , PV: Veneered particleboard / *furnirana iverica*, P2: General purpose boards for use in dry conditions / *ploča za opću uporabu u suhim uvjetima*, MDF: Uncoated MDF / *neobložena MDF ploča*; MDFL: Laminated MDF / *lamelirana MDF ploča*; PLY: Uncoated plywood used in interior application / *neobložena furnirska ploča za uporabu u interijeru*; PLYs: Uncoated plywood used in construction application / *neobložena furnirska ploča za uporabu u graditeljstvu*
Means with different letters are significantly different ($P < 0.05$). / *Srednje vrijednosti s različitim slovom signifikantno su različite (P < 0,05).*
(***) very highly significant effect ($P < 0.001$) / *vrlo visoko signifikantni utjecaj (P < 0,001)*
Vertical bars denote 0.95 confidence intervals / *Okomite dužine označavaju 0,95 intervala pouzdanosti.*

**Figure 1** Comparison of formaldehyde emission measured by EN 717-2 of different types of wood-based panels bonded with different formaldehyde-based resins
**Slika 1.** Usporedba emisije formaldehida iz različitih tipova drvnih ploča s različitim formaldehidnim ljepilima mjerene metodom prema normi EN 717-2

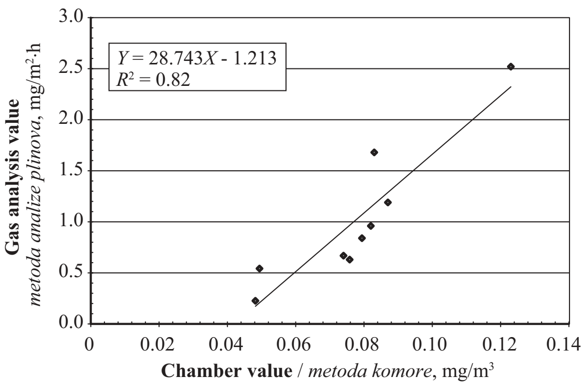



Figure 2 Correlation between EN 717-1 and EN 717-2 values for particleboards, thickness 12-18 mm

**Slika 2.** Korelacija između vrijednosti emisije formaldehida dobivenih različitim metodama (prema EN 717-1 i EN 717-2) za ploče iverice debljine 12 – 18 mm

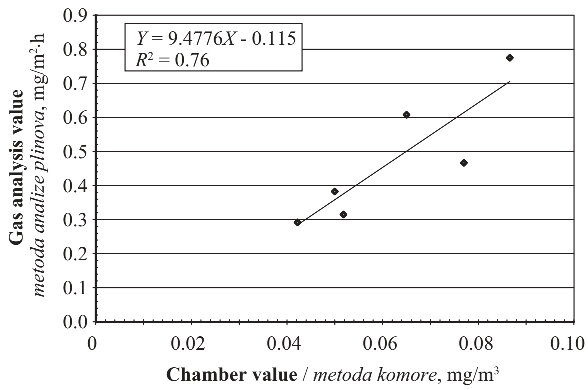



**Figure 3** Correlation between EN 717-1 and EN 717-2 values for fiberboards, thickness 12-18 mm

**Slika 3.** Korelacija između vrijednosti emisije formaldehida dobivenih različitim metodama (prema EN 717-1 i EN 717-2) za ploče vlaknatice debljine 12 – 18 mm

polymers (Pizzi 2003; Meyer 1979). Although these reactions are not likely to produce the other formaldehyde-containing wood adhesives, the UF polymers were distinct as they are susceptible to hydrolysis under some normal conditions used (Myers, 1986).

In accordance with Dunky (2005), the stability against hydrolysis that increased in MUF may be due to stabilization of the C-N-bonding that resulted from the quasi-aromatic ring structure of the melamine and slower decrease of the pH in the bond line and due to the buffer capacity of melamine. In addition, the C-C bonding in the PF resins was very stable against hydrolytic attack.

### 3.4 Relationship between gas analysis and small-chamber values
### 3.4. Odnos između vrijednosti dobivenih metodom analize plinova i metodom male komore

Linear correlation analyses made between the gas analysis (*Y*) and the corresponding average small-chamber values (*X*) were affected by board type, board thickness, and formaldehyde-based resins for particleboard (Figure 2), MDF (Figure 3) and plywood panels (Figure 4). The regression equations ($Y = 24.74 \cdot X - 1.213$, $R^2 = 0.82$, $P < 0.001$ for particleboard panels measured at P2, PV and PL), ($Y = 9.477 \cdot X - 0.115$, $R^2 = 0.76$, $P < 0.05$ for the influences of MDF and MDFL), and ($Y = 2.635 \cdot X - 0.144$, $R^2 = 0.52$, $P < 0.05$ for the effect of PLY and PLYs) suggested that the emissions of formaldehyde resulted from the free formaldehyde or from hydrolysis of the cured resin that might be attributed to board type and thickness levels and different types of resin. The correlation between the gas analysis and the European small-chamber methods was not convincing for plywood panels, the obtained $R^2$ value was 0.52 (see Figure 4) and it was probably related to the difference in the resins used.

## 4 CONCLUSIONS
## 4. ZAKLJUČCI

Samples of particleboard, MDF and plywood products were obtained from commercial plants that produce more than 70 % of the capacity in the Czech Republic. These samples were used in well-controlled

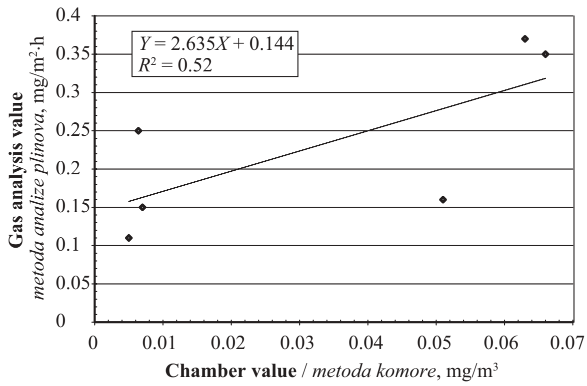



**Figure 4** Correlation between EN 717-1 and EN 717-2 values for plywood, thickness 12-18 mm

**Slika 4.** Korelacija između vrijednosti emisije formaldehida dobivenih različitim metodama (prema EN 717-1 i EN 717-2) za furnirske ploče debljine 12 – 18 mm

chamber tests (small chamber and gas analysis) to estimate the formaldehyde emissions. The European testing of the emitted formaldehyde and evaluation system is based in principle on EN 717-1 but in practice, it is carried out by derived test methods like EN 717-2.

A wide variation in the quantity of free formaldehyde was observed among the three product types. It was clear that the variations between the different values of formaldehyde emissions observed in both methods were resulted from board type and thickness as well as the resin type. In addition, the other factors like edge sealing and test temperature, which have a large effect on the final emission result, should be taken in consideration.

Similar values of free formaldehyde observed in this work are reported for EN 717-1 and EN 717-2. Moreover, all values measured were below the standard limit E1 for EN 717-1 and EN 717-2.

The correlation between the gas analysis and the chamber for the particleboard and MDF were good ($R^2 = 0.82$ and 0.76, respectively) and for plywood ($R^2 = 0.52$), however, it was not convincing.

Finally, emissions of formaldehyde are expected to decrease with the decrease of the coated wood-based panels and board thickness. Results reported in this study apply to freshly manufactured materials.

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**Šumarski fakultet Sveučilišta u Zagrebu**

u suradnji s

organizira i poziva Vas na

## 22. MEĐUNARODNO ZNANSTVENO SAVJETOVANJE

## "DRVO JE PRVO – IZAZOVI SEKTORA PRED ULASKOM U EU"

**21. listopada 2011. godine, Zagrebački velesajam**

Poštovani,

Naše tradicionalno savjetovanje u okviru 38. međunarodnog sajma namještaja, unutarnjeg uređenja i prateće industrije održat će se **21. listopada 2011. na Zagrebačkom velesajmu** pod pokroviteljstvom Ministarstva regionalnog razvoja, šumarstva i vodnoga gospodarstva. Tema ovogodišnjeg savjetovanja je "DRVO JE PRVO – IZAZOVI SEKTORA PRED ULASKOM U EU".

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doc. dr. sc. Goran Mihulja

*Miloš Hitka, Lenka Štípalová*[1]

# Comparing of Employees Motivation Level in Enterprises of Wood Working Industry with other Manufacturing Enterprises in Slovak Republic

## Razina motiviranosti zaposlenih u poduzećima drvnoprerađivačke industrije u odnosu prema zaposlenima u drugim proizvodnim poduzećima u Slovačkoj

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**ABSTRACT** • *This paper is focused on the area of motivation and motivational programs for employees in the wood industry and in other manufacturing enterprises (engineering, food, chemical and textile). The main objective of this paper is to compare the motivation of employees within manufacturing companies of various categories. We analyzed the current state of motivation of employees within manufacturing companies throughout Slovakia. The analysis was made of 21 enterprises with 2 576 employees in different job positions. The order of importance was made for 30 selected motivational factors in wood industry and other manufacturing enterprises. The evaluation of statistical correlation between the two compared groups was made by use of the Spearman correlation coefficient, by which statistical dependence was defined between the category of workers and the category of technical-economic employees. The results show fundamental difference of the importance of motivational factors within technical and marketing staff of woodworking companies and other manufacturing companies. In the category of workers, diversity of the importance of motivational factors is less significant. Our analysis showed that in a long period of time all employees keep their motivation at a constant level.*

***Key words:*** *Employee motivation, motivational program, methods of motivation analysis*

**SAŽETAK** • *Rad je usmjeren na motivaciju i motivacijske programe zaposlenika u drvnoj industriji i drugim proizvodnim poduzećima (strojogradnji, proizvodnji hrane, kemijskoj i tekstilnoj industriji). Osnovni cilj rada bio je us-*

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*porediti motiviranost zaposlenika u različitim proizvodnim poduzećima. Analizirano je trenutačno stanje motiviranosti zaposlenika u više proizvodnih poduzeća na području Slovačke. Istraživanjem je obuhvaćeno 21 poduzeće s ukupno 2 576 zaposlenika na različitim radnim mjestima. Za 30 odabranih motivacijskih činitelja određen je redoslijed važnosti u drvnoprerađivačkoj industriji i drugim proizvodnim poduzećima. Ocjena statističke povezanosti dviju uspoređenih skupina poduzeća napravljena je primjenom Spearmanova koeficijenta korelacije za dvije skupine zaposlenika – skupinu radnika i skupinu tehničko-ekonomskog osoblja. Rezultati su pokazali bitnu razliku glede motivacijskih činitelja važnih za tehničko-ekonomsko osoblje drvnoindustrijskih poduzeća u odnosu prema drugim proizvodnim poduzećima. U skupini radnika, različitost važnosti motivacijskih činitelja manje je naglašena. Na temelju dobivenih rezultata i promatrajući dulje razdoblje, može se zaključiti da radnici zadržavaju jednaku razinu motiviranosti.*

***Ključne riječi**: motiviranost zaposlenika, motivacijski program, metoda analize motivacije*

## 1 INTRODUCTION
## 1. UVOD

The existence of the enterprise, its prosperity and dynamic progress are primarily affected by the quality of human resources. Prosperous enterprises realize that the most profitable capital of the enterprise is its employees and their motivation, through which an enterprise can successfully meet its objectives. All organizations are interested in the options, ways and means that could improve the quality of its employees. This effort can only give good results on the basis of systemically conceived management of human resources, which represents coherent and comprehensive approach to ensuring a mutually supportive policy and practice of employing people.

The uniqueness of human resources, as the contributor of all values, requires that the potential of all employees be used judiciously and developed so as to continue to bring new value. Effective functioning and development of employees requires systematic evaluation and motivation and related evaluation and motivational processes. Programs are mostly used that represent specific definition of the system for dealing with people in an enterprise with a relatively strong focus on positive impact on the work performance of employees (Zámečník, 1999).

As motivating employees is highly impacted by different motivational factors, the manner in which individual managers try to motivate individual employees, teams and organizations is different. Some of them are focused on the rationality and orderliness, others require from employees to handle more difficult processes and some others use self-realization as a basic human need. At present, motivation process in most manufacturing enterprises does not cover all their needs. Business environment and its existence are largely dependent on the use of all business activities. Motivation will be required in every area of business activity for achieving the important objectives. Most businesses, however, have only unified motivational programs for all levels of their employees.

### 1.1 Actual situation of employee motivation in manufacturing enterprises
### 1.1. Aktualna situacija motiviranosti zaposlenika u proizvodnim poduzećima

Surveys of motivational structure of employees should accept the general understanding of motivation theory (the theory of needs, attitudes expected) and should be one of the first gradual steps in developing a motivational program in an organization. Together with other methods of psychological and sociological surveys, it allows to evaluate motivational effects. Without this basic knowledge, the construction and implementation of the proposed measures are only accidental processes (Potkány, 2004).

Work performance is affected by a number of factors. Some have a significant impact on the level of motivation, others have less impact. The effect of many factors is of contingent nature depending on the environment and work situations in which they apply. In terms of motivating performance, some of the most important factors are rewards and sanctions, which mainly mobilize human behavior. Speaking of rewards, people usually think of money. It should be noted, however, that although money is an important factor, it has the strongest effect, as a rule, only the first month. Then the enterprise must focus on other factors leading to the motivation of employees.

At the beginning of this research, we assumed that the work motivation factors (money, physical environment, work content, work team, level and style of management, job satisfaction, personality and leadership and identification with the work) would be dominant for achieving good work results, and that employees would be motivated in the process of Maslow's hierarchy of needs. After completing the analysis and summarizing the results, we can conclude that there is a high diversity of assumptions regarding motivational factors, the actually used motivational factors in businesses and the actual requirements of the analyzed groups of employees. The objective of our work is to confirm the hypothesis of the importance of financial motivation factors and job security as the dominant motivating factors in all categories of employees in woodworking, as well as other manufacturing companies.

## 2 MATERIAL AND METHODS
## 2. MATERIJAL I METODE

Motivational programs (both individual and group) are often used in enterprises as a part of adaptation programs to keep employees' performance at the required level. The motivational program must be tailored to corporate culture and enterprise opportunities

(Růžička and Dražská, 1992). In our organizations, motivational programs are elaborated in detail only exceptionally. Their execution and incorporation into enterprise internal documents is expected to change total access to the role of employees in the enterprise. It would be ideal to create a motivational program tailored to each employee, and however this would be economically unfeasible and time demanding. On the other hand, production of surface motivational programs may miss action because of differences in motivational orientation of individual employees. In many cases there are small differences in the motivational profile of employees who may have a significant impact on the overall performance. In our work, on the basis of past experience and by scientific and statistical methods, we tried to design a model that can be used in enterprises with similar motivation-oriented group of employees.

First of all, analysis was made of enterprises of wood production in first-stage and then also in second stage processing of raw wood material in the region of Central Slovakia. Then we analyzed manufacturing enterprises with other business objects, e.g. mechanical engineering, food, chemicals and textile. We have also used the questionnaire method, which allows collecting in a short time large quantity of information. The questionnaire is one of the specific methods used in social sciences. It is the method for collecting data by posing questions to people. It is suitable for the mass data collection for statistical processing. This makes it possible to capture all views, positions, interests, etc. The basic condition for an effective questionnaire is the exact presentation of the goal and tasks of the questionnaire in relation to the selected problem. It is a relatively quick and easy method. Compared with other analytical methods it has many advantages. One of the best advantages is that respondents are open and relaxed in expressing their opinion as questionnaires are anonymous. Compared to a personal interview, the questionnaire is less stressful and the answers are not largely influenced by the atmosphere and environment. By using a questionnaire, it is also possible to analyze basic information about respondents, such as age, years of work experience, education and so on.

Another method for comparing the motivation levels is the cluster analysis. Given that the system of employee motivation is based on a distribution of criteria into disjunctive groups according to homogenous characteristics, the final assessment of the employee groups use cluster analysis (CLUA), where by the use of appropriate algorithms, we can work towards the creation of different groups to which individual employees can be included (Anděl, 1985). Cluster analysis can be used to explore the possibility of creating types of motivational programs, and it can also provide the possibility of drawing up unified motivation programs for groups of managers with similar motivation profile. The objective of the analysis is to detect whether, based on measurement of similarity of respondent responses to the questionnaire, groups of employees can be distinguished with a similar motivational factor. This could be the basis for elaborating uniformity of motivational programs aimed at simplifying and making more effective the application of motivational schemes in practice. Furthermore, cluster analysis can also be used to further verify the structure and order importance of motivation criteria. A large number of clustering techniques recommend the use of hierarchical clustering method called Ward method for measuring the degree of similarity of answers of individual respondents in the simplest way, using the so-called Euclidean distance.

Analysis was made of a total of 21 enterprises with 2 576 employees of different job positions. 30 selected motivational factors were ranked according to their importance within wood-working enterprises and other manufacturing enterprises. We explored the statistical dependence between the two orders in the category of workers and technical-economic employees. As in our case there are no quantitative data, but only qualitative ones, to assess the statistical significance of correlation between the two compared groups, we have used the Spearman correlation coefficient, which is often used as serial correlation coefficient in assessing the statistical dependence of data quality. Ranking was made of dimensions $X_1, ..., X_n$ (ranking of motivational factors of wood enterprises) and dimensions $Y_1, ..., Y_n$ (ranking of motivational factors of other production enterprises). In testing the hypothesis that $X_i$ and $Y_i$ are independent random dimensions ($i = 1, 2, ..., n$) dimensions $X_1, ..., X_n$ were ordered by size and their sequence $Q_1, ..., Q_n$ was established. Spearman correlation coefficient (Lohninger, 1999) was then calculated as follows: (1)

$$r_s = 1 - \frac{6}{n(n^2-1)} \sum_{i=1}^{n} (R_i - Q_i)^2 \qquad (1)$$

Where:
$r_s$ – Spearman correlation coefficient
$n$ – number of variables (in our case 30)
$R_i$ – order dimensions $X$
$Q_i$ – order dimensions $Y$

Subsequently in the tables of critical values (Anděl, 1985, s. 234) 5% critical value of Spearman's correlation coefficient for $n = 30$ (n is the number of motivational factors) is the value of 0.362 and 1% critical value of 0.467. In the case of workers, the calculated correlation coefficient was $r_s = 0.813$ (Table 4), which means that the importance of motivational factors in workers of woodworking enterprises is pretty identical to the importance of motivational factors of workers in other manufacturing enterprises. In case of technical-economic employees the correlation coefficient was $r_s = 0.497$ (Table 3), which means that technical-economic employees in wood-working enterprises also prefer the same motivational factors as technical-economic employees in other manufacturing enterprises, but the match is not as good as in workers. This can be explained by the fact that workers are not so heavily involved in the production and economic results of enterprises as technical-economic employees. On the other hand, technical-economic employees are aware of a specific wood production over other manufacturing enterprises.

## 3 RESULTS AND DISCUSSION
## 3. REZULTATI I RASPRAVA

At present, in most companies, not enough attention is paid to motivation of employees, although it is a powerful tool to increase performance and productivity. Many enterprises have a way to motivate employees individually, mostly by financial motivating factors, different forms of social care, education and employee benefits. Other enterprises find other ways to motivate employees.

Modern personnel work and modern human resources management have not been for long only a matter of personnel managers, and the tasks of personnel management are more and more assumed by managers at various levels, especially by the line managers. Managers at all levels are the final point where that practical personnel work implements corporate personnel policy. For this reason it must be provided with thorough theoretical and practical knowledge. It is necessary to understand the importance, status and wide personnel mana-

**Table 1** Order scores of motivational factors of workers and technical-economic employees of wood-working and other enterprises
**Tablica 1**. Bodovi na ljestvici motivacijskih činitelja radnika i tehničko-ekonomskog osoblja zaposlenih u drvnoprerađivačkoj industriji i u drugim proizvodnim poduzećima

| **Nos.** *R.br.* | **Motivational factor** *Motivacijski činitelj* | **Sequence scores of motivational factors** / *Bodovi na ljestvici motivacijskih činitelja* | | | |
|---|---|---|---|---|---|
| | | **Workers in woodworking enterprises** / *radnici u drvnoj industriji* | **Workers in other production enterprises** / *radnici u drugim proizvodnim poduzećima* | **TEE wood-working enterprises** *tehničko-ekonomsko osoblje u drvnoj industriji* | **TEE other production enterprises** *tehničko-ekonomsko osoblje u drugim proizvodnim poduzećima* |
| 1 | Workplace atmosphere / *atmosfera na radnome mjestu* | **67** | **45** | **98** | 19 |
| 2 | Workplace safety /*sigurnost na radnome mjestu* | 38 | **50** | **49** | 27 |
| 3 | Another monetary reward / *druga novčana naknada* | **72** | **48** | 28 | **44** |
| 4 | Good work team / *dobar radni tim* | 60 | 68 | **91** | 21 |
| 5 | Physical work demands / *fizički radni zahtjevi* | 7 | 14 | 0 | 17 |
| 6 | Certainty of job / *sigurnost posla* | **83** | **49** | **63** | **45** |
| 7 | Workplace communication / *komunikacija na radnomemjestu* | 25 | **44** | 39 | 32 |
| 8 | Company name / *naziv kompanije* | 27 | 28 | **53** | **60** |
| 9 | Possibility of applying own skills /*mogućnost primjene vlastitih vještina* | 15 | 0 | **56** | 16 |
| 10 | Performance and type of work / *ispunjenje i vrsta posla* | 10 | 17 | 7 | **39** |
| 11 | Familiarity with working results achieved / *upoznatost s postignutim rezultatima* | 8 | 36 | 18 | 19 |
| 12 | Working hours / *radno vrijeme* | 25 | **44** | 0 | **41** |
| 13 | Working environment / *radno okruženje* | 15 | 18 | 14 | 15 |
| 14 | Working process / *radni proces* | 20 | 20 | 14 | 25 |
| 15 | Work achievement / *radna postignuća* | 20 | 38 | 11 | **46** |
| 16 | Competence / *kompetentnost* | 12 | 38 | 18 | 17 |
| 17 | Prestige / *prestiž* | 0 | 0 | 0 | 0 |
| 18 | Access to superiors / *pristup nadređenima* | **52** | 40 | **74** | **43** |
| 19 | Psychological stress / *psihološki stres* | 0 | 0 | 4 | 0 |
| 20 | Independent decision-making / *neovisnost u donošenju odluka* | 17 | 31 | 32 | 33 |
| 21 | Self-realization / *samorealizacija* | 0 | 0 | 0 | 15 |
| 22 | Social benefits / *društvene povlastice* | 35 | 28 | 11 | 6 |
| 23 | Fair evaluation of employee / *poštena ocjena zaposlenika* | **57** | 25 | 7 | **36** |
| 24 | Recognition / *priznanje* | 12 | 6 | 0 | 3 |
| 25 | Company vision / *vizija poduzeća* | 5 | 10 | 0 | 16 |
| 26 | Leisure / *slobodno vrijeme* | 50 | 28 | 21 | 32 |
| 27 | Development region / *područje razvoja* | 7 | 0 | 0 | 7 |
| 28 | Learning and personal growth / *učenje i osobni razvoj* | 0 | 2 | 7 | 9 |
| 29 | Business relationship to environment / *poslovni odnos prema ekologiji* | 0 | 25 | 0 | 31 |
| 30 | Basic salary / *osnovna plaća* | **88** | **73** | **60** | **56** |

gement in relation with other areas of corporate governance. Current business environment and its existence are largely dependent on the use of all business activities, which are able to maintain the required market share while achieving the planned profit.

In the process of evaluation of sequence scores of motivational factors for workers it can be seen that there are more motivational factors, but their significance and importance between wood-working and other enterprises is however less different. In both types there are 2 main areas - financial (base salary and other monetary reward) and work (workplace atmosphere, good work team, access to supervisors). The evaluation of sequence scores of technical-economic employees shows big difference of significance and preferences of individual motivational factors.

To compare the importance of motivational factors in individual categories (technical-economic employees and workers), T-test was performed. It can be concluded from the results that the motivation profile of technical-economic employees in wood-working enterprises is based on relatively much less important factors (according to technical-economic employees many motivational factors were of little importance). Less important factors are less frequent and there are four factors (workplace atmosphere, good work team, access to superiors, certainty of job) consistently considered as highly important (see Table 2 and Figure 2).

**Table 2** Comparison of sequence scores of motivational factors of technical-economic employees
**Tablica 2.** Usporedba poretka bodova motivacijskih činitelja za tehničko-ekonomsko osoblje

| **Technical-economic employees** *Tehničko-ekonomsko osoblje* | **Other manufacturing enterprises** *Druga proizvodna poduzeća* | **Wood-working enterprises** *Drvnoprerađivačka poduzeća* | | |
|---|---|---|---|---|
| | $R_i$ | $Q_i$ | $R_i - Q_i$ | $(R_i - Q_i)^2$ |
| Workplace atmosphere / *atmosfera na radnome mjestu* | 13.5 | 30 | -16.5 | 272.25 |
| Workplace safety / *sigurnost na radnome mjestu* | 17 | 23 | -6 | 36.00 |
| Another monetary reward / *druga novčana naknada* | 26 | 20 | 6 | 36.00 |
| Good work team / *dobar radni tim* | 15 | 29 | -14 | 196.00 |
| Physical work demands / *fizički radni zahtjevi* | 11.5 | 4.5 | 7 | 49.00 |
| Certainty of job / *sigurnost posla* | 27 | 27 | 0 | 0.00 |
| Workplace communication *komunikacija na radnome mjestu* | 19.5 | 22 | -2.5 | 6.25 |
| Company name / *naziv kompanije* | 30 | 24 | 6 | 36.00 |
| Possibility of applying own skills *mogućnost primjene vlastitih vještina* | 9.5 | 25 | -15.5 | 240.25 |
| Performance and type of work / *ispunjenje i vrsta posla* | 23 | 11 | 12 | 144.00 |
| Familiarity with working results achieved *upoznatost s postignutim rezultatima* | 13.5 | 17.5 | -4 | 16.00 |
| Working hours / *radno vrijeme* | 24 | 4.5 | 19.5 | 380.25 |
| Working environment / *radno okruženje* | 7.5 | 15.5 | -8 | 64.00 |
| Working process / *radni proces* | 16 | 15.5 | 0.5 | 0.25 |
| Work achievement / *radna postignuća* | 28 | 13.5 | 14.5 | 210.25 |
| Competence / *kompetentnost* | 11.5 | 17.5 | -6 | 36.00 |
| Prestige / *prestiž* | 1.5 | 4.5 | -3 | 9.00 |
| Access to superiors / *pristup nadređenima* | 25 | 28 | -3 | 9.00 |
| Psychological stress / *psihološki stres* | 1.5 | 9 | -7.5 | 56.25 |
| Independent decision-making *neovisnost u donošenju odluka* | 21 | 21 | 0 | 0.00 |
| Self-realization / *samorealizacija* | 7.5 | 4.5 | 3 | 9.00 |
| Social benefits / *društvene povlastice* | 4 | 13.5 | -9.5 | 90.25 |
| Fair evaluation of employee *poštena ocjena zaposlenika* | 22 | 11 | 11 | 121.00 |
| Recognition / *priznanje* | 3 | 4.5 | -1.5 | 2.250 |
| Company vision / *vizija poduzeća* | 9.5 | 4.5 | 5 | 25.00 |
| Leisure / *slobodno vrijeme* | 19.5 | 19 | 0.5 | 0.25 |
| Development region / *područje razvoja* | 5 | 4.5 | 0.5 | 0.25 |
| Learning and personal growth / *učenje i osobni razvoj* | 6 | 11 | -5 | 25.00 |
| Business relationship to environment *poslovni odnos prema ekologiji* | 18 | 4.5 | 13.5 | 182.25 |
| Basic salary / *osnovna plaća* | 29 | 26 | 3 | 9.00 |
| | | | $\sum_{i=1}^{n}(R_i - Q_i)^2$ | 2261 |
| | | | $r_s$ | 0.497 |

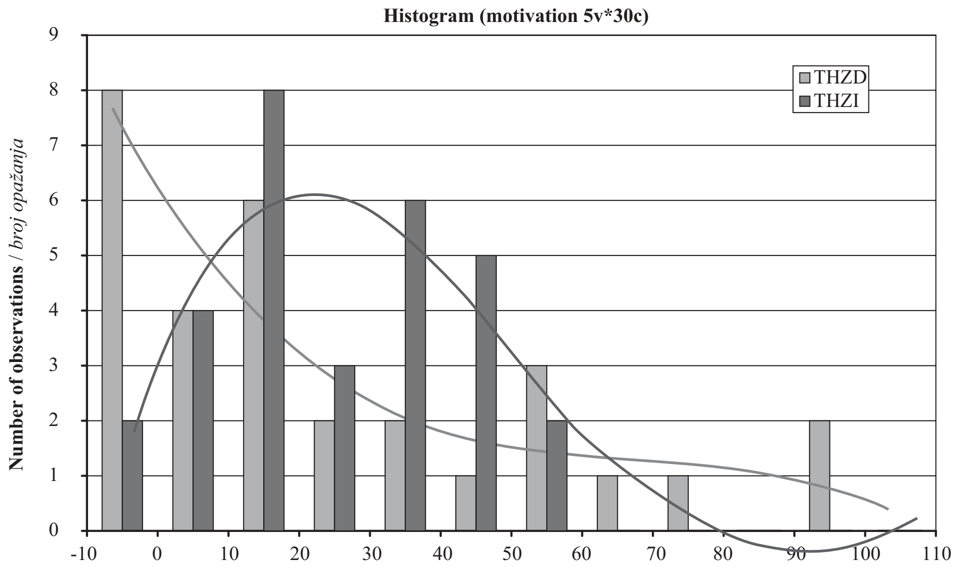


**Figure 1** Histogram comparing motivation of technical employees in wood processing (THZD) and other companies (THZI)
**Slika 1**. Histogram usporedbe motiviranosti tehničko-ekonomskog osoblja u drvno-prerađivačkim poduzećima (THZD) i drugim proizvodnim poduzećima (THZI)

For workers, the situation is similar, but differences in the frequency of occurrence of important motivational factors are smaller and generally more similar to the TH staff in woodworking business. The difference is seen in the fact that for workers in other enterprises the frequency of a few important factors was higher, and it was approximately the same as the frequency of the group of moderate factors and higher than the frequency of factor 2-3, rated as very important. Unlike other businesses, TH staff named two dominant motivational factors - job security and the basic salary (see Table 3 and Figure 2).

## 4 CONCLUSION
## 4. ZAKLJUČAK

The most important prerequisite for a long employment is satisfaction at work and employee willingness to understand the fact that the work performed is meaningful and significant for the enterprise, interesting, appropriately challenging and providing opportunities for personal development. If employees have prospects and specific opportunities for professional development and promotions based on the evaluation of the quantity and quality of work performed, a long

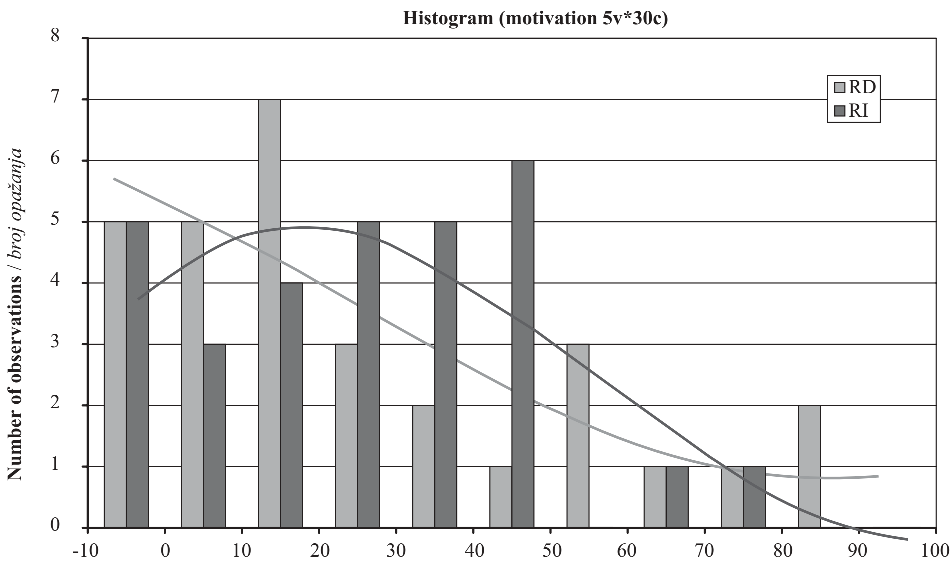


**Figure 2** Histogram comparing motivation of workers in wood processing (RD) and other companies (RI)
**Slika 2**. Histogram usporedbe motiviranosti radnika u drvnoprerađivačkim poduzećima (RD) i drugim proizvodnim poduzećima (RI)

**Table 3** Comparison of sequence scores of motivational factors of workers
**Tablica 3**. Usporedba poretka bodova motivacijskih činitelja za radnike

| **Workers** / *Radnici* | **Other manufacturing enterprises** *Druga proizvodna poduzeća* | **Wood-working enterprises** *Drvnoprerađivačka poduzeća* | | |
|---|---|---|---|---|
| | $R_i$ | $Q_i$ | $R_i$ - $Q_i$ | $(R_i - Q_i)^2$ |
| Workplace atmosphere / *atmosfera na radnome mjestu* | 25 | 27 | -2 | 4.00 |
| Workplace safety / *sigurnost na radnome mjestu* | 28 | 22 | 6 | 36.00 |
| Another monetary reward / *druga novčana naknada* | 26 | 28 | -2 | 4.00 |
| Good work team / *Dobar radni tim* | 29 | 26 | 3 | 9.00 |
| Physical work demands / *fizički radni zahtjevi* | 9 | 7.5 | 1.5 | 2.25 |
| Certainty of job / *sigurnost posla* | 27 | 29 | -2 | 4.00 |
| Workplace communication *komunikacija na radnome mjestu* | 23.5 | 18.5 | 5 | 25.00 |
| Company name / *naziv kompanije* | 16 | 20 | -4 | 16.00 |
| Possibility of applying own skills *mogućnost primjene vlastitih vještina* | 3 | 13.5 | -10.5 | 110.25 |
| Performance and type of work / *ispunjenje i vrsta posla* | 10 | 10 | 0 | 0.00 |
| Familiarity with working results achieved *upoznatost s postignutim rezultatima* | 19 | 9 | 10 | 100.00 |
| Working hours / *radno vrijeme* | 23.5 | 18.5 | 5 | 25.00 |
| Working environment / *radno okruženje* | 11 | 13.5 | -2.5 | 6.25 |
| Working process / *radni proces* | 12 | 16.5 | -4.5 | 20.25 |
| Work achievement / *radna postignuća* | 20.5 | 16.5 | 4 | 16.00 |
| Competence / *kompetentnost* | 20.5 | 11.5 | 9 | 81.00 |
| Prestige / *prestiž* | 3 | 3 | 0 | 0.00 |
| Access to superiors / *pristup nadređenima* | 22 | 24 | -2 | 4.00 |
| Psychological stress / *psihološki stres* | 3 | 3 | 0 | 0.00 |
| Independent decision-making *neovisnost u donošenju odluka* | 18 | 15 | 3 | 9.00 |
| Self-realization / *samorealizacija* | 3 | 3 | 0 | 0.00 |
| Social benefits / *društvene povlastice* | 16 | 21 | -5 | 25.00 |
| Fair evaluation of employee / *poštena ocjena zaposlenika* | 13.5 | 25 | -11.5 | 132.25 |
| Recognition / *priznanje* | 7 | 11.5 | -4.5 | 20.25 |
| Company vision / *vizija poduzeća* | 8 | 6 | 2 | 4.00 |
| Leisure / *slobodno vrijeme* | 16 | 23 | -7 | 49.00 |
| Development region / *područje razvoja* | 3 | 7.5 | -4.5 | 20.25 |
| Learning and personal growth / *učenje i osobni razvoj* | 6 | 3 | 3 | 9.00 |
| Business relationship to environment *poslovni odnos prema ekologiji* | 13.5 | 3 | 10.5 | 110.25 |
| Basic salary / *osnovna plaća* | 30 | 30 | 0 | 0.00 |
| | | | $\sum_{i=1}^{n}(R_i - Q_i)^2$ | 842 |
| | | | $r_s$ | 0.813 |

employment and good job performance can be expected from them. To maintain this situation, it is necessary to keep staff motivated. Since the development of motivation may be variable sometimes, it is necessary to keep the motivational needs of employees, to analyze them and, where appropriate, to introduce incentive programs to update the organization.

Analysis was carried out of motivational factors of workers that matched in a certain number of motivational factors for different groups of employees. The importance of motivational factors was then compared in each category (white-collar employees and workers). It can be concluded from the results that the technical-economic employees of woodworking enterprises have many factors with a relatively marginal importance, fewer medium significance factors and 4 highly relevant factors (workplace atmosphere, good work team, access to managers, job security). The technical-economic employees of other companies have underperforming factors with major and minor importance (most of the factors considered moderately important). An incentive program designed with the emphasis on a wider range of motivational factors would be more favorable for them. The workers showed smaller differences in the frequency of occurrence according to the importance of motivational factors. The difference is the increasing frequency of a few important factors, which has approximately the same frequency as a group of moderate factors and factors 2-3 rated as very important. In our analysis, it should be noted that in the long run staff should maintain their motivational needs. Based on the analysis of the company Slovak Power Plant, it can be concluded that a fundamental change in motivation occurred after five years in all job categories. This period may not be the same for other businesses. Based on experience, regular analysis of motivation is recommended in one year interval. For the sake of objectivity, analysis of motivational factors should be carried out systematically and the results obtained should be compared with the prospects of the enterprise performance and business objectives. Economic factors should be monitored for a long period of time (2-6 years), as well as the overall economic and social situation.

At the beginning of the research, we assumed that the reported motivation factors (financial motivational factors and job security) would be dominant for achieving good work results and that employees would be motivated in the process of Maslow's hierarchy of needs. After completing the analysis and summarizing the results, we can conclude that there is a high diversity of assumptions regarding motivational factors, the actually used motivational factors in businesses and the actual requirements of the analyzed groups of employees. The main difference is seen in the way of motivating the TH employees, where the dominant factors are the workplace atmosphere, good work team and access to superiors. The factor of job security has been clearly confirmed by our research. In the category of workers, the two main motivation factors are job security and the basic salary, which clearly confirmed our assumptions that these motivation factors should be used in enterprises to maintain the required performance of employees.

Finally, it is necessary to emphasize the need for continuous updating of incentive programs in accordance with the development of value orientated staff, which may vary, and to recommend the possibility of individualisation of the general incentive program with motivational factors related to self-realization and personal ambitions of individual employees or groups.

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# Determining the Characteristics of Composite Structure Laminae by Optical 3D Measurement of Deformation with Numerical Analysis

## Određivanje svojstava kompozitnih uslojenih konstrukcija optičkim 3D mjerenjem deformacija uz primjenu numeričkih analiza

**Original scientific paper • Izvorni znanstveni rad**
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**ABSTRACT •** *Experimental determination of the elastic constants of orthotropic composite materials and their bearing capacity (strength) for furniture intended for sitting, and numerical verification of the experiment results by analysing with the final elements, was performed on the basis of the theory of elasticity of orthotropic and anisotropic composite materials. The requisite and sufficient material constants were determined in the experiments: moduli of elasticity and Poisson's coefficients (longitudinal and tangential) and skate modulus for plain stress. These constants, calculated by 3D measurements of deformation, are sufficient for determining the constitutive matrix of the lamina, and for reducing stiffness of the composite irrespective of the thickness of the layers, fibre orientation and choice of material. Experiments were conducted for the stiffness, shear and flexing of uniformly and complexly layered beech veneer sheets, while for new materials experiments for stiffness and shear in a uniform orientation were sufficient.*

*Analysis of stiffness and deformations were conducted layer by layer, as well as by reduced volume stiffness for multi-layered orthotropic shells of chair systems by a method of final elements by application of a composite final element, where combined reduced membrane matrices and flexing matrices are used. Numerical verification of the experiments, including systems of furniture intended for sitting – chairs – was conducted using the KOMIPS software system, which contains in its library a composite final element of the sheet. Experiments with chairs were performed with the aim of determining the stiffness of such systems, and they were confirmed by analytical results and measurement of the real movements on selected models. The results of research provide the design, re-design, construction and determination of the dimensions of not just chairs, but also of any other girder or surface system based on laminates.*

***Keywords***: *optical 3D measurement, chair, shell, composite, material constants, stress, beech wood, finite elements*

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**SAŽETAK** • *Na temelju teorije elastičnosti ortotropnih i anizotropnih kompozitnih materijala eksperimentalno su određene elastične konstante i nosivost (čvrstoća) ortotropnih kompozitnih materijala za namještaj za sjedenje te je provedena numerička potvrda eksperimentalnih rezultata analizom uz primjenu konačnih elemenata. U radu su određene ove konstante materijala: modul elastičnosti i Poissonov koeficijent (uzdužni i tangencijalni) te klizni modul za naprezanje u ravnini. Te konstante, izračunane na temelju 3D mjerenja deformacija, dovoljne su za određivanje konstitutivnih matrica uslojenog drva i za smanjenje krutosti kompozita, bez obzira na debljinu slojeva, orijentaciju vlakanaca i odabrani materijal. Na uzorcima od uslojenih podjednakih bukovih furnira provedena su eksperimentalna mjerenja krutosti, čvrstoće smicanja i savijanja, iako su za nove materijale dovoljna samo ispitivanja krutosti i smicajne čvrstoće u istom smjeru.*

*Analiza krutosti i deformacija napravljena je sloj po sloj, kao i za smanjenu volumnu krutost višeslojnih ortotropnih ploča za stolce, metodom konačnih elemenata, uz primjenu kompozitnoga konačnog elementa, pri čemu se primijenjuje kombinacija reduciranih membranskih matrica i matrica savijanja. Numerička potvrda rezultata eksperimenta, uključujući sustav namještaja za sjedenje – stolce – provedena je primjenom softvera KOMIPS, koji u svojoj zbirci ima kompozitni konačni element za ploče. Eksperiment sa stolcima proveden je radi određivanja krutosti takvog sustava te je potvrđen analitičkim rezultatima i mjerenjima stvarnih pomaka na izabranim modelima. Rezultati istraživanja omogućuju dizajn, redizajn, konstruiranje i određivanje dimenzija ne samo stolaca nego i drugih nosača ili površina utemeljenih na uslojenom drvu.*

***Ključne riječi***: *optičko 3D mjerenje, stolac, kompoziti, konstante materijala, naprezanje, bukovina, konačni elementi*

## 1 INTRODUCTION
1. UVOD

Research into the possibilities of rational exploitation of wood demands constant study of the properties of wood, wood products and new materials used as substitutes for wood in certain areas. Wood has excellent aesthetic and constructive properties, ensuring its superiority in many fields of application. However, wood does have some unfavourable properties limiting its use in certain fields of exploitation. For instance, wood has different (anisotropic) properties in different orientations and poor durability in conditions of variable moisture. These shortcomings of wood call for a permanent search for technological and engineering solutions that would provide a reduction of wood anisotropy and an increase in its durability. Development of composites based on wood made of veneer sheets creates a possibility of a considerable reduction in the natural anisotropy of wood. Further research of possibilities of expanding the use of veneer and the employment of certain advantages of veneer slabs have led to considerable use of veneer in the manufacture of furniture made of laminated wood. Laminated wood is a product made of several sheets of veneer glued together and i tused for diverse construction needs and shaped differently. Thin veneer sheets are pressed together for an exactly defined period of time, pressure and temperature. Finished in this way, laminates can be used for various constructions, in particular the manufacture of laminated constructive elements in furniture-making. The types of wood used, veneer thickness, manner of layering, regimes of pressing and processing are factors which considerably affect the mechanical properties of the laminate, therefore also laminated bearings as a product.

Veneer sheets are made of at least three layers (laminae) of veneer, with alternating sheets grain at right angles, and layered sheets are made of several sheets (laminae) of veneer, their fibres running in the same direction.

Construction of chairs can be viewed according to a number of criteria. Viewed by the type of manufacture, chairs can be made of pure wood, layered wood, or a combination of the two, or may be woven, metal or plastic. By the manufacturing technology, chairs are divided into prototypes, series-production units of mass production units. Chairs may be used for residential or public buildings. They can be used at work or for relaxation, when due to altered functional measures they become semi-armchairs, or full armchairs. Initially people sat on stools, chairs that had no back. When a backrest and armrests were added to anatomically properly designed chairs, the feeling of comfort was considerably enhanced. Irrespective of the material of which they are made, problems in the manufacture of chairs may be complex. Industrial production of veneers was first mentioned in 1885 as peeled veneer. In 1834 Frenchman Charles Pikot patented a veneer-cutting machine, but it was first used in 1860. The invention of a wood-peeling machine by Garant in 1944 enabled the rapid rise of manufacture of plywood, where peeled veneers are mainly used, as the so-called blind veneers, which when glued together form plywood. Like all new products, plywood initially did not sell well. The decisive role in increasing the use of plywood, as in the case of chipboards and fibreboards nowadays, was played by the technology of manufacturing furniture. The development of plywood particularly increased the value of beech wood, which had generally only been used as firewood. Owing to its sensitivity to drying and motivated by research in the U.S.A. for different industrial purposes, B. Hausmann made a significant contribution to the use of beech wood for blind veneers around 1910 by constructing an artificial drying facility with an endless fabric loop for the requirements of veneers.

### 1.1 Historical overview
1.1. Povijesni pregled

Industrial development at the end of the 19$^{th}$ century, and particularly the start of the 20th, with new engineering solutions and the invention of the motorcar, led to chairs acquiring revolutionary new forms. A contribution to this was made by new materials and the enthusiasm of people who desired a maximum level of comfort in their cars, and chairs became a new challenge, wherever they were used. Particularly prominent were flexed solid-wood and veneer-sheet forms, as well as upholstered furniture. Veneer laminate plates were first made in 1850 as combinations of three or more veneer laminas, with the grain orientations alternating by $90^0$ to make the plate harder. The manufacture was developed by German American John Brlter, who succeeded in bending the plates along all three axes, using heat. Others commercialised the process, while more serious experiments with the plates were performed by Michael Thonet in 1880. Although known more for his invention of making furniture by bending steamed wood, Thonet is mentioned by most of the $20^{th}$ century Modernists as influencing them in respect of work with laminated plates. Production of the material, its flexibility and durability were perfected during the First World War by way of widespread use in the manufacturing industries. When the avant-garde architects and designers of the 1920s looked into the possibility of manufacturing cheap mass-produced furniture, veneer laminate plate seemed the ideal solution. The first breakthrough was made in 1918 by the famous Dutch designer, Gerrit Thomas Rietveld, who used a piece of the laminate as the seat in his famous Red and Blue chair (Figure 1).

The construction of the chair is clearly defined by standardised wood elements, which interfuse and overlap mutually. The three decades that followed were marked by numerous now classical designs in which this material was used.

World-famous Finnish Modernist architect Alvar Aalto was a leading force in the design of veneer-plate furniture. Thanks to his constructive genius and the opportunities for widespread use of the material, Aalto founded an experimental workshop in 1929. Together with his wife Aino, Alvar manufactured prototypes and conducted tests for four years, leading to the first-ever elastic chair with a back in 1930, the "Pamio" (Figure 2).

While Aalto was initiating his wood laminate experiments in Finland, Marcel Breuer, who had already lectured at the Bauhaus, travelled to London early in 1930 and was employed by *Isokon*, who specialised in veneer laminate furniture. Breuer designed one-piece shaped veneer laminate furniture as seen in Figure 3 around 1935.

**Figure 2** Console chair with backrest, 1930
**Slika 2.** Konzolni stolac s naslonom, 1930.

New materials took over in the 1960s and 1970s, but veneer laminates made their comeback in 1988, when British designer Jasper Morisson formed his sleek veneer plate chair for the Berlin Exhibition which he left 'half-finished' with visible cut-outs of the plate, and which was later produced by *Vitra*. From the 1990s veneer sheets have again been a favourite of designers and manufacturers. In the past two decades veneer laminate furniture pieces have appeared and by their technological and design quality they represent the continuation of the foundation laid in the 1930s and lasting until the late 1950s in furniture veneer laminate furniture design.

Frank O. Gehery 'Cross Check' chair, designed by the architect in the period 1989-92, is perhaps the best known for its radical organic design. Gehery experimented for three years on laminate wooden structures with the famous firm *Knoll*.

In designing the chair, the objective was to make use of the structural characteristics and flexibility of the laminate ribbons so as to make from them every part of the chair. The ribbons are interwoven, reminiscent of wickerwork, only on a much larger scale. The chair is structurally stable, flexible and durable, visually very powerful and recognisable (Figure 4).

Finally, the seating furniture with which we are entering the $21^{st}$ century is best promoted by the Azumi team, who designed in 2002 a bench for the Italian ma-

**Figure 1** "Roodblauwe" chair, with backrest, 1918
**Slika 1.** Stolac *Roodblauwe* s naslonom, 1918.

**Figure 3** 'Organic armchair', 1935
**Slika 3**. Organski naslonjač, 1935.

**Figure 4** 'Gehery Cross Check' chair, 1992
**Slika 4.** Stolac *Gehery Cross Check*, 1992.

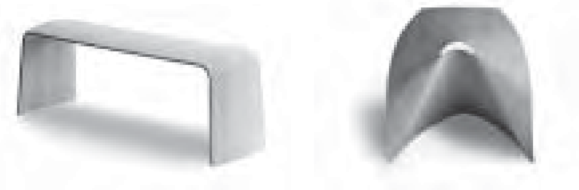


**Figure 5** 'Volta' bench and 'AP' backless chair, 2002
**Slika 5**. Klupa *Volta* i stolac *AP*, 2002.

nufacturer *La palma* made of a single piece of veneer laminate, bent along all three axes and 120 cm long with no extra supports, capable of seating two or three persons, as well as a backless chair (Figure 5). The two pieces shown represent a major design challenge in the application of new technologies.

### 1.2 An overview of research and experiences
1.2. Pregled istraživanja i iskustava

Solid-wood chairs have been the subject of research of many authors, who generaly focused on their dimensioning and constructional joints. C.A. Eckerman analysed the bearing strength of joints in 1966. Tkalec and Prekrat (1997) investigated various joining methods in chairs made of pine and beech. The experimental results showed that the same joints cannot be used with equal success for different types of wood. Gustafsson (1999) introduced the application of final elements in chairs and latticework furniture, with an accent on determination of input parameters of elasticity modules and Poisson numbers. Skakić and Janićijević (2000) researched the strength of chairs in the lateral apron - rear leg joints. Together with a theoretical analysis, by applying final elements and experiments, Smardzewski and Papuga (2004), determined stress and critical spots on the example of a chair in exploitation. Vlaović *et al*. (2010) looked into deformation and the seating comfort index proceeding from the mechanical properties of a chair researched. The influence of shear components on the magnitude of stress in the stretching loads of a seven-lamina veneer sheet were researched by Kljak and Brezović (2007) on standard parallel and cross-layered veneer test-tubes. In the cross-layering veneer, the concentration of the stress was in the section of the test-tube between its wider and narrower parts.

In view of the foregoing, the objective of this paper is to establish the material characteristics of veneer lamina determined by optical 3D measurement of deformations sufficient for determining the rigidity of any veneer laminate (irrespective of fiber orientation and layer thickness). By calculating the rigidity of concrete composites in this manner, a stress deformation analysis can be performed of any chair by introducing reduced membrane stress and bending elasticity matrices.

## 2. MATERIAL AND METHODS
2. MATERIJAL I METODE

### 2.1 Determination of the requisite parameters for calculating rigidity and stress in wood laminate structures
2.1. Određivanje parametara potrebnih za izračun krutosti i naprezanja u drvenim uslojenim konstrukcijama

The stress-deformation and the inverse deformation-stress relationships of anisotropic material bodies made of laminated wood is shown by a theoretical concept which will not be discussed in this paper. We will deal with defining a composite material model made of wood based on experimental determination of its material constants. The work was conceived so that on the basis of established models of standard methods of testing composite materials an experimental determination of stretching and shearing properties is performed, as well as the flexing properties of composite wood laminates. The influence of the manner of positioning the wood fibres in composite wood laminates was assessed in respect of several aspects, which fully describe the behaviour under static load action.

### 2.2 The experimental part
2.2. Eksperimentalni dio

The experimental work was focused on two types of laminates from which nine groups of test-tubes were extracted for determining the mechanical properties of the wood laminates. There is insufficient data for a complex and uniform stacking of veneer sheets on the basis of the experiments performed to determine all the properties of beech laminates, which include its orthotropicness similar to solid wood. The material characteristics include determination of three moduli of elasticity, three moduli of shear and three Poisson's coefficients. As regards the subject covered here, we may say that seating furniture – the chairs on which we spend long periods of our lives and which differ according to the place of their use, the materials of which they are made, their construction and the technology of manufacture – are not easy to produce. Design, engineering and manufacturing technology participate in an equal degree in the creation of a new product. Harmonising the three and ensuring the best possible economics always results in the best possible solution.

### 2.3 Determining the mechanical properties of wood laminates by tensometry
2.3. Određivanje mehaničkih svojstava drvenih uslojenih materijala tenzometrijom

The mechanical properties of wood (veneer) laminates were determined using appropriate test-tubes extracted from laminates where veneer sheets were layered in a complex manner (crossed fibres) - P1 (Figure 6) and uniform (parallel fibres) - P2, (Figure 7).

Based on the experimental results the constitutive matrix of elasticity equals

$$Q = \begin{bmatrix} \dfrac{E_x}{(1-\nu_{xy}\nu_{yx})} & \dfrac{\nu_{xy}E_y}{(1-\nu_{xy}\nu_{yx})} & 0 \\ \dfrac{\nu_{yx}E_x}{(1-\nu_{xy}\nu_{yx})} & \dfrac{E_y}{(1-\nu_{xy}\nu_{yx})} & 0 \\ 0 & 0 & G_{xy} \end{bmatrix} = \begin{bmatrix} 17.648 & 0.9726 & 0 \\ 0.9726 & 2.136 & 0 \\ 0 & 0 & 1045 \end{bmatrix} \times 10^3\, MPa$$

where the material constants of the analysis composites have the following values (Nestorović, 2010).

$E_x$=17190 $E_y$=2078 $G_{xy}$=1145 MPa $v_{xy}$=0,456 $v_{yx}$=0,0565

The above values were used in specific numerical analyses of the chair system.

### 2.4 Determining the properties of laminae by optical 3D measurement of deformation
### 2.4. Određivanje svojstava uslojenog drva optičkim 3D mjerenjem deformacija

Sufficiently accurate measurement of stress and deformations in elements of laminates – wood-based laminae – is an area that can be upgraded by modern technological methods of measurement such as optical 3D measurements of deformations and the application of measuring ribbons that contain optical fibres on one or more laminated veneer sheets.

This method was used to verify the elasticity moduli calculated by experimental research using the tubes with uniform veneer stacking, by way of the testing of one lamina made of beech veneer with parallel fibre orientation.

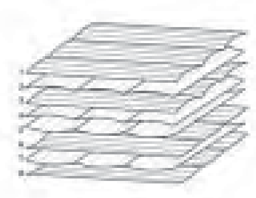


**Figure 6** P1 sheet – complex layering of veneer sheets
**Slika 6**. Ploča P1 – složeno uslojavanje listova furnira

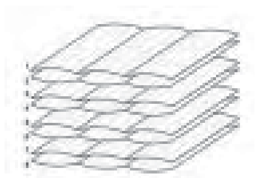


**Figure 7** P2 sheet – uniform layering of veneer sheets
**Slika 7**. Ploča P2 – jednolično uslojavanje listova furnira

### 2.5 Equipment for testing optical 3D measurements of deformation
### 2.5. Oprema za optičko 3D mjerenje deformacija

This paper describes the experiment and the numerical methodology of analysing the characteristics of plastic deformations, representative for their rigidity in real time. The equipment used for the experiments included German-made ‘GOM’ 3D optics (Figure 8) and ‘ARAMIS’ software. The numerical analysis was performed with software that applies the method of final elements. The main question that needs to be answered is connected to the breaking point of the lamina under test (Figure 10) – does the deformation precede the plastic behaviour, or vice versa? This paper will show how the results of the experiment can be predicted using the method of final elements; this is regarded as a very reliable supporting tool that will help designers improve the structural rigidity of future products. Experimental and numerical analyses conducted so far exhibit a high degree of correlation. The intention was to emphasise the advantages of using modern optical 3D measurement of deformations in identifying the effects of deformations resulting from various stresses. The equipment consists of two mobile optical digital stereo cameras for determining the re-distribution of deformations caused by static and dynamic loads.

ARAMIS analyses, calculates and records deformations of sections, or of the entire structure.

Fields of application of the measuring equipment are as follows:

- Detection of 3D deformations, shifts and vibrations
- Measurement of dynamic behaviour up to 25 Hz
- Linear and non-linear behaviour of viscous-elastic materials
- Creep testing and testing the effects of ageing of complex structures

Based on diagrams establishing an interdependence of the distances between the points of measurement, *L*, and the force, *F*, as well as time, the elasticity modulus of the lamina is determined. Taking the value noted in status 1 (linear status) of *L*=114.027 mm, and the force *F*=200 N (Figure 9), for the dilatation stress, the following values can be calculated:

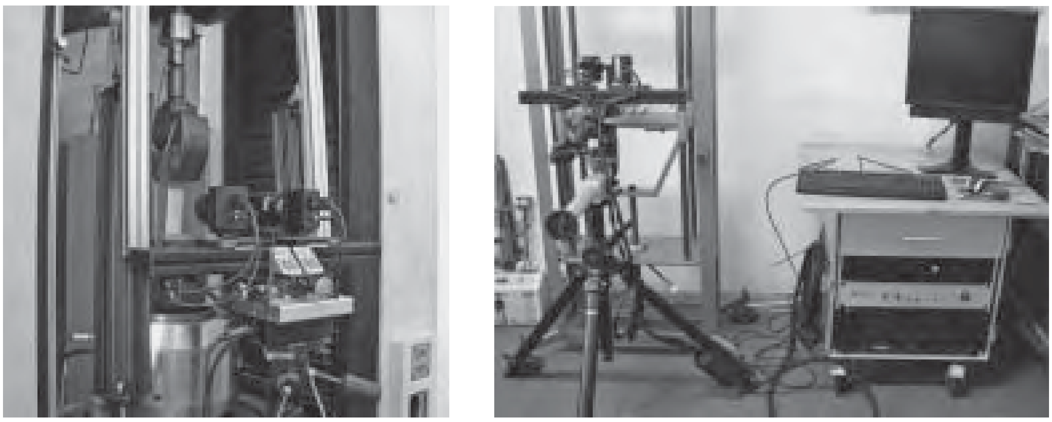


**Figure 8** Optical 3D static measurement of deformations
**Slika 8.** Optičko 3D statičko mjerenje deformacija

$$\varepsilon = \frac{L - L_0}{L_0} = \frac{114.027 - 113.996}{113.996} = 0.00027194$$

$$\sigma = \frac{F}{b \cdot d} = \frac{200}{29 \cdot 1.5} = 4.5977\,MPa$$

from which the following result for the elasticity modulus $E_x$ (only in longitudinal direction) is obtained

$$E_x = \frac{4.5977}{0.00027194} = 16.907 \text{ GPa} \approx 17.0 \text{ GPa}$$

which was confirmed in practice by experiments on uniform-orientation lamina test-tubes using tensometry. This experiment is currently the most advanced type for determining the properties of test materials in a relatively simple manner, and replaces complex experiments that use measuring ribbons.

The software package for analysing laminated structures. Stress-deformation analysis of the construction of chairs was conducted using the KOMIPS ('Computer Modelling and Calculation of Structures') software developed by dr. Taško Maneski (Maneski, 1998): This programme system, based on the method of final elements, possesses an extensive library of elements, from one-dimensional all the way to general three-dimensional elements, providing a possibility of modelling the geometry and physical discretisation of very complex structures. The software system has a pre-processor and a post-processor, enabling the user to make simple description and control of geometry and the analysis of the results achieved. In respect of the number of final elements, degrees of freedom and stress, KOMIPS has no limitations.

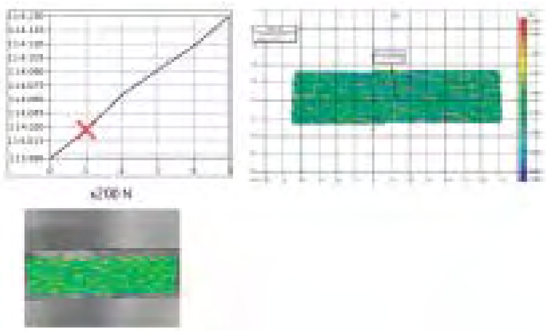


Figure 9 Graphic presentation of momentary stress of a lamina acted on by a force of 200 N
**Slika 9.** Grafički prikaz kratkotrajnog naprezanja uslojenog materijala pod utjecajem sile od 200 N

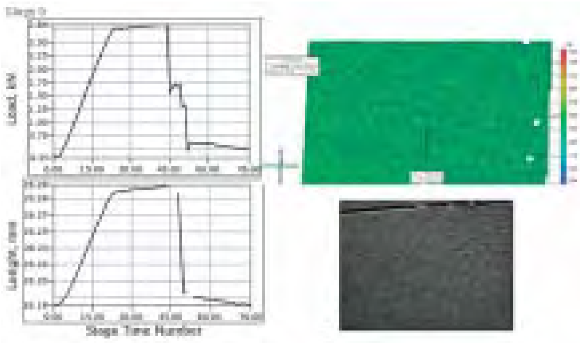


**Figure 10** Diagrams of the flow of force (kN) and elongation (mm) in stretching test-tubes until the breaking point
**Slika 10**. Dijagram kretanja sile (kN) i produljenja (mm) tijekom testa istezanja do trenutka loma

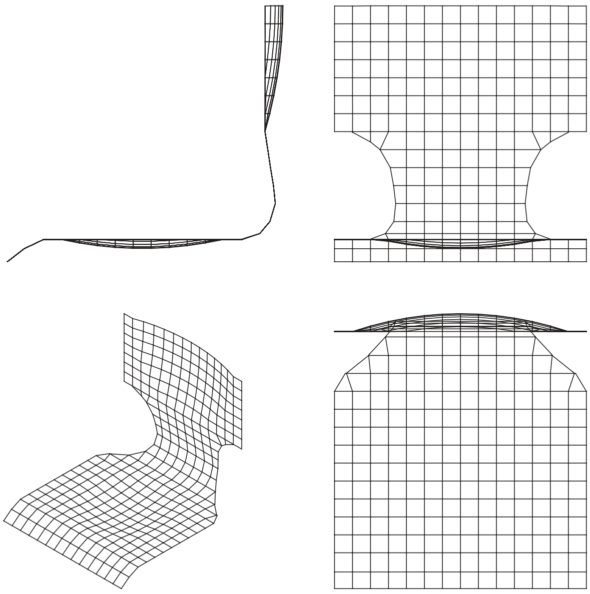


**Figure 11** A freely formed shell
**Slika 11.** Slobodno oblikovana ljuska

## 3 RESULTS AND DISCUSSION
## 3. REZULTATI I RASPRAVA

This paper is especially focused on the final element of the laminate, given that it represents the basis for all our numerical analyses. Calculating the stiffness matrix of the laminate final element calls for volume integration. The problem of volume integration can be translated into integration by the area of the final element by introducing the so-called reduced stiffness of the laminate, which makes the procedure of formulating the stiffness matrix more efficient and identical to the classical plate theory. For those reasons a new subroutine was developed in the software used to calculate the reduced stiffness of the laminate.

### 3.1 Numerical analysis of laminated wooden structures by using the final elements method
### 3.1. Numerička analiza uslojene drvne konstrukcije primjenom metode konačnih elemenata

Differential equations of plate membrane stress and flexing are well-known. Integration of these equations, i.e., development of an analytical solution, for arbitrary geometry and arbitrary marginal conditions in a general case, is not possible. This problem was also overcome long ago by the development of a method of mathematical and physical discretisation.

Wooden structures laminated geometrically of a geometrically freely shaped shell with axonometric projection are given in Figure 11. Load and deformation of freely formed shell is shown in Figure 12. The results of stress deformation analysis for the adopted network of final elements by applying reduced stiffness are presented graphically in Figure 13.

### 3.2 Properties of the layers
3.2. Svojstva slojeva

Composite $t$ = 8 x 1.0 = 8.0 mm   0/90/0/0 / 0/0/90/0 (orientation of the laminae in the laminated plate)

| *H1* | *H2* | *Q11* | *Q12* | *Q16* | *Q22* | *Q26* | *Q66* | *Theta* |
|---|---|---|---|---|---|---|---|---|
| 4.0 | 3.0 | 1.77E+04 | 9.73E+02 | 0.00E+00 | 2.19E+03 | 0.00E+00 | 1.05E+03 | 0.00E+00 |
| 3.0 | 2.0 | 2.19E+03 | 9.73E+02 | 0.00E+00 | 1.77E+04 | 0.00E+00 | 1.05E+03 | 9.00E+01 |
| 2.0 | 1.0 | 1.77E+04 | 9.73E+02 | 0.00E+00 | 2.19E+03 | 0.00E+00 | 1.05E+03 | 0.00E+00 |
| 1.0 | .0 | 1.77E+04 | 9.73E+02 | 0.00E+00 | 2.19E+03 | 0.00E+00 | 1.05E+03 | 0.00E+00 |
| .0 | -1.0 | 1.77E+04 | 9.73E+02 | 0.00E+00 | 2.19E+03 | 0.00E+00 | 1.05E+03 | 0.00E+00 |
| -1.0 | -2.0 | 1.77E+04 | 9.73E+02 | 0.00E+00 | 2.19E+03 | 0.00E+00 | 1.05E+03 | 0.00E+00 |
| -2.0 | -3.0 | 2.19E+03 | 9.73E+02 | 0.00E+00 | 1.77E+04 | 0.00E+00 | 1.05E+03 | 9.00E+01 |
| -3.0 | -4.0 | 1.77E+04 | 9.73E+02 | 0.00E+00 | 2.19E+03 | 0.00E+00 | 1.05E+03 | 0.00E+00 |

*H1*, *H2* (mm) – top and botom surface of laminate, *Q*ij (kN/cm$^2$) – 2D stress state elastisity matrix of laminate, *Theta* (°) – angle of the main stress direction.

### 3.3. Reduced elasticity matrices of laminates
3.3. Reducirane elastične matrice uslojenog materijala

| | 1,1 | 1,2 | 1,6 | 2,2 | 2,6 | 6,6 |
|---|---|---|---|---|---|---|
| *QA(i,j)* | 1.3789E+04 | 9.7300E+02 | 0.0000E+00 | 6.0590E+03 | 0.0000E+00 | 1.0450E+03 |
| *QB(i,j)* | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 | 0.0000E+00 |
| *QD(i,j)* | 1.3064E+04 | 9.7300E+02 | 0.0000E+00 | 6.7837E+03 | 0.0000E+00 | 1.0450E+03 |

Where *QA(i, j)*, *QD(i, j)*, *QB(i, j)* (kN/cm$^2$) – are elements of membrane, bending and coupled reduced laminate elasticity matrices, respectively.

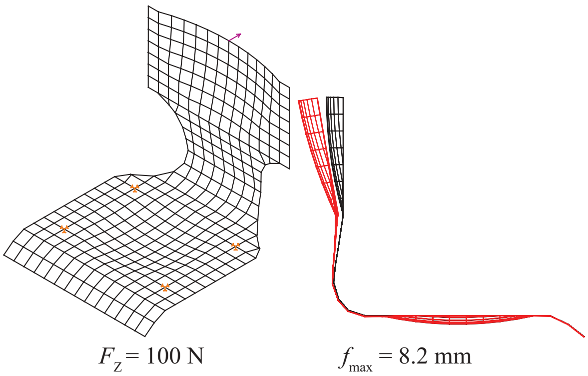



**Figure 12** Load and deformation of freely formed shell
**Slika 12**. Opterećenje i deformacija slobodno oblikovane ljuske

Measurement of the flexing of the back of the laminated freely formed shall was performed experimentally. An angle of $f_{max}$ = 8.3 mm was calculated at a force of 100 N, and 21 mm at a force of 250 N. It should be noted that the numerical values of the flexing exhibit very good correlation with experimental values (Figure 14). It may be concluded that an increased concentration of stress has taken place on the radius of the back. The concentration of stress would probably be reduced by a less pronounced radius (Figure 13). Flexing and forces were measured on the back of a freely formed shell, at its highest point. The flexing was measured by German-made FLUKE 416D laser equipment, which has an accuracy of 1 mm. Force was measured using a Taiwan-made FORCE GAUGE FG – 5100 dynamometer, with an accuracy of 1 N and a measurement range of 0 to 1500 N.

Figure 15 shows changes of normal stresses according to the thickness of laminate for the case of the true stiffness of the laminate (solid line) and reduced stiffness of the laminate (dotted line) for the case of a composite plate (Figure 15). It may be concluded that

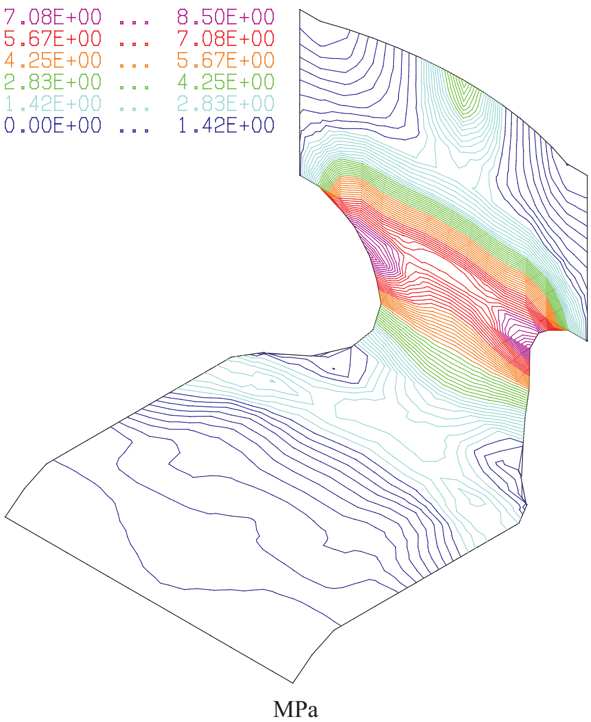
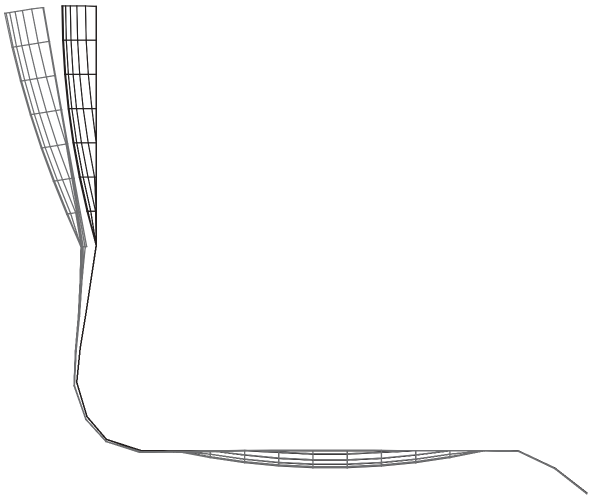



**Figure 13** Stress field (Von Measses) of freely formed shell by applying reduced stiffness
**Slika 13**. Polja naprezanja (Von Measses) slobodno oblikovane ljuske primjenom reducirane krutosti

for both diagrams the same areas are formed of reduced (dotted line) and non-reduced (full line) stiffness, leading to identical (corresponding) results.

## 4 CONCLUSIONS
4. ZAKLJUČCI

Beech wood veneer may be used with arbitrary layering to form various composites, of which different pieces of furniture for sitting can be made of freely-formed shape.



$f_{max}$ = 8.8 mm

**Figure 14** Deformation of freely formed shell by applying reduced stiffness
**Slika 14**. Deformacija slobodno oblikovane ljuske primjenom reducirane krutosti

**Tension** / *Naprezanje*, MPa

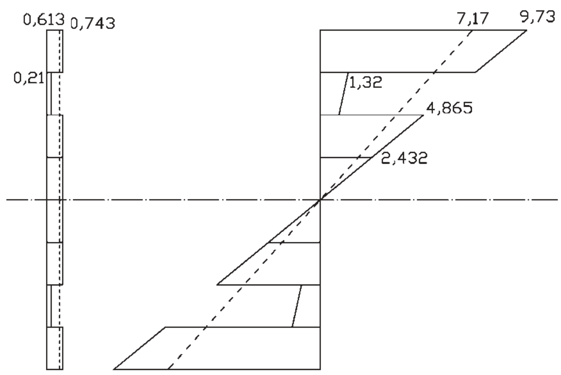



**Figure 15** Changes of normal stresses by laminate thickness for reduced and non-reduced plates
**Slika 15**. Promjene normalnih naprezanja po debljini uslojenog materijala za reducirane i nereducirane ploče

The material properties of veneer laminae determined by optical 3D measurement of deformations are sufficient to calculate the stiffness of any veneer laminate (irrespective of fibres orientation and layers thickness). This measurement efficiently replaces complex and expensive deformation measurement by tensometric method.

Having calculated the stiffness of concrete composites in this way, by introducing reduced elasticity matrices of membrane stress and flexing (Figure 16), the stress deformation analysis can be performed of any chair, using an appropriate software package.

On the basis of the foregoing, a pragmatic example could be that of a reclining 'Savannah Rocker III' chair manufactured in 2009 (Figure 17) by British designer Jolyon Yates. The chair is made of uniform beech laminate and has dimensions of 990 mm x 520 mm x 990 mm.

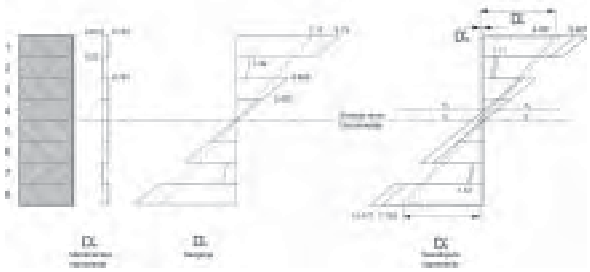


**Figure 16** Reduced stresses
**Slika 16.** Smanjena naprezanja

**Figure 17** Freely formed chair of uniform laminate
**Slika 17**. Slobodno oblikovani stolac od jednolično uslojenog drva

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*Richard P. Vlosky*[1]

# A Comparison of the Primary and Secondary Wood Products Sectors in Louisiana

## Usporedba primarnoga i sekundarnog sektora drvnih proizvoda u državi Louisiani

**Original scientific paper • Izvorni znanstveni rad**
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**ABSTRACT •** *As part of an ongoing research program, the Louisiana forest products industry is surveyed every five years to identify salient issues, challenges, and opportunities. In this paper, we compare the results from two studies conducted on the primary and secondary sectors in Louisiana. In the past, we produced two papers based on research results, one for the primary and one for the secondary sector. However, this paper compares the answers to questions asked in both surveys. Louisiana's forests represent an important resource for the state, both in terms of income to landowners and as inputs to the forest products industry. Both primary and secondary respondents indicate an interest in increasing their workforce in the next five years. The issues that drive the company expansion fall into four areas: the overall attractiveness of the business climate of the community and state, labor productivity, costs and supply, and financing. The results of this study can be used by Louisiana industry members in the primary and secondary sectors to identify common challenges, opportunities and issues that promote or hinder sector development. Policymakers can work more efficiently with industry members where commonalities exist. Understanding the markets, plant location decisions, raw material availability, workforce training needs, and other issues can be a source of competitive advantage for Louisiana manufacturers.*

***Keywords:*** *wood products, Louisiana, United States, primary products, secondary products*

**SAŽETAK •** *Industrija šumskih proizvoda u Louisiani prati se u sklopu tekućega istraživačkog programa i u njoj se svakih pet godina provodi anketa da bi se ustanovili aktualni problemi, izazovi i mogućnosti. U radu se uspoređuju rezultati dvaju uzastopnih istraživanja primarnoga i sekundarnog sektora drvnih proizvoda u Louisiani. Do sada su već napisana dva članka o rezultatima tih istraživanja, jedan o primarnom sektoru i jedan o sekundarnome. U ovom radu uspoređuju se odgovori na zajednička pitanja iz oba istraživanja. Šume u Louisiani važan su državni resurs u smislu prihoda zemljoposjednika i u smislu ulazne sirovine za industriju drvnih proizvoda. Ispitanici i u primarnome i sekundarnom sektoru pokazuju zanimanje za povećanje broja zaposlenih u sljedećih pet godina. Činitelji koji pokreću povećanje poduzeća pripadaju jednoj od četiri skupine: sveobuhvatnoj privlačnosti poslovne klime u društvu i državi, produktivnosti rada, troškovima i nabavi, financiranju. Rezultatima ove studije mogu se koristiti članovi primarnoga i sekundarnog sektora drvnih proizvoda u Louisiani da bi usta-*

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*novili izazove, mogućnosti i probleme koji promoviraju ili sprječavaju razvoj sektora. Političke se odluke mogu donositi mnogo učinkovitije u suradnji s predstavnicima struke ako postoje zajednički interesi. Poznavanje tržišta, odluke o lokaciji tvornica, dostupnost sirovina, obučavanje radne snage i druga pitanja mogu biti izvor kompetetivnih prednosti prozvođača u Lousiani.*

***Ključne riječi***: *drvni proizvodi, Louisiana, Sjedinjene Države, primarni proizvodi, sekundarni proizvodi*

## 1 INTRODUCTION
1. UVOD

"Lumber industry hit hard" was the caption in The Baton Rouge Advocate, daily newspaper (Calder 2008). It was referring to the housing slump that saw the lowest number of new housing starts since 1959 (US Census Bureau 2008). Housing is a major driving force of wood markets where 70 percent of wood building materials, primarily softwood lumber and structural panels, are used in residential construction including both new construction and remodeling (UNECE/FAO 2008). With such a downturn in the housing industry, production and prices of wood building materials have collapsed. According to Random Lengths (2009), overall softwood production was down 27 percent in 2008 compared to 2005, and prices for framing lumber were down 38 percent from their 2004 peak. Panel production suffered similar market turns, dropping 25 percent from 2005 and composite structural panel prices plunged 37 percent from 2004 (Random Lengths 2009). As of early 2009, prices have been even weaker and many mills are curtailing production and/or downsizing (IBIS World 2009, Wood Digest 2008).

In August 2005, two Category 5 hurricanes hit the Gulf Coast of the United States. Hurricane Katrina made landfall with a direct hit to New Orleans causing catastrophic levee failure and widespread flooding. One month later, Hurricane Rita hit the West Louisiana/East Texas border. Combined, they damaged over 4.4 billion board feet of standing timber and wiped out the equivalent of more than two years' worth of pine sawtimber harvest and more than 11 years' worth of hardwood sawtimber harvest for the entire state (Chang, 2006). The closest timber loss Louisiana faced, up to then, was the southern pine beetle outbreaks of 1985-86, with a loss of 1.1 billion board feet (Mistretta and Bylin, 1987). In this paper, we present a brief history of the forest sector in Louisiana and then discuss the results of a study which offers a perspective on the state of the forest products industry in Louisiana three years after the hurricanes hit the state.

### 1.1 Louisiana's forest products industry
1.1. Industrija šumskih proizvoda u Louisiani

The development of the lumber industry in Louisiana began in the period following the Civil War. There was a great demand for lumber to rebuild the war-torn areas of the South as well as to supply the industrial revolution taking place in the North (Maxwell, 1973; Quarterman and Keever, 1962; Foster, 1912). Longleaf yellow pine was abundant throughout the state. The chief demand for lumber was for construction, telegraph poles, railroad ties, and furniture manufacturing (Maxwell, 1973). In addition to pine, Louisiana sawmills also cut oak, ash, gum, and cypress as well as many other woods. The milling of cypress had significant economic importance to the southeastern region of the state, where it was used principally for manufacturing of shingles and cisterns (Kellogg, 1909).

Forests cover 13.5 million acres or 48 percent of Louisiana with pine accounting for 52 percent and hardwoods for 48 percent (LFA 2008). Forests and forestry are an important part of Louisiana's history, culture and economy. Although Louisiana forests are almost evenly divided between pine and hardwoods, approximately six times more softwood is harvested annually than hardwood (LDAF 2007). In 2006, the output of softwood roundwood products totaled 712 million cubic feet, while the output of hardwood roundwood products was 175 million cubic feet (SRS 2007).

Over the past decade, forestry has been Louisiana's number one agricultural crop, generating $3.3 billion in farm gate value and value-added revenue in 2008 (LSU AgCenter 2009). However, 2008 marked two consecutive years of significant reductions in the forest products sector of Louisiana's economy, which coincides with the sharp contraction in the national economy that began toward the end of 2007. Pine sawtimber harvest decreased by 30 percent, to a total statewide harvest of 833.2 million board feet. The hardwood sawtimber harvest fell to 137.7 million board feet (a 21 percent decrease) in 2008 (LSU AgCenter 2009).

The Louisiana wood products manufacturing sector is comprised of an estimated 75 primary manufacturers and 545 secondary manufacturers (furniture, cabinet, millwork) (Louisiana Forest Products Development Center 2009). Primary products are those produced directly from raw timber input. Examples include chips, lumber, veneer, plywood and their by-products. Secondary products use primary products as input for remanufacturing. Examples include various types of panels, engineered composites or dimension stock. Secondary products can also include final consumer products such as furniture (Hughes and Vlosky, 2000). The forest sector, including forestry and forest products, is Louisiana's second largest employer with approximately 17,000 manufacturing jobs and 8,000 jobs in the harvesting/transportation of timber (LFA, 2008).

In an effort to provide information to Louisiana forest industry members, policymakers and other stakeholders, the Louisiana Forest Products Development Center (LFPDC) has periodically conducted primary and secondary wood products industry surveys for the past 15 years to identify salient issues, challenges, and opportunities. Vlosky, Chance, and Harding (1994) conducted an industry survey, which showed that the secondary wood products industry in Louisiana was fragmented and consisted of many small businesses, with 75 percent having 10 employees or less. At that time secondary industry companies were relying primarily on word-of-mouth to promote products directly to customers, thereby limiting the distribution of their sales.

Vlosky (1995) reported on the primary sector in Louisiana. He found that in 1993, nearly half of respondent companies had sales of at least $10 million. The majority of respondents were strictly softwood producers (45.5 percent), while 30.0 percent were using only hardwoods and 24.5 percent used both softwood and hardwood raw materials. In contrast to secondary manufacturers, 47 percent of sales were made out-of-state and 12 percent of sales went to export markets. Primary respondents also used word-of-mouth as the main vehicle to promote and sell their products. The factors that were considered to be the greatest impediments to company expansion were workman's compensation, proximity to raw materials, taxes, availability of capital, labor training issues and community industrial climate.

One of the recurring themes in these studies is the need for a trained and qualified workforce in the forest products industry. In each study, industry respondents indicated that they would have liked to add employees; however the lack of adequately trained labor was a limiting factor in doing so. In order to better understand the specific training needs in Louisiana, Vlosky and Chance (2001) conducted a study of the secondary sector. The overall conclusion was that appropriate training of the workforce must become a priority for Louisiana's value-added industry to be competitive in the marketplace. The most desired knowledge was concerning safety regulations and in dealing with customers, followed by quality and process control and basic problem-solving skills.

In this paper, we compare the results of two studies conducted on the primary and secondary sectors in Louisiana. In the past, we produced two papers based on research results, one for the primary and one for the secondary sector. However, this paper, based on the 2009 study, compares the results of the questions common to both surveys.

## 2 MATERIAL AND METHODS
2. MATERIJAL I METODE

Using a directory of Louisiana wood products industries compiled by the Louisiana Forest Products Development Center (2009), 75 primary solid wood products companies and 545 secondary or value-added companies were surveyed. The study was conducted using mailed surveys. Survey development and implementation generally followed methods and procedures recommended by Dillman and described as the Tailored Design Method (TDM) (Dillman, 2000). Accordingly, the survey process included a pre-notification postcard, first survey mailing, a reminder postcard, second mailing and, because response rates were not what we expected, after two mailings, a third mailing. After accounting for undeliverable surveys and unusable returned surveys, the adjusted response rates were 42 percent and 10 percent for primary and secondary companies, respectively. The response rate for the primary sector is quite good but, unfortunately, the response rate for the secondary sector is lower than we have experienced in past years. Although Jones and Lang (1980) point out that increasing the response rate does not necessarily improve the precision of survey results, we feel the secondary sector results can be considered as being exploratory (Adams, 1986; Hochstim, 1967).

Walonick (1993) believes that most researchers view non-response bias as a continuum, ranging from fast responders to slow responders (with non-responders defining the end of the continuum). Research has shown that late respondents typically respond similarly to non-respondents. Accordingly, second mailing respondents, as a proxy for non-respondents, were compared to first mailing respondents to test for non-response bias (Donald, 1960). Out of the 60 comparable variables, differences were detected at $\alpha=0.05$ for three variables (5 percent).

## 3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Figure 1 indicates that primary industry was located at higher concentration in the forested areas of Louisiana in the Northeast, Central and Southeast parts of the state and secondary industry was more prevalent in urban areas of Baton Rouge, New Orleans and Lafayette in Southern Louisiana. Seventy-six percent of primary respondents are headquartered in Louisiana with the balance having headquarters in Pennsylvania, South Carolina, Tennessee, Texas and Washington. All secondary manufacturers are headquartered in Louisiana. Louisiana is divided into parishes, known in the other 49 states as counties.

Figure 2 shows the percent of respondents manufacturing primary products. Multiple responses were possible as some companies are diversified and produce more than one product. Hardwood lumber is the highest ranked product with 66 percent of respondents followed by softwood lumber (48 percent). Past studies of Louisiana production had these products reversed. The economic downturn and subsequent soft demand for softwood lumber for construction is the likely reason for this reversal in order. Respondents in the secondary industry manufacture a wide range of value-added products (Figure 3). In this case as well, multiple responses were possible. Cabinets were mainly produced in 2008 with 71 percent of respondents, followed by molding and millwork (55 percent).

Figure 4 shows where respondents obtained their wood raw materials in 2008. Sixty-eight percent and 69 percent of primary and secondary producer respondents sourced raw materials from Louisiana, respectively. Often there can be concerns from forest sector industry members and stakeholders that "too much" raw materials are imported from other states to manu-

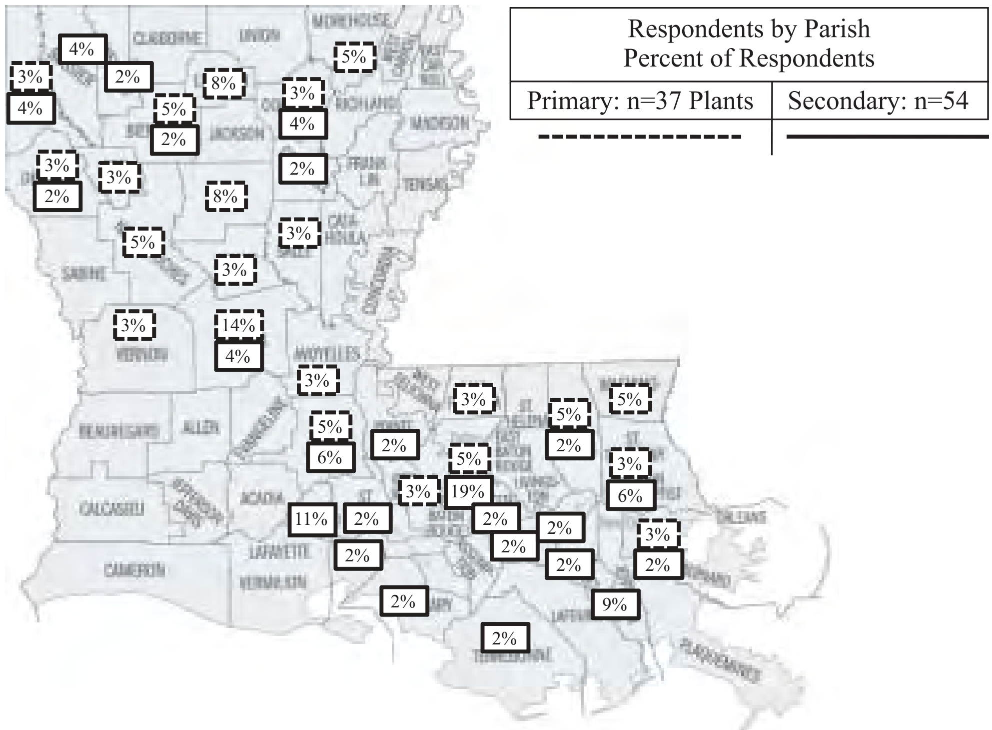


**Figure 1** Respondent location by parish (percent of respondents) (Primary: *n*=37; Secondary: n=54)
**Slika 1.** Lokacija ispitanika prema okruzima (postotak ispitanika) (primarni sektor *n*=37, sekundarni sektor *n*=54)

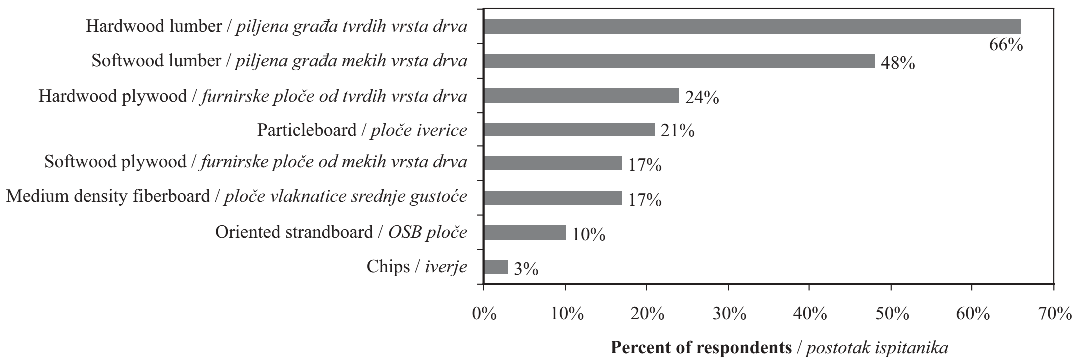


**Figure 2** Products manufactured by primary producers (percent of respondents) (multiple responses possible, *n*=53)
**Slika 2.** Proizvodi primarnih proizvođača (postotak ispitanika) (mogući višestruki odgovori, *n*=53)

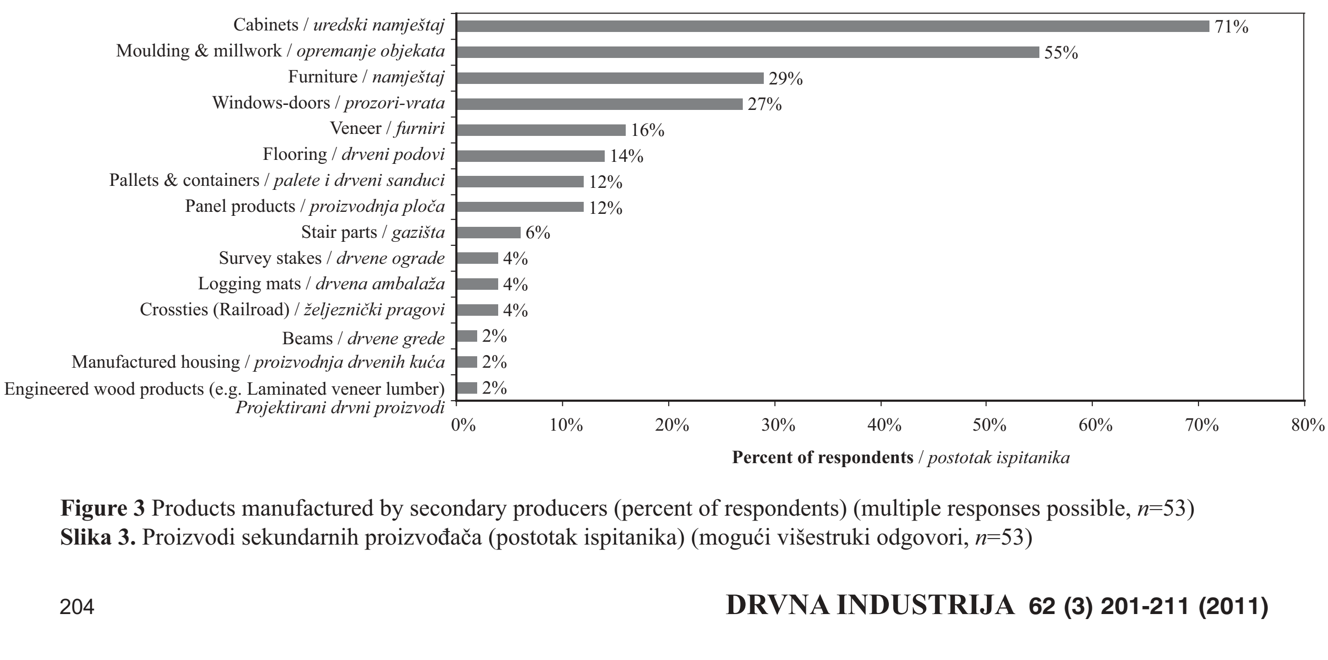


**Figure 3** Products manufactured by secondary producers (percent of respondents) (multiple responses possible, *n*=53)
**Slika 3.** Proizvodi sekundarnih proizvođača (postotak ispitanika) (mogući višestruki odgovori, *n*=53)

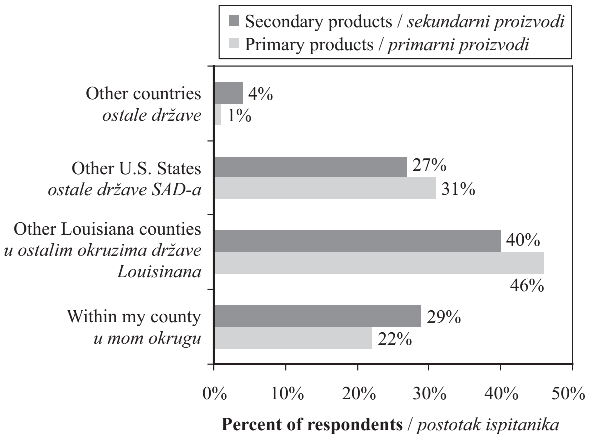


**Figure 4** Where respondents obtain wood raw materials (percent of respondents) (Primary: $n$=29; Secondary: $n$=51)
**Slika 4.** Gdje ispitanici nabavljaju drvnu sirovinu (postotak ispitanika) (primarni sektor $n$=29, sekundarni sektor $n$=51)

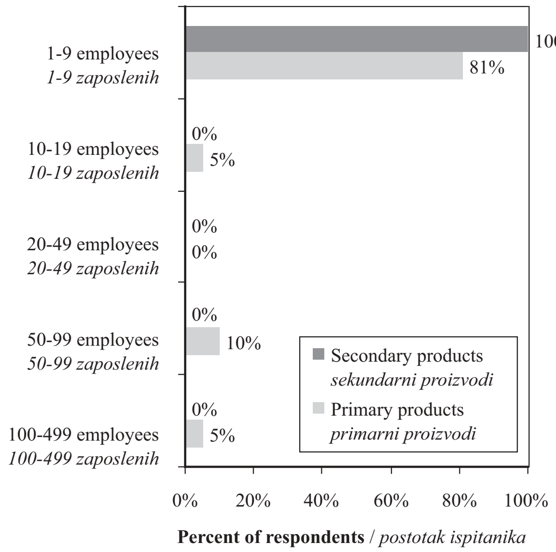


**Figure 6** Respondent company size by number of part-time employees (Primary: $n$=21; Secondary: $n$=24)
**Slika 6.** Veličina poduzeća ispitanika izražena brojem zaposlenika sa skraćenim radnim vremenom (primarni sektor $n$=21, sekundarni sektor $n$=24)

facture wood products, thereby forgoing adding as much value as possible from in-state raw materials.

Figure 5 compares primary and secondary respondent company size in terms of number of full-time employees. The number of respondents for primary industry respondents was fairly evenly distributed among the employee categories while 87 percent of secondary industry respondents had 19 or fewer employees. A Chi-Square test was performed to compare these frequencies and they were found to be significantly different ($\chi^2$=33.37, asymptotic 2-sided significance=0.000). With regard to part-time employees, both primary and secondary respondents are skewed strongly to having 1-9 employees in this category (Figure 6). Secondary respondents had 100 percent of their part-time employees in this category. A Chi-Square test indicated a

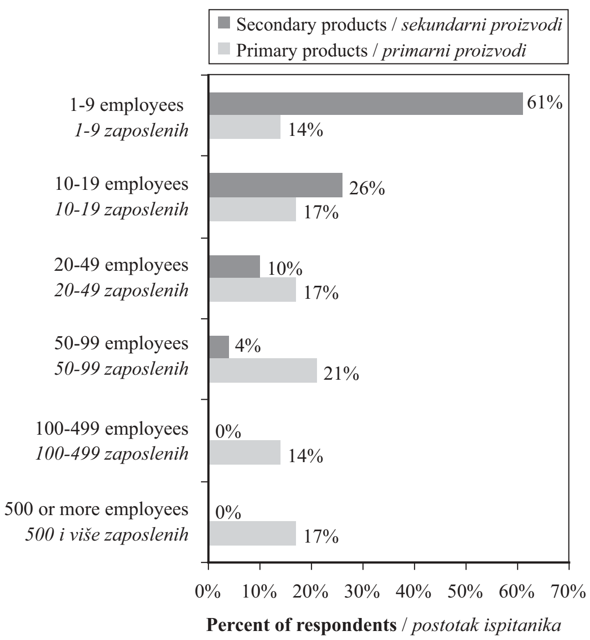


**Figure 5** Respondent company size by number of full-time employees (Primary: $n$=29; Secondary: $n$=51)
**Slika 5.** Veličina poduzeća ispitanika izražena brojem zaposlenika s punim radnim vremenom (primarni sektor $n$=29, sekundarni sektor $n$=51)

lack of a significant difference in the part-time employee frequencies ($\chi^2$=5.02, asymptotic 2-sided significance=0.171).

Figure 7 indicates plans by respondents to increase workforce in 2009 and 2010-2014. For both time periods, secondary industry respondents were planning on hiring more employees (38 percent and 49 percent) than in primary industry (33 percent and 38 percent). This too is likely due to the economic downturn that has negatively impacted housing starts.

There are many reasons for respondents not planning to add to their work force (Table 1). The primary sector respondents' main reason was the lack of markets for their company's products (28 percent of respondents), followed by lack of adequate labor (21 percent), workmen's compensation costs (17 percent) and state taxes (17 percent). Secondary industry respondents shared some concerns. Their main reasons were workmen's compensation costs (28 percent), lack of adequate labor (26 percent), cost of training employees (20 percent), wages (18 percent) and health costs (18 percent).

Using Likert-type scales anchored on levels of importance, respondents evaluated different methods of promoting their products (Scale: 1=very unimportant; 3=neither unimportant nor important; 5=very important) (Table 2). The results were compared to determine significant differences from the neutral midpoint using one sample t-tests and sorted by t-statistic values. The shaded portion of the table indicates non-significant results (at $\alpha$=0.05). For primary respondents, radio ads, direct mailing and newspaper ads were significantly lower than the midpoint while distributor support, word of mouth, and sales reps were significantly higher than the midpoint. For secondary respondents, manufacturers, all except one promotion method, word of mouth, had a negative t-value and all except using the

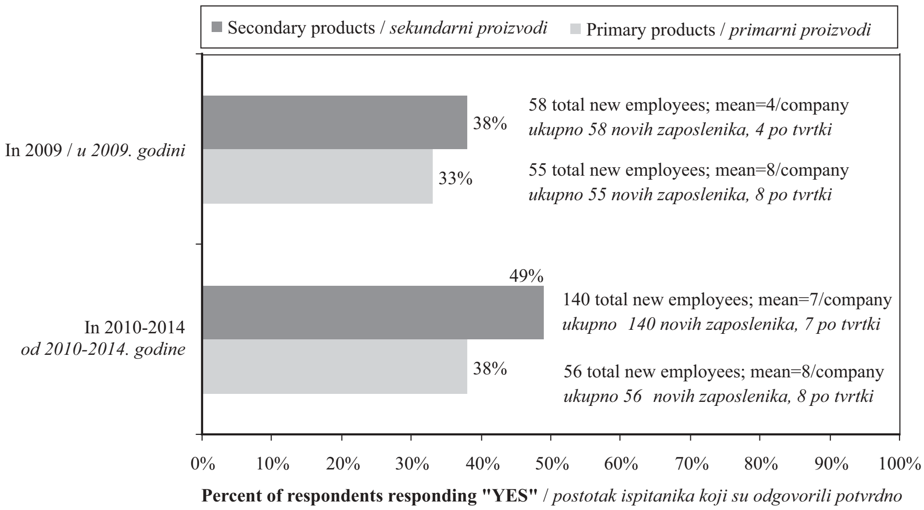


**Figure 7** Plans to increase workforce in 2009 & 2010-2014 (Primary: *n*=27; Secondary: *n*=48)
**Slika 7.** Planovi za povećanje broja zaposlenih u 2009. i u razdoblju 2010 – 2014. (primarni sektor *n*=27, sekundarni sektor *n*=48)

World Wide Web (a carryover term from previous studies) were significantly different from the neutral point.

What factors make wood products companies successful? Again, using the same scale of importance and comparisons to the 3.0 neutral midpoint, respondents were asked to rate factors that contribute to their company's success (Table 3). For primary industry respondents, all but two factors were statistically significant with regard to positive differences from the neutral midpoint (at $\alpha$=0.05). One was negatively non-significant (Internet presence) and the other was positively non-significant (computer capabilities). Factors identified as having the highest contribution to company success were "Product availability" and "Long-term customer relationships" (both 4.8/5.0). For secondary manufacturers, in addition to "Internet presence" and "Computer capabilities", "Marketing skills" was also not significantly different from the midpoint. Means for all the three of these non-significant factors were above the midpoint. Factors with the highest means were "Our product quality", "Long-term customer relationships", and "Company reputation" (all 4.9/5.0).

Challenges that companies face in achieving or maintaining success are on the other end of the spectrum (Table 4). Three statistically significant factors (different from midpoint at $\alpha$=0.05) were common to both primary and secondary respondents. These were "Volatile pricing", "Getting quality raw material", and "Getting consistent raw material". One additional factor was statistically significant for secondary industry respondents, "Finding ways to promote my company's products".

**Table 1** Reasons for not having plans to hire new employees (multiple responses possible) (Primary: n=18; Secondary: n=30)
**Tablica 1.** Razlozi nepovećanja broja zaposlenih u idućem razdoblju (mogući višestruki odgovori, primarni sektor *n*=27, sekundarni sektor *n*=48)

| | **Primary** *Primarni* | **Secondary** *Sekundarni* | |
|---|---|---|---|
| Lack of markets for my company's products *Nedostatak tržišta za proizvode poduzeća* | 28% | 28% | Workmen's compensation costs *Troškovi plaća radnika* |
| Can't find adequate labor *Nemogućnost pronalaska adekvatne radne snage* | 21% | 26% | Can't find adequate labor *Nemogućnost pronalaska adekvatne radne snage* |
| Workmen's compensation costs *Troškovi plaća radnika* | 17% | 20% | Can't afford to train employees *Nemogućnost obučavanja zaposlenika* |
| State taxes *Državni porezi* | 17% | 18% | Labor health costs are too high *Previsoki troškovi zdravstvenog osiguranja* |
| I do not want to grow the company *Ne želim rast poduzeća* | 14% | 18% | Wages required to hire new employees *Troškovi zapošljavanja novih zaposlenika* |
| Labor health costs are too high *Previsoki troškovi zdravstvenog osiguranja* | 14% | 14% | I do not want to grow the company *Ne želim rast poduzeća* |
| Local taxes / *Lokalni porezi* | 3% | 10% | State taxes / *Državni porezi* |
| Can't afford to train employees *Nemogućnost obučavanja zaposlenika* | 3% | 10% | Local taxes *Lokalni porezi* |
| Wages required to hire new employees *Troškovi zapošljavanja novih zaposlenika* | 0% | 4% | Lack of markets for my company's products *Nedostatak tržišta za proizvode poduzeća* |

**Table 2** Methods of promoting company products (One-Sample Statistics Compared to 3.0) (Neutral Point) (Scale: 1=very unimportant; 3=neither unimportant nor important; 5=very important)

**Tablica 2**. Metode promidžbe proizvoda poduzeća (statistička usporedba jednog uzorka s neutralnom točkom 3,0) (1 – potpuno nevažno; 3 – ni nevažno ni važno; 5 – vrlo važno)

| **Primary industry respondents** *Ispitanici primarne industrije* | | | | | | | |
|---|---|---|---|---|---|---|---|
| | *N* | **Mean** *Srednja vrijednost* | **Std. Deviation** *Standardna devijacija* | **Std. Error Mean** *Standardna pogreška* | *t* | *df* | **Sig. (2-tailed)** |
| Radio ads / *Radijski oglas* | 24 | 1.8 | 1.179 | 0.241 | -5.022 | 23 | 0.000 |
| Direct mailing / *Izravno pismo* | 24 | 2.0 | 1.083 | 0.221 | -4.337 | 23 | 0.000 |
| Newspaper ads / *Oglas u novinama* | 25 | 2.1 | 1.320 | 0.264 | -3.484 | 24 | 0.002 |
| World wide web / *Internetske stranice* | 24 | 2.7 | 1.239 | 0.253 | -1.318 | 23 | 0.201 |
| Trade magazine ads *Oglas u poslovnim novinama* | 26 | 2.7 | 1.468 | 0.288 | -1.202 | 25 | 0.241 |
| Catalogs / *Katalozi* | 25 | 2.7 | 1.345 | 0.269 | -1.189 | 24 | 0.246 |
| Magazine ads / *Oglas u časopisu* | 26 | 2.7 | 1.373 | 0.269 | -1.000 | 25 | 0.327 |
| Trade shows / *Sajmovi* | 26 | 3.2 | 1.415 | 0.277 | 0.693 | 25 | 0.495 |
| Distributor support / *Potpora distributera* | 27 | 3.7 | 1.347 | 0.259 | 2.857 | 26 | 0.008 |
| Word of mouth / *Usmenim putem* | 29 | 3.9 | 1.407 | 0.261 | 3.299 | 28 | 0.003 |
| Sales reps / *Trgovački predstavnik* | 28 | 4.0 | 1.170 | 0.221 | 4.684 | 27 | 0.000 |
| **Secondary industry respondents** *Ispitanici sekundarne industrije* | | | | | | | |
| Radio ads / *Radijski oglas* | 39 | 1.5 | 0.790 | 0.126 | -11.559 | 38 | 0.000 |
| Direct mailing / *Izravno pismo* | 39 | 1.7 | 0.977 | 0.157 | -8.355 | 38 | 0.000 |
| Catalogs / *Katalozi* | 39 | 2.0 | 1.112 | 0.178 | -5.761 | 38 | 0.000 |
| Trade magazine ads *Oglas u poslovnim novinama* | 41 | 1.9 | 1.300 | 0.203 | -5.406 | 40 | 0.000 |
| Newspaper ads / *Oglas u novinama* | 41 | 2.0 | 1.204 | 0.188 | -5.318 | 40 | 0.000 |
| Magazine ads / *Oglas u časopisu* | 40 | 2.0 | 1.300 | 0.206 | -5.109 | 39 | 0.000 |
| Trade shows / *Sajmovi* | 39 | 2.1 | 1.244 | 0.199 | -4.635 | 38 | 0.000 |
| Distributor support / *Potpora distributera* | 40 | 2.4 | 1.372 | 0.217 | -2.882 | 39 | 0.006 |
| Sales reps / *Trgovački predstavnik* | 40 | 2.5 | 1.536 | 0.243 | -2.162 | 39 | 0.037 |
| World wide web / *Internetske stranice* | 40 | 2.9 | 1.598 | 0.253 | -0.396 | 39 | 0.694 |
| Word of mouth / *Usmenim putem* | 50 | 4.8 | 0.815 | 0.115 | 15.436 | 49 | 0.000 |

The final question common to both sectors asked respondents to rate different infrastructure-related factors that influence their decisions to either expand capacity at existing facilities or build new production facilities. A Likert-type scale anchored on levels of agreement was used (Scale: 1=strongly disagree; 3=neither disagree nor agree; 5=strongly agree). A discussion with the director of forestry, agriculture and food sectors with the Louisiana State Department of Economic Development (Short, 2009) led to the decision to combine primary and secondary respondents to conduct a factor analysis for these influences. The rationale was to tease out the major constructs that influence the wood products industry as a whole. Understanding these dimensions is a potentially useful tool from a policy and planning perspective.

Table 5 shows the results of the Factor Analysis. Principal component factor analysis, with varimax rotation was conducted to identify these underlying dimensions. Several preliminary factor analysis solutions were examined before the final factor analysis solution was found. The 12 infrastructure-related influences posed were reduced to 10. The sample size (n=71) for the 10 variables exceeds the minimum required number of 5 observations per variable required for factor analysis (Hair et al. 1998). The Kaiser-Meyer-Olkin overall Measure of Sampling Adequacy (0.689), Bartlett test of nonzero correlations (0.000), Measures of Sampling Adequacy (range from 0.573 to 0.852) on the anti-image correlation matrix, and small partial correlations all indicate that the data set is suitable for Factor Analysis.

The latent root criterion (eigenvalue ≥1) was used in extracting the factors. Orthogonal varimax rotation was used to disperse the factor loadings within the factors to achieve a more interpretable solution (Field 2000). The four factors explain 77.8 percent of the total variance of the 10 variables as follows: Factor 1 (24.5%); Factor 2 (21.8%); Factor 3 (17.6%); Factor 4 (13.9%). The cut-off point for interpretation of the loadings was ±0.50.

- Factor 1 has three significantly high loadings (0.697-0.899), which are related to taxes and ove-

**Table 3** Attributes contributing to company success (One-Sample Statistics Compared to 3.0 (Neutral Point) (Scale: 1=very unimportant; 3=neither unimportant nor important; 5=very important)
**Tablica 3**. Svojstva koja pridonose uspjehu poduzeća (statistička usporedba jednog uzorka s neutralnom točkom 3,0) (1 – potpuno nevažno; 3 – ni nevažno ni važno; 5 – vrlo važno)

| **Primary industry respondents** *Ispitanici primarne industrije* | | | | | | | |
|---|---|---|---|---|---|---|---|
| | ***N*** | **Mean** *Srednja vrijednost* | **Std. Deviation** *Standardna devijacija* | **Std. Error Mean** *Standardna pogreška* | ***t*** | ***df*** | **Sig. (2-tailed)** |
| Internet presence / *Postojanje interneta* | 28 | 2.8 | 1.101 | 0.208 | -1.030 | 27 | 0.312 |
| Computer capabilities / *Mogućnosti računala* | 28 | 3.4 | 1.166 | 0.220 | 1.784 | 27 | 0.086 |
| Distribution capabilities *Mogućnosti distribucije* | 28 | 3.9 | 1.145 | 0.216 | 3.959 | 27 | 0.000 |
| Marketing skills / *Marketinške vještine* | 27 | 3.9 | 0.907 | 0.175 | 4.878 | 26 | 0.000 |
| Access to markets / *Pristup tržištu* | 27 | 4.1 | 0.864 | 0.166 | 6.905 | 26 | 0.000 |
| Flexible delivery / *Fleksibilnost isporuke* | 27 | 4.2 | 0.801 | 0.154 | 7.932 | 26 | 0.000 |
| Fair prices / *Poštene cijene* | 29 | 4.3 | 0.857 | 0.159 | 8.453 | 28 | 0.000 |
| Fast response to inquiries *Brz odgovor na potraživanja* | 28 | 4.4 | 0.737 | 0.139 | 9.996 | 27 | 0.000 |
| Company reputation / *Reputacija poduzeća* | 29 | 4.7 | 0.850 | 0.158 | 10.711 | 28 | 0.000 |
| Knowledgeable sales people *Sposobnost ljudi u prodaji* | 28 | 4.5 | 0.637 | 0.120 | 12.752 | 27 | 0.000 |
| Our product quality / *Kvaliteta proizvoda* | 29 | 4.7 | 0.702 | 0.130 | 13.229 | 28 | 0.000 |
| High level of overall customer service *Visoka razina usluga potrošačima* | 28 | 4.6 | 0.567 | 0.107 | 15.000 | 27 | 0.000 |
| Product availability / *Dostupnost proizvoda* | 28 | 4.8 | 0.518 | 0.098 | 17.870 | 27 | 0.000 |
| Long-term customer relationships *Trajni odnosi s kupcima* | 28 | 4.8 | 0.476 | 0.090 | 20.265 | 27 | 0.000 |
| **Secondary industry respondents** *Ispitanici sekundarne industrije* | | | | | | | |
| Internet presence / *Postojanje interneta* | 41 | 3.3 | 1.342 | 0.210 | 1.280 | 40 | 0.208 |
| Computer capabilities *Mogućnosti računala* | 42 | 3.4 | 1.322 | 0.204 | 1.751 | 41 | 0.087 |
| Marketing skills / *Marketinške vještine* | 40 | 3.4 | 1.357 | 0.214 | 1.981 | 39 | 0.055 |
| Distribution capabilities *Mogućnosti distribucije* | 41 | 3.7 | 1.309 | 0.204 | 3.461 | 40 | 0.001 |
| Access to markets / *Pristup tržištu* | 41 | 3.7 | 1.175 | 0.183 | 3.589 | 40 | 0.001 |
| Knowledgeable sales people *Sposobnost ljudi u prodaji* | 42 | 4.1 | 1.435 | 0.221 | 5.055 | 41 | 0.000 |
| Flexible delivery / *Fleksibilnost isporuke* | 44 | 3.9 | 1.117 | 0.168 | 5.399 | 43 | 0.000 |
| Fast response to inquiries *Brz odgovor na potraživanja* | 44 | 4.1 | 1.268 | 0.191 | 5.943 | 43 | 0.000 |
| High level of overall customer service *Visoka razina usluga potrošačima* | 46 | 4.5 | 1.110 | 0.164 | 9.295 | 45 | 0.000 |
| Product availability / *Dostupnost proizvoda* | 44 | 4.5 | 0.901 | 0.136 | 10.708 | 43 | 0.000 |
| Fair prices / *Poštene cijene* | 50 | 4.6 | 0.697 | 0.099 | 16.443 | 49 | 0.000 |
| Long-term customer relationships *Trajni odnosi s kupcima* | 47 | 4.9 | 0.612 | 0.089 | 20.971 | 46 | 0.000 |
| Our product quality / *Kvaliteta proizvoda* | 51 | 4.9 | 0.575 | 0.080 | 23.637 | 50 | 0.000 |
| Company reputation / *Reputacija poduzeća* | 50 | 4.9 | 0.566 | 0.080 | 24.000 | 49 | 0.000 |

rall industrial climate, thus the factor was named "*Taxes/Business Climate*".

- Factor 2 also has three significantly high loadings (0.638-0.866) on variables associated with labor productivity and costs. Accordingly, the factor was named "*Labor Productivity and Costs"*.
- Factor 3 has two items with significantly high loadings (0.839-0.898) on bank financing and availability of working capital and was named *"Financing"*.
- Factor 4 has two significant loadings (0.745-0.842) that are the availability of unskilled and skilled labor. This factor was named *"Labor Supply"*.

**Table 4** Factors in company challenges to success One-Sample Statistics Compared to 3.0 (Neutral Point) (Scale: 1=very unimportant; 3=neither unimportant nor important; 5=very important)
**Tablica 4.** Čimbenici u poduzeću koji onemogućuju uspjeh (statistička usporedba jednog uzorka s neutralnom točkom 3,0) (1 – potpuno nevažno; 3 – ni nevažno ni važno; 5 – vrlo važno)

| **Primary industry respondents** / *Ispitanici primarne industrije* | | | | | | | |
|---|---|---|---|---|---|---|---|
| | *N* | **Mean** *Srednja vrijed-nost* | **Std. Deviation** *Standardna devijacija* | **Std. Error Mean** *Standardna pogreška* | ***t*** | ***df*** | **Sig. (2-tailed)** |
| Lack of adequate machinery<br>*Nedostatak potrebnih strojeva* | 26 | 2.6 | 1.206 | 0.236 | -1.789 | 25 | 0.086 |
| Inefficient processing capabilities<br>*Neučinkoviti proizvodni procesi* | 26 | 2.7 | 1.129 | 0.221 | -1.563 | 25 | 0.131 |
| Competition from producers in my state<br>*Konkurentni proizvođači u državi* | 26 | 2.8 | 1.405 | 0.276 | -0.558 | 25 | 0.582 |
| Delivery problems / *Problemi isporuke* | 27 | 2.9 | 1.121 | 0.216 | -0.515 | 26 | 0.611 |
| Not having enough capacity / *nedovoljni kapaciteti* | 28 | 3.0 | 0.943 | 0.178 | 0.000 | 27 | 1.000 |
| Competition from producers in my region<br>*Konkurentni proizvođači u regiji* | 27 | 3.3 | 1.209 | 0.233 | 1.433 | 26 | 0.164 |
| Finding ways to promote my company's products<br>*Nepostojanje dobre promidžbe proizvoda* | 28 | 3.4 | 1.129 | 0.213 | 1.674 | 27 | 0.106 |
| Volatile pricing / *Nepostojane cijene* | 25 | 4.2 | 0.866 | 0.173 | 6.928 | 24 | 0.000 |
| Getting quality raw material / *Dobava kvalitetne sirovine* | 28 | 4.3 | 0.897 | 0.169 | 7.586 | 27 | 0.000 |
| Getting consistent raw material / *Dosljedna dobava sirovine* | 29 | 4.4 | 0.825 | 0.153 | 9.234 | 28 | 0.000 |
| **Secondary industry respondents** / *Ispitanici sekundarne industrije* | | | | | | | |
| Delivery problems / *Problemi isporuke* | 40 | 2.7 | 0.987 | 0.156 | -1.763 | 39 | 0.086 |
| Lack of adequate machinery / *Nedostatak potrebnih strojeva* | 42 | 2.8 | 1.353 | 0.209 | -1.026 | 41 | 0.311 |
| Inefficient processing capabilities<br>*Neučinkoviti proizvodni procesi* | 40 | 2.9 | 1.228 | 0.194 | -0.386 | 39 | 0.701 |
| Competition from producers in my region<br>*Konkurentni proizvođači u regiji* | 41 | 3.2 | 1.283 | 0.200 | 0.852 | 40 | 0.399 |
| Competition from producers in my state<br>*Konkurentni proizvođači u državi* | 42 | 3.2 | 1.284 | 0.198 | 1.202 | 41 | 0.236 |
| Not having enough capacity / *Nedovoljni kapaciteti* | 40 | 3.3 | 1.137 | 0.180 | 1.669 | 39 | 0.103 |
| Finding ways to promote my company's products<br>*Nepostojanje dobre promidžbe proizvoda* | 41 | 3.5 | 1.247 | 0.195 | 2.380 | 40 | 0.022 |
| Volatile pricing / *Nepostojane cijene* | 44 | 4.1 | 1.108 | 0.167 | 6.395 | 43 | 0.000 |
| Getting quality raw material / *Dobava kvalitetne sirovine* | 47 | 4.4 | 0.919 | 0.134 | 10.158 | 46 | 0.000 |
| Getting consistent raw material / *Dosljedna dobava sirovine* | 46 | 4.4 | 0.906 | 0.134 | 10.413 | 45 | 0.000 |

**Table 5** Factor analysis of influences on company decision to expand current capacity or build new facilities (Primary and Secondary respondents combined) (*n*=71)
**Tablica 5**. Analiza čimbenika koji utječu na odluku poduzeća da poveća postojeće kapacitete ili izgradi nove objekte (kombinirani odgovori ispitanika primarnoga i sekundarnog sektora, *n*=71)

| | **Factor** / *Čimbenik* | | | |
|---|---|---|---|---|
| | **Business climate** *Poslovna klima* | **Labor productivity & costs** / *Produktiv-nost i troškovi* | **Financing** *Financiranje* | **Labor supply** *Ponuda radne snage* |
| State taxes / *Državni porezi* | **0.899** | 0.284 | 0.053 | 0.102 |
| Local taxes / *Lokalni porezi* | **0.893** | 0.163 | 0.012 | 0.138 |
| Community industrial climate<br>*Društvena industrijska klima* | **0.697** | 0.063 | 0.314 | -0.128 |
| Productivity of labor / *Produktivnost rada* | 0.073 | **0.866** | 0.041 | 0.197 |
| Labor costs / *Radni* troškovi | 0.283 | **0.854** | 0.181 | 0.016 |
| Workman's compensation / *Plaće radnika* | 0.470 | **0.638** | 0.293 | 0.110 |
| Available capital / *Raspoloživi kapital* | 0.128 | 0.169 | **0.898** | 0.053 |
| Bank financing / *Bankovno financiranje* | 0.119 | 0.103 | **0.839** | 0.171 |
| Unskilled labor supply<br>*Ponuda neobučene radne snage* | 0.124 | -0.036 | 0.150 | **0.842** |
| Skilled labor supply / *Ponuda obučene radne snage* | -0.046 | 0.381 | 0.055 | **0.745** |

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

## 4 CONCLUSION
### 4. ZAKLJUČAK

In the aftermath of Hurricanes Katrina and Rita in 2005, combined with the national recession and associated severe decline in housing starts that began in 2008, the Louisiana wood products sector seems to be hanging on. In fact, even though this study was conducted early in 2009, when these market conditions were apparent, over a third of respondents from both the primary and secondary sectors said that they had plans to increase employment levels in 2009 and in the 2010-2014 period. For those respondents not planning to hire new employees, labor-related issues were most cited such as the lack of an available labor pool, lack of ability to train new employees, and onerous workmen's compensation costs.

With regard to factors that promote or hinder company success, long-term relationships with customers, general reputation in the market place, products quality and availability were most important success factors for both respondent groups. Information technology competencies such as simply having computing capabilities or an Internet presence were deemed to be the least important factors for company success. These data infer that the wood products industry, at least in Louisiana, remains a "people business" where personal contact counts. With regard to business challenges, neither group identified a plethora of factors that hinder success. The consistent challenges for all respondents had to do with volatile pricing which generally has to do with market and economic conditions, and raw material issues, particularly the ability to procure a consistent source of supply for quality inputs.

Finally, when we looked at the issues that drive company expansion, respondent data were segmented nicely into four areas: the overall attractiveness of the business climate of the community and state, labor productivity, costs and supply, and financing. Overall business and community climate relate to a number of issues including quality of life for employees and their families, tax structures and other typically state-level infrastructure issues. Labor issues in the Louisiana wood products have been researched frequently over the past 16 years and have been consistently identified as constraints to industry growth and competitiveness. Lack of training options targeting the unique skill sets of the primary and secondary industry has been a particularly serious problem over this period. Financing and availability of capital are issues facing any industrial sector regardless of location. These are also important influences on respondent company growth or expansion. Many companies would like to grow but cannot due to these infrastructure, labor and financing constraints.

In summary, Louisiana has an established wood products industry and a significant forest land base. The forest sector provides significant contributions to the economies of most of parishes in Louisiana and is a major employer statewide. The results in this article help to provide the much needed continuity of the understanding of the wood products industry in the state.

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# Potentials of Liquefied CCB Treated Waste Wood for Wood Preservation

## Mogućnosti uporabe utekućenoga otpadnog drva obrađenoga krom-bakar-boratom za zaštitu drva

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**ABSTRACT •** *Recovered wood is frequently contaminated with biocides and therefore its use is limited. Even more, wood, impregnated with classical chromated copper arsenate (CCA) preservatives is classified as a hazardous waste, therefore solutions for reuse or recovery of this material are sought. One of the options, discussed in this paper is liquefaction and further applications of liquefied wood containing biocide remainings. In order to elucidate this possibilty, spruce and beech wood was impregnated with liquefied CCB treated and untreaded spruce wood of various concentrations and exposed to wood decay fungi according to the EN 113 procedure. In paralel, the leaching experiments (ENV 1250-2) were performed as well. The results do not clearly show that liquefied wood is bio-inactive. In most cases the mass loss by fungal attack is decreased compared to the untreated controls. On the other hand, copper leaching from spruce wood, impregnated with the liquefied CCB treated wood was significantly reduced. Thus, there are indications that the liquefied wood could be utilized as a binding agent for inorganic biocides.*

***Keywords:*** *liquefied wood, wood decay fungi, wood preservation, leaching, CCB, copper*

**SAŽETAK •** *Prikupljeno uporabljeno drvo često je onečišćeno biocidima te je njegova ponovna uporaba ograničena. Osim toga, drvo impregnirano klasičnim krom-bakar-arsenat (CCA) zaštitnim sredstvima klasificirano je kao opasni otpad te je nužno pronaći rješenje za ponovnu uporabu ili sanaciju tako onečišćenog drva. Jedna od mogućnosti, prezentirana u ovome radu, jest utekućenje drva i daljnja primjena tako utekućenog drva koje sadržava preostale biocide. Radi razjašnjenja te mogućnosti, smrekovo i bukovo drvo impregnirano je utekućenom nezaštićenom smrekovinom i utekućenom smrekovinom zaštićenom krom-bakar-boratom različitih koncentracija. Tako obrađeno drvo izloženo je djelovanju gljiva, sukladno postupku opisanom u normi EN 113. Paralelno je proveden eksperiment ispiranja (ENV 1250-2). Rezultati istraživanja nisu jasno pokazali da utekućeno drvo nije bioaktivno. U većini je slučajeva gubitak mase zbog djelovanja gljiva smanjen u usporedbi s neobrađenim kontrolnim uzorcima. Osim toga, ispiranje bakra iz smrekovine impregnirane utekućenim drvom zaštićenim CCB-om znatno je smanjeno. Prema tomu, postoje znakovi da se utekućeno drvo može upotrijebiti kao vezivno sredstvo za anorganske biocide.*

***Ključne riječi:*** *utekućeno drvo, gljive truležnice, zaštita drva, ispiranje, CCB, bakar*

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## 1 INTRODUCTION
## 1. UVOD

Concerns about the safety and environmental impacts of impregnated recovered wood have increased in recent years and so has also research into methods to solve the handling problem of this important material. The main problem with impregnated recovered wood is that it still contains significant portions of preservatives, which were chosen due to their toxicity towards wood decay organisms. However, these preservatives are also toxic to other organisms and are thus potentially harmful to humans and to the environment (Amartey *et al.*, 2007).

The present paper focuses on waste wood that was originally preserved with inorganic copper-based preservatives, of which CCA (chromated copper arsenate) and CCB (chromated copper borate) are the most abundant. CCA treated wood is classified as hazardous wood waste at the end of its service life in some member states of the EU and is subject to stringent requirements. In other member states it is classified as non-hazardous and therefore subject to much less stringent requirements (Helsen and Van den Bulck, 2005).

Even though the use of CCA and CCB has decreased recently in several countries (due to a ban on consumer use of arsenic treated wood in the EU, the USA, and Canada), the amount of CCA treated waste wood is expected to increase drastically in several countries in the years to come, e.g. Florida, USA (Solo-Gabriele and Townsend, 2000) and Denmark (Affald 21, 1999). The demand for methods that ensure environmentally safe and economically feasible handling of this impregnated wood waste is huge.

Different methods for the disposal of CCA and CCB treated wood waste are currently under development or have been implemented in various countries (either in a demonstration phase or in an industrial setup). These methods include recycling and recovery of the wood, thermal destruction and remediation (e.g. bioremediation, extraction, etc.). The different methods of dealing with this treated wood waste were outlined by Helsen and Van den Bulck (2005). Reuse involves the use of wood in new constructions e.g. land piling and fences whereas recycling involves the production of wood based composites. However, in several countries, reuse and recycling of impregnated wood is forbidden. Nevertheless, at some point, the wood ends up as waste wood even though it has been reused (Amartey *et al.,* 2007).

Liquefaction of treated wood and its possible uses for wood protection are outlined herein. Liquefaction is one of the techniques that can convert wood biomass into useful liquid materials (Tatsuhiko and Hirokuni, 2001). Shiraishi and Hse (2001) recycled creosote-treated southern pine by liquefaction in phenol and were able to prepare novolac resin from the liquefied creosote treated wood. They discovered that this resin is suitable for production of adhesives for plywood. Lin and Hse (2005) reported that more than 90 % of toxic metals (Cu, Cr, or As) can be removed from liquefied CCA-treated wood by precipitation. However, up to our best knowledge, there are no literature data on a potential (re)use of the liquefied CCB treated wood as a preservative solution. The aim of the study presented herein was to clarify the fungicidal properties and leaching resistance of liquefied CCB containing wood.

## 2 MATERIAL AND METHODS
## 2. MATERIJAL I METODE

Two types of Norway spruce (*Picea abies* Karst.) wood were used for liquefaction: uncontaminated spruce wood sawdust and Norway spruce wood impregnated with a commercial preservative CCB solution, consisting of 34.0 % $CuSO_4 \times 5H_2O$, 37.3 % $K_2Cr_2O_7$ and 28.7 % $H_3BO_3$ (Silvanol, Silvaprodukt, Ljubljana, Slovenia). Norway spruce wood sawdust was soaked to the aqueous solution of CCB for three days in order to achieve uniform distribution and sufficient absorption. Afterwards, impregnated wood was oven dried at 60 °C for 7 days to ensure complete reduction of chromium. Retention of the CCB in treated wood was 4 kg m$^{-3}$, as required for the most frequent use class 3 applications (outdoor) (Willeitner, 2001). The liquefaction was carried out in a 1000 mL reactor equipped with a stirrer and a cooler. The spruce wood sawdust was fractionated using a 0.24 mm sieve and oven dried (24 h, 103 °C) prior to liquefaction. The reaction mixture was prepared with 150 g of uncontaminated spruce wood sawdust or spruce wood sawdust impregnated with the commercial preservative solution - CCB, 450 g of ethylene glycol and 13.5 g of sulphuric acid. The mixture was then transferred into a glass reactor and the reactor was immersed in an oil bath preheated to 180 °C to start the reaction. The reaction time was set to 90 min. After elapsed time, the liquefied wood was used for impregnation and subsequent analysis.

The reaction between ethylene glycol and sulphuric acid without wood was performed as well, in order to determine the fungicidal effect of the "liquefaction" product without wood (450 g of ethylene glycol and 13.5 g of sulphuric acid, 90 min). Prior to impregnation of beech and Norway spruce wood specimens, the liquefied wood was diluted with water, because the undiluted liquefied wood was too viscous to be used for impregnation (dilution ratios are presented in Table 1). The diluted liquefied wood was homogenized with a disperser (T 25 digital ultra-turrax, Ika) for 10 min. Concentration of copper in impregnated wood and in liquefied CCB treated wood was determined with X-ray fluorescence spectroscopy (Oxford instruments, Twin-x). The measurements were performed with PIN detector ($U$ = 26 kV, $I$ = 112 µA, $t$ = 360 s) on three parallel specimens.

The samples for the tests with fungi were made of beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* Karst.) wood. The dimensions (1.5 cm × 2.5 cm × 5.0 cm) and orientation met the requirements of the standards EN 113 (2004) and ENV 1250-2 (2004). The samples were vacuum-pressure impregnated (20 min vacuum -0.9 bar; 2 h 9 bar, 10 min vacuum -0.8 bar) (impregnation chamber Kambič) with 11 different preservative solutions as can be seen in Tables 1 and 2. Uptake of preservative solutions, and retentions were determined gravimetrically. The impregnated specimens were conditioned in the first two weeks after the treatment in closed chambers, the third week in half-closed and the fourth week in open ones, according to the recommendations of the standards ENV 1250-2 and EN 113. The control specimens exposed to wood decay fungi were left un-impregnated.

Resistance of impregnated wood against wood decay fungi was determined according to the modified EN 113 (2004) procedure. Beech wood specimens were exposed to white rot fungi (*Trametes versicolor* (L.:Fr.) Quél. and *Hypoxylon fragiforme* (Pers.) J. Kickx f.) and spruce wood specimens were exposed to brown rot ones (*Gloeophyllum trabeum* (Pers.) Murrill, and *Antrodia vaillantii* (DC.) Ryvarden). Two specimens were exposed in the same incubation jar (V = 500 ml), one impregnated and the other one un-impregnated. Control specimens were also exposed in separate jars, as the virulence controls. The surface of the inoculated nutrient medium was approximately 115 $cm^2$ large. After 16 weeks of exposure, mass losses of the decayed specimens were determined gravimetrically. The biological part of the investigation was performed on five replicate specimens.

For the leaching tests, only two series of wood specimens, impregnated with two different diluted liquefied CCB wood solutions were chosen (see the first two rows in Table 2). For comparison (the third row in Table 2), an aqueous solution containing the same amount of copper as in the three times diluted liquefied wood was included as well ($c_{Cu}$ = 170 ppm). Prior to impregnation, axial surfaces of the specimens were end sealed with an epoxy coating (Epolor, Color). In order to further speed up the experiment, the following two modifications of the ENV 1250-2 standard procedure were done: instead of five, three specimens were positioned in the same vessels and water mixing was achieved with shaking by the non-rotatory shaker (Kambič) device instead of using magnetic stirrer. To obtain three parallel leaching test data sets, nine specimens per solution/concentration/treatment were put in three separate vessels (three specimens per vessel). Afterwards, the samples in the vessels were positioned with weights. 300 g of deionized water was added per vessel and the vessels with its contents were shaken with a frequency of 60 $min^{-1}$. Water was replaced for six times in four subsequent days, as prescribed by the standard. Leachates from the same vessel were collected and aggregated. Afterwards, atomic absorption spectroscopy (Varian SpectrAA Duo FS240) analysis of the leachates was performed. Percentages of the leached copper were calculated from the amount of retained copper, determined gravimetrically and the amount of copper in the collected leachates was established.

## 3 RESULTS AND DISCUSSION
## 3. REZULTATI I RASPRAVA

The impregnation process resulted in rather high uptakes of preservative solutions. The average uptakes of preservative solutions were about 650 $kg·m^{-3}$. Wood species and composition of preservative solution did not have significant influence on the uptake. This is rather surprising, as the uptake of a viscous solution is usually higher with beech specimens than the uptake with spruce specimens (Lesar and Humar, 2010). Presumably, there are two main reasons for comparable uptakes of beech and spruce wood specimens: firstly, the specimens were rather small, with rather high portions of axial surfaces and secondly, the liquefied wood contained ethylene glycol that causes wood swelling (Mantanis *et al.* 1994), which enables penetration of larger molecules of liquefied wood to less permeable wood species (such as spruce).

Mass loss of the control specimens varied between 15.9 % and 36.3 %. The highest mass loss was measured with beech wood exposed to *H. fragiforme* and the lowest one with spruce wood exposed to *A. vaillantii* (Table 1). It should be considered that this mass loss is rather low, but this is in line with our previous results (*e.g.* Humar and Lesar, 2008). This fungal strain was chosen as it is extremely tolerant to copper and some other biocides, and with copper treated specimens mass losses are generally higher than mass losses of control specimens (Humar and Lesar, 2008), which can be clearly seen from our results as well.

Polyols are frequently used for liquefaction of wood. The results of Budija et al. (2009) clearly indicated that liquefied wood contains considerable portions of polyol. Thus, the influence of the reaction product between pure ethylene glycol and sulphuric acid, without wood, on fungal growth was of a particular interest as well. The results presented in Table 1 clearly show that the reaction product of ethylene glycol and $H_2SO_4$ reduced decay, but not enough to fulfill the requirements of the EN 113 standard. According to EN 113, wood protection provided by a wood preservative at a given concentration is regarded as adequate if the mean mass loss of treated specimens is less than 3 % of their initial dry mass. For example, mass losses of the control specimens exposed to *G. trabeum* (33.8 %) were approximately three times higher than mass losses of spruce wood specimens, impregnated with the aqueous solution of the product formed during the reaction between ethylene glycol and $H_2SO_4$ (13.3 %). But this value is still more than four times higher than prescribed by the EN 113 standard for effective preservatives. Similar influence of the glycol – sulphuric acid reaction product was determined with other specimens, exposed to wood decay fungi, with an exemption of *A. vaillantii.* Mass loss of the specimens, impregnated with the ethylene glycol - $H_2SO_4$ product was in this case only two percentage points lower than the mass loss of the control spruce wood specimens (Table 1).

Despite the fact that more than 100 $kg·m^{-3}$ of the dry liquefied wood remained in the impregnated wood

**Table 1** Influence of impregnation with various aqueous solutions based on liquefied (liq.) wood and liquefied CCB treated wood on mass losses of spruce or beech wood specimens after 16 weeks of exposure to wood decay fungi (standard deviations are given in brackets)
**Tablica 1**. Utjecaj impregnacije različitim vodenim otopinama na bazi utekućenog drva i utekućenoga drvnog otpada zaštićenoga CCB-om na gubitak mase uzoraka od smrekovine i bukovine nakon 16 tjedana izlaganja gljivama truležnicama (standardne devijacije dane su u zagradama)

| **Impregnation solution** *Otopina za impregnaciju* **water : liquefied wood mass ratio** *maseni omjer voda : utekućeno drvo* | **Retention** *Retencija* kg/m$^3$ | **Wood decay fungi*** / *Gljiva truležnica* | | | |
|---|---|---|---|---|---|
| | | ***A. vaillantii*** | ***G. trabeum*** | ***T. versicolor*** | ***H. fragiforme*** |
| | | **Mass loss, %** / *Gubitak mase, %* | | | |
| 3 : 1 liq. wood / *3: 1 utekućeno drvo* | 89.5 (12.1) | 19.2 (2.6) | 19.1 (2.0) | 22.8 (1.7) | 21.7 (3.1) |
| 9 : 1 liq. wood / *9: 1 utekućeno drvo* | 44.0 (8.5) | 14.9 (1.1) | 15.3 (2.4) | 17.4 (2.4) | 15.7 (3.3) |
| 27 : 1 liq. wood / *27: 1 utekućeno drvo* | 14.8 (2.5) | 9.4 (0.3) | 25.1 (3.3) | 21.9 (3.5) | 23.4 (1.1) |
| 50 : 1 liq. wood / *50: 1 utekućeno drvo* | 8.2 (1.6) | 13.0 (1.7) | 28.5 (3.2) | 18.8 (3.4) | 26.1 (1.8) |
| 100 : 1 liq. wood / *100: 1 utekućeno drvo* | 4.5 (1.2) | 12.4 (1.0) | 31.7 (3.4) | 20.7 (2.9) | 27.3 (3.5) |
| 3 : 1 liq. CCB treated wood *3 : 1 utekućeno drvo zaštićeno CCB-om* | 112.2 (11.2) | 25.9 (1.5) | 21.1 (1.9) | 20.8 (2.3) | 19.4 (0.8) |
| 9 : 1 liq. CCB treated wood *9 : 1 utekućeno drvo zaštićeno CCB-om* | 44.9 (3.2) | 14.6 (2.0) | 17.4 (3.2) | 14.4 (2.4) | 15.1 (3.7) |
| 27 : 1 liq. CCB treated wood *27 : 1 utekućeno drvo zaštićeno CCB-om* | 14.8 (1.7) | 10.5 (2.4) | 22.2 (3.3) | 25.0 (1.8) | 27.1 (1.3) |
| 50 : 1 liq. CCB treated wood *50 : 1 utekućeno drvo zaštićeno CCB-om* | 11.7 (2.7) | 11.0 (1.8) | 22.4 (3.0) | 17.9 (2.1) | 25.0 (3.3) |
| 100 : 1 liq. CCB treated wood *100 : 1 utekućeno drvo zaštićeno CCB-om* | 7.0 (4.7) | 11.9 (1.2) | 25.1 (1.8) | 15.0 (1.9) | 26.0 (2.1) |
| 3 : 1 ethylene glycol + $H_2SO4$ *3 : 1 etilen glikol +* $H_2SO4$ | 47.7 (8.0) | 12.6 (1.7) | 13.3 (1.7) | 14.2 (1.9) | 14.4 (0.8) |
| Control / *kontrolni uzorak* | / | 15.9 (1.5) | 33.8 (3.2) | 26.7 (1.8) | 36.3 (2.6) |

*The *A. vailantii* and *G. trabeum* tests were performed with spruce wood specimens and the *T. versicolor* and *H. fragiforme* tests with beech wood specimens. / *Gljive A. vailantii i G. trabeum primijenjene su za uzorke od smrekovine, a T. versicolor i H. fragiforme za uzorke od bukovine.*

after impregnation (Table 1), it did not have a major influence on fungal decay. In general, mass losses of the specimens, impregnated with the liquefied wood were higher than mass losses of the specimens impregnated with the ethylene glycol - $H_2SO_4$ reaction product only. Even more, mass losses of the specimens impregnated with liquefied wood and exposed to *Antrodia vaillantii* were even higher than mass losses of control specimens. Similar results were obtained with specimens impregnated with other combinations of liquefied wood. This result indicates that liquefied wood did not have significant fungicidal effect, and therefore cannot be utilized for preservation in a current form. This is in line with the results of Alfredsen *et al*. (2004). They have screened four different tall oil derivates. The derivatives exhibited some fungicidal properties in agar screening test, but none of them was proven as a fungicide during mini block testing (agar block test).

It was expected that the liquefied CCB containing wood could perform better than the pure liquefied wood, due to the remained biocides (copper and boron). The concentration of copper in the three times diluted liquefied CCB treated wood (3 : 1 liq. CCB treated wood) was 170 ppm. Therefore, the results of the fungicidal test were unexpected. Wood, impregnated with the liquefied CCB containing wood, exhibited the same weak resistance against wood decay fungi as wood impregnated with the pure liquefied spruce wood, despite the fact that there was approximately 0.12 kg·m$^{-3}$ of copper in wood impregnated with the highest solution of the liquefied CCB treated wood. It has been reported (Humar and Lesar, 2008) that this retention is sufficient to protect wood at least against copper sensitive fungi like *G. trabeum* and *T. versicolor.* There could be two reasons for low efficacy of wood impregnated with the liquefied CCB treated wood. Firstly, copper in liquefied wood might be in insoluble or in a less fungicidal form, which decreases its efficacy. And secondly, liquefied wood is acidic. Average pH of liquefied wood is around 1 (Budija, 2010). It is well known that copper is considerably less fungitoxic in an acid environment than in a neutral one (Humar *et al.*, 2005).

In the second part of the research we were interested in the leaching of the active ingredients from wood, impregnated with the liquefied CCB containing wood. This question was of a general interest, as one of the issues related to copper based preservatives is how to achieve sufficient copper fixation in wood. Between 40 % and 60 % of copper is leached from wood impregnated with the aqueous solution of copper without liquefied wood (Richardson, 1997). Similar leaching ratios were also determined with spruce and beech wood specimens impregnated with copper(II) sulphate solution in our experiment (Table 2).

Surprisingly, considerably lower leaching rates were determined from wood impregnated with the liquefied CCB treated wood. The leaching rates were particularly low with spruce wood specimens. For in-

**Table 2** Copper leaching from wood specimens impregnated with liquefied CCB impregnated wood determined according to the ENV 1250-2 procedure
**Tablica 2**. Ispiranje bakra iz uzoraka drva imregniranih utekućenim drvom zaštićenim CCB-om, određeno prema postupku ENV 1250-2

| **Impregnation solution** / *Otopina za impregnaciju* **water : liquefied wood mass ratio** / *maseni omjer voda: utekućeno drvo* | **Wood species** *Vrsta drva* | **Leached Cu, %** *Isprani bakar, %* |
|---|---|---|
| 3 : 1 liq. CCB treated wood *3 : 1 utekućeno drvo zaštićeno CCB-om* | beech / *bukovina* | 17.7 (2.1) |
| | spruce / *smrekovina* | 4.2 (0.6) |
| 9 : 1 liq. CCB treated wood *9 : 1 utekućeno drvo zaštićeno CCB-om* | beech / *bukovina* | 20.1 (1.7) |
| | spruce / *smrekovina* | 5.4 (0.3) |
| * aqueous solution of copper(II) sulfate *vodena otopina bakar(II)sulfata* | beech / *bukovina* | 57.8 (2.9) |
| | spruce / *smrekovina* | 56.7 (2.4) |

*For comparison, specimens were treated with the aqueous solution of copper(II) sulfate of the same concentration as in liquefied CCB treated wood (of the 3 : 1 dilution ratio). Standard deviations are given in the parenthesis. / *Za usporedbu, uzorci su obrađeni vodenom otopinom bakar(II)sulfata jednake koncentracije kao i uzorci obrađeni utekućenim drvom zaštićenim CCB-om (omjer razrjeđenja 3:1). Standardne devijacije dane su u zagradama.*

stance, from spruce wood blocks, impregnated with the liquefied CCB treated wood, between 4.2 % and 5.4 % of retained copper was leached. This is considerably lower than reported for copper(II) sulfate treated wood. Furthermore, these leaching rates are comparable to the leaching rates determined with copper-ethanolamine treated wood (Zhang and Kamdem, 2000). However, leaching from beech wood, impregnated with the liquefied CCB treated wood, was approximately four times higher (Table 2). This might be somehow related to the fact that liquefied CCB treated wood was made of spruce wood. Similar results were observed with the leached beech and spruce wood blocks, impregnated with the aqueous solutions of boric acid and liquefied spruce wood (Lesar *et al.,* 2011). This presumption needs to be addressed in future studies.

Normally, the observed low leaching rates of copper from wood, impregnated with the liquefied wood containing CCB, can be considered useless in the context of disappointingly low antifungal resistance of wood, impregnated with the CCB liquefied wood. However, low copper leaching supports the assumed reason for low efficacy: copper in combination with the liquefied wood assumably formed less soluble or insoluble forms. A possible application of the recovered CCB contaminated wood could be in the preparation of new wood protecting copper based solutions. Careful tuning of the ratio between liquefied wood and copper in such solutions could retain some copper efficacy on one side and on the other side decrease its leaching. The appropriate fungicidal efficacy could be improved by the addition of a co-biocide.

## 4 CONCLUSIONS
## 4. ZAKLJUČCI

Wood, impregnated with liquefied wood did not exhibit sufficient resistance against wood decay fungi. Also the wood, impregnated with the liquefied CCB containing wood, was not effectively protected against the selected wood degrading fungi. This indicates that CCB treated liquefied wood needs to be supplemented with additional biocides to ensure sufficient protection. However, copper leaching from spruce wood, impregnated with the liquefied CCB treated wood, was significantly reduced. Thus, there are indications that the liquefied wood could be utilized as a binding agent for inorganic biocides. However, up to our best knowledge, we are not aware of studies on energy consumption during wood liquefaction processes. Potentially, wood liquefaction could be costly and economically inefficient in industrial scale. So, there is an urgent need to perform economic analyses of wood liquefaction before a decision for industrial applications of liquefied wood is made.

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# Analysis of Occupational Diseases Occurring in Forestry and Wood Processing Industry in Slovakia

## Analiza pojavnosti profesionalnih bolesti u šumarstvu i drvnoprerađivačkoj industriji Slovačke

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**ABSTRACT •** *The scope of this paper is the analysis of occupational diseases occurred in forestry and wood processing industry (WPI) between 2000-2009. The aim of this analysis is to highlight the development of occupational diseases and the impact of selected factors on development trend. The basis for the analysis was the basic information on affected persons - gender, job, age and duration of exposure to harmful agents, as well as the information about specific diseases and factors that support the appearance of the disease. Data for the ten-year observation period were evaluated graphically and the correlation between the selected qualitative characteristics was determined by the method of contingency tables. An interesting result is the proportion of diseases among women in the WPI, which reaches nearly 40%, in forestry where men are mostly harmed. The most often represented disease in forestry is vibration disease. The total share of the three types of this disease (vibration disease of joints, bones, tendons and muscles; disease of blood vessels and nerves; other vibration diseases and combined diseases caused by vibration) accounts for up to 52% of all occupational diseases. In the wood processing industry the damage of workers' hearing was the most frequently occurring harm.*

***Key words****: occupational diseases, forestry, wood industry*

**SAŽETAK •** *Cilj rada bio je prikazati analizu pojavnosti profesionalnih bolesti u šumarstvu i drvnoprerađivačkoj industriji (WPI) u razdoblju 2000 – 2009. godine u Slovačkoj. Svrha analize bila je naglasiti razvoj profesionalnih bolesti i utjecaj određenih činitelja na trend njihova razvoja. Analize se temelje na osnovnim podacima o oboljelima – na spolu, poslu, godinama starosti, trajanju izlaganja štetnim tvarima te na podacima o posebnim bolestima i činiteljima koji su pridonijeli pojavi bolesti. Podaci za desetogodišnje razdoblje prikazani su grafički, a analiza korelacije između određenih kvalitativnih obilježja napravljena je metodom kontingencijskih tablica. Zanimljiv je rezultat udjela oboljelih žena u drvnoprerađivačkoj industriji koji doseže gotovo 40 %, a u šumarstvu su oboljeli uglavnom muškarci. Najčešća bolest u šumarstvu jest bolest prouzročena izlaganjem vibracijama. Ukupan udio triju tipova te bolesti (bolesti zglobova, kostiju, tetiva i mišića; bolesti krvnih žila i živaca; drugih bolesti od*

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*vibracija ili u kombinaciji s vibracijama) u svim profesionalnim bolestima iznosi 52 %. U drvnoprerađivačkoj je industriji najzastupljenija bolest oštećenje sluha radnika.*

***Ključne riječi**: profesionalna bolest, šumarstvo, drvnoprerađivačka industrija*

## 1 INTRODUCTION
## 1. UVOD

Current status of occupational diseases in the Slovak Republic can be characterized in terms of statistics as a positively evolving. It is confirmed by the information on the number of newly reported occupational diseases in 2008, when 201 cases were registered. Compared to 2007 (413 cases) it is a significant drop, particularly in terms of more negligible decrease in the number of workers in hazardous workplaces from 116,297 workers in 2007 to 115,825 workers in 2008, representing approximately 0.4 % (Statistical Office of the Slovak Republic).

Forestry and wood processing industry affect these facts significantly. They are among the sectors with the highest risk of occupational diseases, work injuries, etc. Vibration, noise, long-term unilateral excessive workload of the body, but also diseases transmitted by wood ticks are regarded as the most important factors with the harmful effect on humans. The most common diseases transmitted by wood ticks (in the Slovak Republic Ixodes ricinus) are the Lyme disease and wood tick-borne encephalitis. Untreated, these diseases can have serious consequences.

The term vibration means the oscillating movement of bodies or mechanical continuum. Vibrations can be transmitted to the organism as a whole, or to its parts, especially to hands:

1. Overall vibration is transmitted to a seated or standing person from vibrating seat, floor or platform so that it causes intense vibration of the whole body.
2. Vibrations transmitted to the hands are transferred from the vibrating handle or other object held by hands, especially to hands of exposed persons – e. g. vibrations transmitted to the workers from the handles of manual pneumatic tools, steering wheel, etc.
3. Vibrations that cause intense shivering of upper spine and head are regarded as vibrations transmitted in a special way. Vibrations from the seat are considered as overall vibrations.

In the case of workers engaged in logging, it is necessary to pay special attention to vibrations transmitted from a portable chain saw (PCHS) to hands. Negative synergistic effect of vibrations and cold may have the effect of white fingers disease. Untreated, the disease ends up in gangrene in many cases.

It is possible to eliminate the effects of vibrations on human body by appropriate work and rest regime, selection of appropriate anti-vibration gloves, and by the use of tools of appropriate age, technical conditions and maintenance. A relationship between vibrations level and the age of instrument used was shown only in 55 cases out of 107 portable chainsaws (Goglia and Žgela, 2003).

In addition to fixed hand tools, the sources of vibration in the wood processing industry are also woodworking machines, saws. Goglia and Grbac (2005) analyze the measurement results of the whole-body vibration transmitted to the frame saw operator during an ordinary working day. Vibration was measured in all operations performed during the normal frame saw working cycle. Frequency spectra were obtained for all measurements and the results were graphically presented according to the ISO 2631-1-1986 recommendations. The weighted r.m.s. acceleration was also calculated, and the duration of each single frame saw operation was measured. The energy-equivalent vibration level, corresponding to the total duration of exposure was calculated, too. Thus obtained values were compared with the daily exposure limits according to the ISO 2631-1-1997.

The noise is a side-effect of vibrations. It can be defined as any unwanted sound that causes an ugly or disruptive perception or harmful effect. The noise is directly harmful to the organ of hearing and causes permanent hearing loss if the sound level is higher than 85 dB(A). Above 130 dB(A), adverse effects have already been observed on tissues (the pain threshold) and above 160 dB(A) the drum damage occurs.

Occupational hearing loss occurs when the organ of hearing is continuously and repeatedly exposed to noise during work or working process. The core of occupational time-worn of hearing is a degenerative damage up to complete destruction of sensory cells of hearing organ by the noise with the subsequent damage of other elements inside the ear. The inception and severity of the occupational hearing disease depends on:

- character of noise,
- conditions of noise exposure,
- particular factors related to the exposed person.

OSHA (Occupational Safety and Health Administration) has set a maximum permissible average noise level of 90 dB(A) per eight-hour working day. The permissible noise exposure rises to a maximum of 115 dB(A), a level that can be tolerated for only 15 minutes or less per day. A circular saw produces between 100 and 109 dB(A), a medium-sized woodworking shop in full operation averages about 110 dB(A), and a chain saw may peak at 130 dB(A) (OSHA *In* Wellborn).

The Croatian scientists tried to reduce the effects of circular saw noise using a rubber damper (damping rubber-ring). The noise was analyzed using nine rolls - three of different diameter and three of different type. Due to the whistling sound, the blades without slots emitted very high sound pressure levels. There were no significant changes when the rubber damping-rings were used. The use of the rubber damping-rings on the samples with radial slots eliminates the whistling noise. The saws with copper corks did not emit a whistling noise at all and their aerodynamic noise was 2-3 dB(A) lower than the aerodynamic noise of the saws with radial slots (Beljo Lučić and Goglia, 2001).

During the noise loading measurement of the operator of the tractor, with additional striking rotary cultivator, at work in the cabin with open vent holes, in all the cases reported higher levels of noise were recorded than permitted by law. The highest values exceeding the maximum allowable noise levels were measured in the workplace of ŠS Námestovo - 89.2 dB(A) (Klč and Radocha, 1998).

A common problem in both sectors is a disease of long-term, unilateral overloading of limbs. Occupational diseases caused by long-term, unilateral overloading affect the structure of the locomotor limb system - bones, joints, tendons, muscles, nerves and blood vessels. They are caused by various business activities associated with an overloading of limbs without providing time necessary for recovering. The inception of the disease depends on the factors at work and individual anatomo-functional characteristics of a worker related to the type and way of work performance.

A specific factor affecting the human health in the wood processing industry is dust generated by wood processing. The effect of dust on the human body depends on its physical, chemical and biological properties and its quantity in the air and respiratory activity (eg. strain). The dust particles are inhaled through the nose and mouth and some 40 to 50% of particles with the size of 0.02 mm are caught on the nose hairs, nose mucous membranes, mouth and in the upper respiratory tract. The upper respiratory system retains most particles larger than 0.005 mm. Only the respirable dust, which is deposited in the tracheas and alveolars, gets into the lower respiratory tract. The dust also pe netrates into the conjunctival sac, settles on the skin and causes thecoryza and conjunctivitis, skin eczema, breathlessness and allergic reactions (Irša, 2010).

Dzurenda et al. (2010) analyzed the dust particles of oak wood that was cut with a frame saw with a narrow slice, before and after thermal modification. The sawdust of the thermally modified dry oak created in the sawing process consists of chip granularity ranging from 0.0412 mm to 3.6 mm, whereas the unmodified oak wood chips sawdust consists of granularity in the range from 0.0448 mm to 12.1 mm.

A new phenomenon, of which the inhabitants of Slovakia are already getting aware, is bioenergetics. For the workers in forestry this means, in terms of safe work, identification and definition of new risks (Suchomel and Belanová, 2009) and analysis of previously defined risks in this sphere. In the whole process of energetic chips production (from the establishment of plantations of fast-growing trees, their management, and energy management to their cutting), there is a wide range of risks: the risk of working with chemicals in the fertilization in case of small areas, the risk of accidents during trimming, but also during cutting by a cutter, and especially when using a portable chain saw, which is also physically demanding. It is therefore recommended only for small areas (Trenčiansky *et al.*, 2007). In the processing of forest biomass, there are the risks such as the above mentioned noise, vibration, dust and the risk of accident and also the risks occurring in storing of and work with energy chips such as fungi, mold, dust, terpenes and many other allergens.

In solving issues related to safety and health of workers (SHW), the prevention plays an important role. The basis for applying this approach to ensure safety and health at workplace is knowledge, which is required not only at senior officer level, but also for workers. Therefore, based on a risk analysis, a proposal of preventive, organizational and control measures should be developed in the forestry practice and wood processing industry in the Slovak Republic. It is also necessary to make technical and design changes of machinery and equipment, changes in technology, procedures and regulations, particularly in the SHW-area.

## 2 MATERIAL AND METHODS
## 2. MATERIJAL I METODE

The data necessary for the purpose of occupational diseases analysis were obtained from the National Health Information Center. The information obtained is related to the occupational diseases recorded for the years 2000-2009 in Slovakia in the business activity (by NACE) 02 - Forestry, timber logging and related services and 20 - Manufacture of wood and wood and cork products, except furniture; straw products and products made of plaiting materials.

The database contains data categorized by:

- occupation of affected person,
- age of affected person,
- gender of affected person,
- specific disease,
- harmful agent,
- duration of exposure to the harmful factors.

They were sorted by year and the above mentioned business activities.

The biggest deficiency found in the obtained documents was the absence of some information for certain periods. There were no data mainly for 2003 and 2004, describing the duration of workers' exposure. The duration of exposure to a certain harmful factor plays an important role e.g. in the development of standards and subsequent compliance of work and rest regime, which is reflected in the number of occupational diseases, but also in the occurrence of accidents.

In the reports for the period 2000-2002 there was a lack of essential information about the harmful factor, exposure to which caused the occupational disease. The relevance of this information mainly lies in the effort to improve the state of SHW in Slovakia, primarily in the form of prevention, in the effort to increase the efficiency and to optimize the work processes and to ensure the return of the workforce, etc.

### 2.1 Analytical works
### 2.1. Analitički radovi

For the reasons stated in the previous paragraph, the evaluation of occupational diseases was not simple. The essential information on duration of exposure had to

**Table 1** Example of Contingency Table
**Tablica 1.** Primjer tablice kontingencije

| Factor *B* | | Degrees of factor *B* | | | | | | $\sum$ |
|---|---|---|---|---|---|---|---|---|
| Factor *A* | | $B_1$ | $B_2$ | ...... | $B_j$ | ...... | $B_m$ | |
| Degrees of factor A | $A_1$ | $n_{11}$ | $n_{12}$ | ...... | $n_{1j}$ | ...... | $n_{1m}$ | $m_1$ |
| | $A_2$ | $n_{21}$ | $n_{22}$ | ...... | $n_{2j}$ | ...... | $n_{2m}$ | $m_2$ |
| | . | . | . | | | | | . |
| | . | . | . | | | | | . |
| | $A_i$ | $n_{i1}$ | $n_{i2}$ | ..... | $n_{ij}$ | ..... | $n_{im}$ | $m_i$ |
| | . | . | | | | | | . |
| | . | . | | | | | | . |
| | $A_k$ | $n_{k1}$ | $n_{k2}$ | | $n_{kj}$ | | $n_{km}$ | $m_k$ |
| $\sum$ | | $n_1$ | $n_2$ | ..... | $n_j$ | ..... | $n_m$ | $n$ |

be analyzed separately for the "first" and "second" period. Similarly, the data about occupation had to be evaluated in two parts because of the occupation list. The database was evaluated in Excel charts. The results were compared cumulatively for the entire period, within the scope of specific business activities and years.

### 2.2 Contingency table
2.2. Tablice kontingencije

The method of Contingency Table was used to analyze the relationship between quality characters.

When there are two multipal qualitative factors *A*, *B*, of which the first occurs in the variations (degrees) $A_1$, $A_2$, $A_3$, ... $A_k$ and the second in the variations (degrees) $B_1$, $B_2$, $B_3$ ... $B_m$, their sorting forms *k* x *m* contingency table as shown in Tab. 1.

The degree of dependence between the multiple qualitative factors *A*, *B* is measured by comparing the actual frequencies in particular stages of the Contingency Table $n_{ij}$ with the expected multiplicity $n'_{ij}$ assuming the independence of factors *A*, *B*. The expected dependences are calculated according to equation:

$$n'_{ij} = \frac{m_i \cdot n_j}{n} \tag{1}$$

They are calculated by multiplying the marginal frequencies ($m_i$ for factor *A* and $n_j$ for *B* factor) range divided by a set of *n*.

The basis for the calculation is the quantity $\chi^2$ (chi square), which is specified by the relationship:

$$\chi^2 = \sum_{i=1}^{k} \sum_{j=1}^{m} \frac{(n_{ij} - n'_{ij})}{n'_{ij}} \tag{2}$$

The calculation of $\chi^2$ is done directly in the contingency table, where the expected frequencies $n'_{ij}$ or the differences ($n_{ij} - n'_{ij}$) are recorded in each grade (box table) except the actual frequencies. Other symbols *n*, *k*, *m* are known from the text.

The expected frequencies must also be calculated for the table boxes where the actual frequencies do not occur. The frequencies in the respective boxes enter the calculation of $\chi^2$ with the value

$$\frac{(0 - n'_{ij})^2}{n'_{ij}} = n'_{ij} \tag{3}$$

The formula gives reliable results when the sample size is $n > 40$. If any of the frequencies in the contingency table is less than 5, the appropriate correction must be made in order to make the result reliable. The most advantageous correction is the one proposed by Yates (Myslivec, 1957, in Šmelko and Wolf, 1977) residing that the value of 0.5 be added to the minimum frequency and the other frequencies be adjusted so as to keep the marginal frequencies unchanged. In the case that $20 < n < 40$ and any of the expected frequencies $n'_{ij}$ is less than 5, the class in which the frequency is included should be merged with the neighboring (closest relative) class of *A* or *B* factor. For the range set $n < 20$ this methodology should not be used at all.

Variable $\chi^2$ is the basis for a test of hypothesis about the independence of factors *A* and *B*. Its small values argue in favor of the hypothesis, the large values against the hypothesis.

In practice, the compliance with the asymptotic distribution is considered to be sufficient if $a_{ij} > 5\ \forall i,j$. If the $\chi^2 > \chi^2_{(k-1)(m-1)}(\alpha)$, the hypothesis of independence of factors *A*, *B* is rejected. The critical values of $\chi^2_{(k-1)(m-1)}(\alpha)$ are tabulated, while *(k-1) (m-1)* represent the number of degrees of freedom.

Sometimes the $\chi^2$ is also called the ratio of assurance. The value of $\chi^2$ variable tells whether the dependency between factors *A* and *B* could be regarded as statistically significant or not. It does not say anything, however, about the dependence degree of these factors. The degree of dependence can be expressed by a coefficient of correlation of two multiple qualitative factors *A*, *B*, which is calculated by the Čuprov formula (Urbach, *In* Šmelko and Wolf 1977):

$$r_{AB} = \sqrt{\frac{\chi^2}{n \cdot \sqrt{(k-1) \cdot (m-1)}}} \tag{4}$$

## 3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

From the reports on occupational diseases, risk of occupational disease, professional poisonings and other health damages at work, we evaluated 505 illnesses in

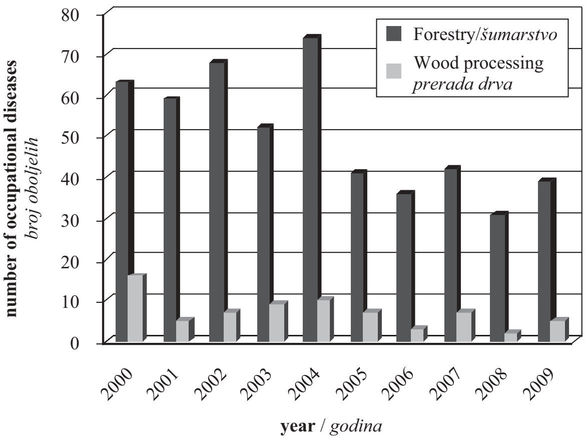


**Figure 1** Frequency of occupational diseases classified by years
**Slika 1.** Pojavnost profesionalnih bolesti u promatranom razdoblju po godinama

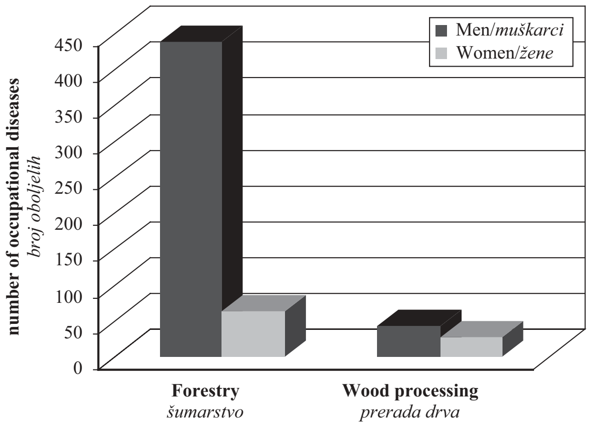


**Figure 2** Frequency of occupational diseases in forestry and WPI classified by gender
**Slika 2.** Pojavnost profesionalnih bolesti u šumarstvu i drvnoprerađivačkoj industriji prema spolu

business activity (NACE) 02 - Forestry, logging and related services and 71 diseases in business activities 20 - Manufacture of wood and products of wood and cork, except furniture, manufacture of articles of straw, plaiting and suchlike materials for the period 2000 – 2009.

The maximum number of diseases occurred in forestry in 2004 and in WPI in 2000. Interesting is the decrease in the occurrence of occupational diseases in the last five years (Fig. 1), i.e. since 2005 (mainly in forestry). Further annual development of diseases frequency has a fluctuating nature. In the future, however, it may be expected that occupational diseases frequency will have a decisively negative impact on this development as the way of performance of forest activities has changed in the Forests of Slovakia, the State Enterprise. They are now performed on contract basis, the non-employment arrangements with no possibility to relax and with newly adopted systemic measures (e.g. regular special medical examinations). In the WPI the highest number of occupational diseases was recorded in 2000. In 2004 the curve reached the second maximum and the trend is similar to forestry sector up to 2009. Like in forestry, an increase of occupational diseases can be expected.

The disproportion in the number of occupational diseases in forestry classified by gender can be justified by the number of female employees in this activity and also by the character of work (Fig. 2). The proportion of women with recognized occupational disease in the WPI, however, is up to 39% of all affected workers. This phenomenon can be partly explained by the fact that women are mostly occupied as auxiliary workers in this activity. Their work is often physically demanding, performed under adverse conditions and with a low level of mechanization. This situation has arisen due to the above mentioned facts and because the limits of women physical loading has been disregarded.

The occurrence of specific types of disease was evaluated by activities (Fig. 3) and also by gender (Fig. 4). Most of the diseases present in forestry are diseases caused by vibration –vibration disease of joints, bones, tendons and muscles (2802), disease of blood vessels and nerves (2801) and other vibration diseases and combined diseases caused by vibration (2803). The total share of these three types of diseases is only 52% of all diseases. This fact may be affected by the proportion of work carried out by machanes affecting the human body by vibration. The occurrence of diseases

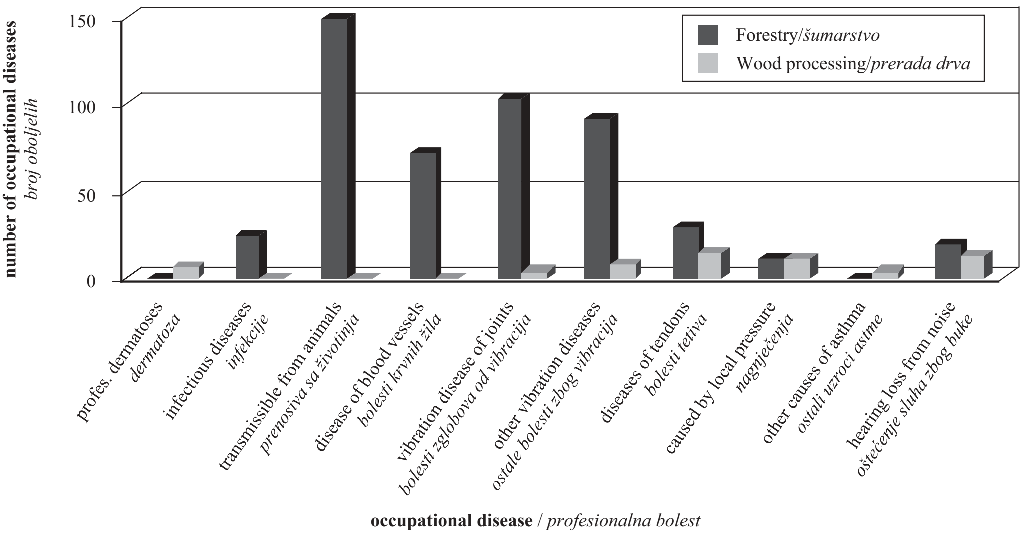


**Figure 3** Occurrence of specific diseases classified by activities
**Slika 3.** Zastupljenost pojedinih profesionalnih bolesti u šumarstvu i drvnoprerađivačkoj industriji

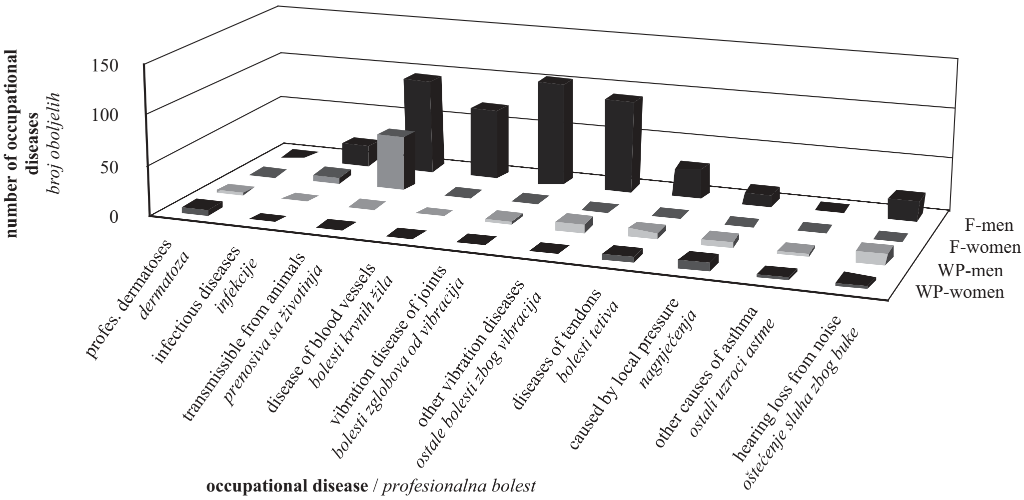


**Figure 4** Occurrence of specific diseases in forestry and WPI classified by gender
**Slika 4.** Zastupljenost pojedinih profesionalnih bolesti u šumarstvu i drvnoprerađivačkoj industriji prema spolu

transmissible from animals to humans either directly or through a vector (2600) is largely influenced by the nature and conditions of workplace. This disease dominates in women working in forestry, as they are mostly the ones who carry out silvicultural activities. In 2009, the disease „acute carbon monoxide poisoning“ was reccorded in forestry for the first time in the observed period. In specific conditions (dense young vegetation – tending felling and regeneration felling - natural regeneration, respectively) a specific microclimate (enclosed space) develops with little wind, which may lead to contamination of the environment with $CO_2$ when the portable chain saw is used.

Dominant diseases in men in WPI correspond to the overall occurrence of occupational diseases in the WPI, thus mostly hearing is harmed by an excessive noise. The occurrence of diseases defined as other vibration diseases and combined diseases from vibrations (2803), diseases of tendons, tendon sheaths and muscle insertions from excessive overloading (2902) and vibration disease of joints, bones, tendons and muscles (2802) can be characterized as high. Inwomen, the most often recognized disease had the nature of permanent nerve palsy caused by local pressure (2904), then diseases of tendons, tendon sheaths and muscle insertions from excessive overloading (2902) and professional dermatoses caused by other chemicals (organic and inorganic) (2217) follow.

Harmful factors occurring in forestry and woodworking industry, generating an occupational disease, or risk of occupational disease inception, poisoning, etc. are discussed in Figure 5 (Fig. 5). A simple analysis of the occurrence of occupational diseases in forestry indicated the most frequent harmful factor - vibrations. The share of vibrations transmitted to the limbs (machines, tools) (2002000001) accounted for 35 % and the share of mechanical vibrations (2002000000) accounted for almost 10 % of these factors. The WPI had the largest share of harmful factors - repetitive work with unilateral movements (4000020004), a significant share of vibrations transmitted to the limbs (machine, tools) (2002000001) and the noise (continuous noise, interrupted noise, noise in liquids) (2001010001). Noteworthy is the share of noise as a harmful factor, because it reached nearly 16 % of all the above factors in wood processing industry and in forestry the noise factor accounted for approximately 2.9 %. It can be assumed that the differences are caused by the specific noise spreading in large workshops and in open spaces. In assessing diseases caused by noise, the following factors should also be taken into consideration: noise parameters of machines and equipment, time of exposure to noise, technological and organizational measures, selection of adequate personal protective equipment and their proper use. In open space, it would be appropriate to assess the synergistic effect of weather on the action of vibration and noise as a harmful factor. In order to compare the age of occupational disease recognition in forestry and wood processing industry particular ages were categorized. The maximum in both activities was reflected in the range of 50 to 55 years. The curve describing the development of the occupational disease frequency in dependence on age has the course corresponding to the development shown in the chart (Fig. 6). Statistically, this distribution of frequencies can be characterized as right-asymmetric, i.e.: with the increasing age, the num-

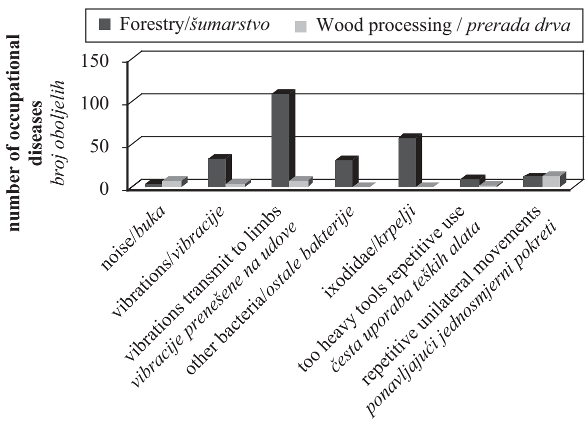


**Figure 5** Occurrence of harmful factors
**Slika 5.** Zastupljenost štetnih činitelja u šumarstvu i drvnoprerađivačkoj industriji

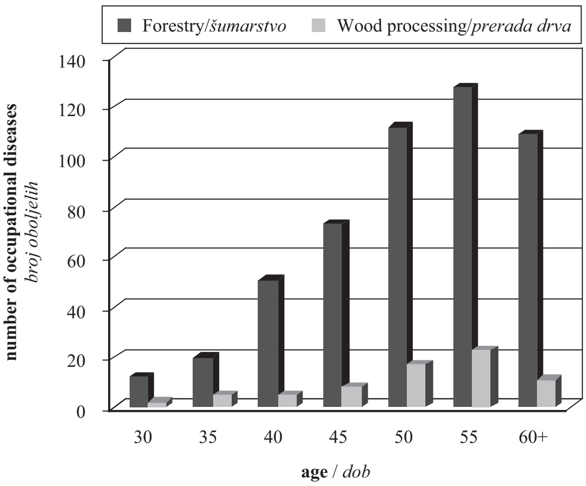


**Figure 6** Frequency of occupational diseases in forestry and WPI
**Slika 6.** Pojavnost profesionalnih bolesti u šumarstvu i drvnoprerađivačkoj industriji prema godinama starosti

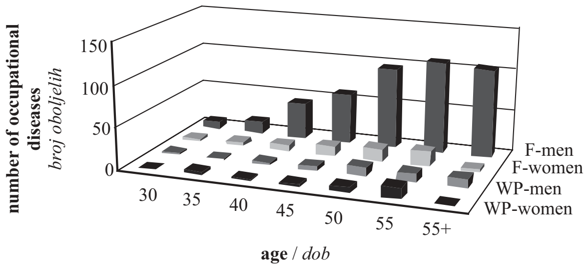


**Figure 7** The age of occupational disease recognition classified by gender
**Slika 7.** Godina prepoznavanja profesionalne bolesti u šumarstvu i drvnoprerađivačkoj industriji prema spolu

ber of recognized occupational diseases goes up. The development of occupational diseases by age is dependent on physical age of the worker, on duration of exposure and on individual susceptibility of the worker to the noise loading.

The same sort of intervals was also used to compare the age of occupational disease recognition classified by gender (Fig. 7). In forestry, in men, the highest number of recognized occupational diseases occurs in the age of 50 to 55, and there is also a high occurrence in the two adjacent age classes (45-50, 55 +), where the number of diseases in men working in the WPI also dominates. The culmination of recognized diseases in women is significant in both sectors in the age ranging between 50 and 55.

It has been possible to evaluate the duration of exposure as a factor influencing the risk of occupational diseases due to a database of information obtained only for the period 2000-2002 and 2005-2009. The chart (Fig.8) shows that the highest frequency of occurrence of occupational diseases in wood processing industry was registered in workers who were exposed for a period of 5 years. This is due to the fact that after 1989 there was an increase of ordinal reconstruction, i.e building of private low-capacity sawmills with saws for primary wood processing with a very simple mechanization. Similarly, work staff was not selected on condition of passing a medical examination at a specialized medicine department or Occupational Medicine Clinic. These conditions have probably led to this result. In forestry, workers who have been exposed to harmful factors for 6 to 10 years during their work are mainly affected. The number of occupational diseases caused by exposure from 11 to 30 years is relatively balanced. This may be affected by a responsible attitude of the employer who, because of the risk of occupational or professional disease, ensures the shift of employees to another position.

In this context, Sowa and Leszczyński (2007) recommend to shorten the exposure time. They established the highest risk of hearing damages in 50 years old workers with a 30-year exposure.

The frequency of occupational diseases is completely different, depending on the duration of exposure in men and women (Fig. 9). In the category with the exposure up to 5 years, they had a relatively similar number of recognized diseases. A maximum number of diseases occurred in women, and fewer diseases occurred in men. Based on this result it can be said that the female body has a higher sensitivity to harmful factors, mainly in the early years of exposure to a given factor. For men working in forestry a balanced course of the curve is typical, describing the frequency of occurrence of occupational diseases in dependence on the duration of exposure. And for men working in the WPI, two maximum values were recorded in the category with the exposure from 5 to 10 years and from 30 to 35 years during the observed period.

The analysis of the occurrence of occupational diseases classified by occupation was only possible in two separate parts because of changes in job classification. In the period 2000 - 2002 (Fig. 10), the workers in timber logging process (excluding mobile machinery operator) (6142), as well as workers working as operators of sawmills and other equipment for woodworking (8141) and operators of agricultural and forestry machinery (8331) were frequently affected by occupational diseases. A high percentage of occurrences of occupational diseases in timber logging workers is in accordance with a high risk of work and the share of these workers in forestry.

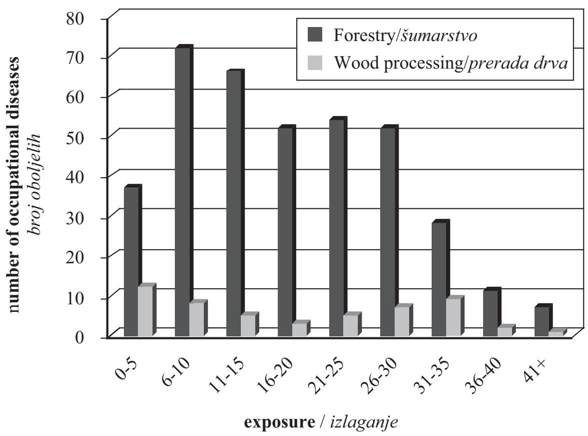


**Figure 8** Frequency of occupational diseases in forestry and WPI related to the duration of exposure
**Slika 8.** Pojavnost profesionalne bolesti u šumarstvu i drvnoprerađivačkoj industriji u odnosu prema trajanju izlaganja

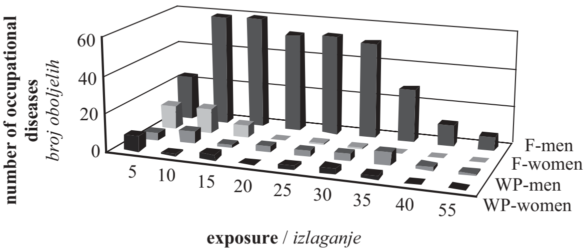


**Figure 9** Frequency of occupational diseases related to the duration of exposure and gender
**Slika 9.** Pojavnost profesionalne bolesti u šumarstvu i drvnoprerađivačkoj industriji prema trajanju izlaganja i spolu

The results of the assessment of occupational diseases in relation to occupation and work nature in the period 2003 - 2008 show that the highest number of recognized diseases was recorded in workers of group 61. This group is made of qualified (skilled) workers working in agriculture, forestry, fishing and hunting. It is the most numerous group of workers with the highest exposure to harmful agents at workplace. The significant risk also occurred in groups 32 (Technicians in biology, medical and agricultural workers and related branches workers) and 92 (Auxiliary and unqualified workers in agriculture, forestry, fisheries and related branches). Affected persons were also recorded in the following professions:
6141 – Workers in silviculture and forest treatment,
9212 – Auxiliary and unqualified forestry workers,
3212 – Technicians in Agronomy, Forestry, Agriculture and Water Management,
71 – Qualified workers at raw material exploitation, builders and employees in close branches (except operators of machines and devices),
83 – Drivers and operators of mobile machinery.

In the woodprocessing industry (Fig. 11) persons employed as operators of woodworking machines and those working in papermill (8149), cabinetmakers, woodcarvers and producers of wood products including the repairers (through the use of simple tools) (7422) and timber harvesting workers (except the mobile plant operators) (6142) were the most affected in the first period (2000-2002). The qualified market oriented workers in agriculture, forestry, fishery and hunting (61) were assessed as the most hazardous professions (with 9 reports) in the second monitored period, they were followed by operators of industry devices (81) with 7 reports and then came the auxiliary and unqualified workers in mines, quarries, industry, building, transport and related sections (93) with 5 reports. Other affected person’s professions were:
7123 – Carpenters and cabinetmakers,
8141 – Operators of saw and other wood processing devices,
8240 – Operators of automatic and semi-automatic woodworking machines (except machine setters),
8285 – Assembly workers mounting wood and wood based products,
74 – Other qualified processors and makers, else unmentioned (except machine and device operators),
82 – Operators of stationary devices and assembly workers,
91 – Auxiliary and unqualified employees oriented to distribution and service,
92 – Auxiliary and unqualified employees in agriculture, forestry, fishing and kindred profession,
99 – Unclassified or unknown.

The above mentioned method of the Contingency Tables (Tab. 2) has been used for statistical evaluation of dependency on its degree in the case of qualitative indicators: for the duration of exposure and number of occupational diseases in men and women in forestry and wood processing industry.

The formulation of the null hypothesis: there is no correlation between duration of exposure and the

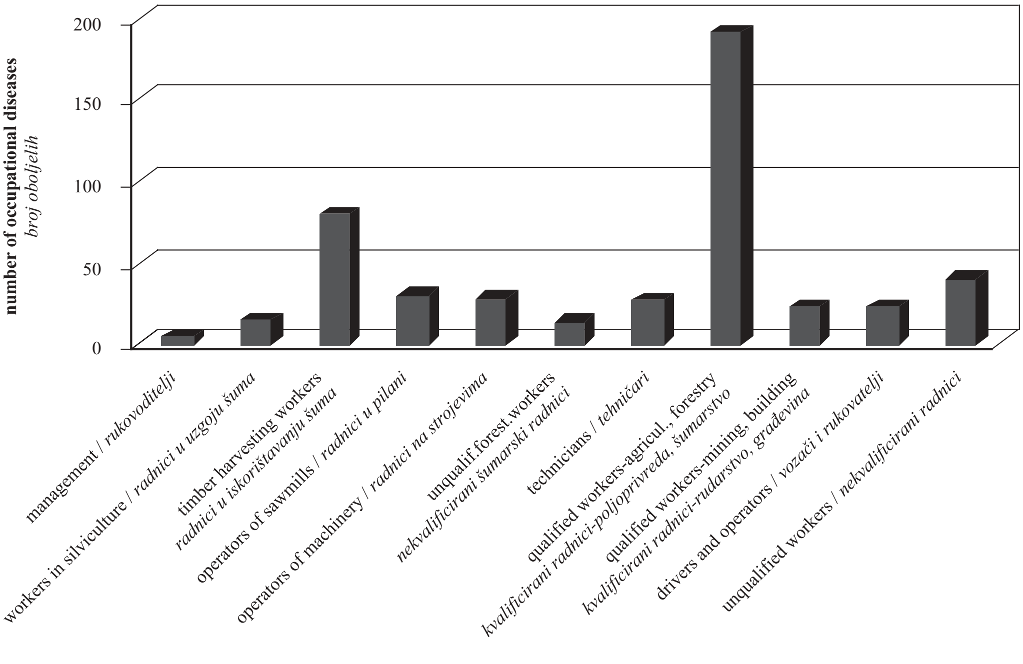


**Figure 10** Frequency of occupational diseases in forestry in relation to the affected person’s profession
**Slika 10.** Pojavnost profesionalne bolesti u šumarstvu prema radnome mjestu oboljelih

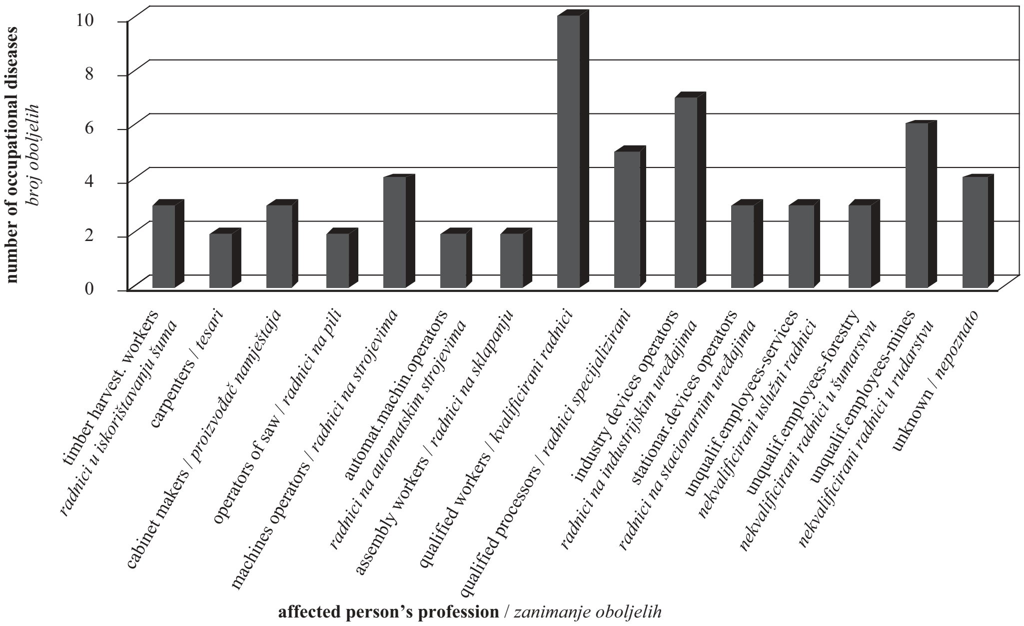


**Figure 11** Frequency of occupational diseases in WPI related to the affected person's profession
**Slika 11.** Pojavnost profesionalne bolesti u drvnoprerađivačkoj industriji prema radnome mjestu oboljelih

occurrence of occupational disease in men and women in forestry and WPI.

With the 5 % significance level and the degree of freedom 2, the chi square tabulated value is represented by 6.0 ($\chi^2 < \chi^2_{2(0.05)}$), thus it can be concluded that the presented hypothesis is rejected with 95 % probability. The significant differences were observed in the interval with the duration of exposure up to 5 years, when the men reported the lowest occurrence of occupational diseases. The women, with regard to the range of specified intervals, represent the category with the highest occurrence of occupational diseases. This argument confirms the different sensibility of men and women and also the varying intensity of harmful factors activity.

$r_{AB} = 0.28953703$

The dependence existing between the occurrence of occupational diseases, or professional diseases in men and women, in relation to the duration of exposure can be defined as poor.

The application of the Contingency Tables method also allows the evaluation of the correlation between the industrial deafness, vibration disease and workers' age (Tab. 3).

**Table 2** Number of occupational diseases in men and women in relation to the exposure duration
**Tablica 2.** Broj profesionalnih bolesti muškaraca i žena u odnosu prema trajanju izlaganja

| **Occupational diseases** / *Profesionalna oboljenja* | | | |
|---|---|---|---|
| **Exposure duration** *Trajanje izlaganja* | **Men** *Muškarci* | **Women** *Žene* | Σ |
| up to 5 years *do 5 godina* | 28 | 21 | 49 |
| | 42.97447796 | 6.025522 | |
| 5 – 20 years *5 – 20 godina* | 183 | 23 | 206 |
| | 180.6682135 | 25.33179 | |
| more than 20 years *više od 20 godina* | 167 | 9 | 176 |
| | 154.3573086 | 21.64269 | |
| Σ | 378 | 53 | 431 |
| $\chi^2$ = 51.0975997; Degree of freedom (DF): 2 | | | |

**Table 3** Correlation between industrial deafness, vibration disease and workers' age
**Tablica 3.** Korelacija između industrijske gluhoće, bolest zbog izlaganja vibracijama i godina starosti

| **Occupational diseases** / *Profesionalne bolesti* | | | |
|---|---|---|---|
| **Age** / *Godine starosti* | **Industrial deafness** / *Industrijska gluhoća* | **Vibration disease** / *Bolesti zbog vibracija* | Σ |
| 24 - 44 | 2.5 | 68.5 | 71 |
| | 7.352750809 | 63.647249 | |
| 45 + | 29.5 | 208.5 | 238 |
| | 24.64724919 | 213.35275 | |
| Σ | 32 | 277 | 309 |
| $\chi^2$ = 4.638594; Degree of freedom (DF): 1 | | | |

The formulation of the null hypothesis: there is no correlation between age and occurrence of industrial deafness and vibration disease. As one of the frequencies in the contingency table was less than 5, the Yates correction was applied.

The critical value of chi square for the 1st degree of freedom and significance level $\alpha$ = 5 % is $\chi^2_{1(0.05)}$ = 3.8. As the calculated value of $\chi^2$ (4.64) is greater than the tabulated critical value, it can be said with 95 % probability that the presented hypothesis is rejected.

The coefficient of association $r_{AB}$ = 0.122522 characterizes the dependence between age and deafness and vibration disease occurrence as weak.

## 4 CONCLUSIONS
## 4. ZAKLJUČCI

Although nowadays a variety of jobs are provided, where human presence may be almost completely eliminated, there are still occupations in which the human factor dominates for many reasons. Despite of preventive measures and compliance with safety and health at work, it is not possible to prevent occupational diseases and professional diseases, respectively.

The analysis of results showed that the occurrence of diseases recorded during the last reporting period is not negligible either. There is a high proportion of diseases in women in WPI, which reaches nearly 40 %, while in forestry men are mostly affected. The most frequent disease in forestry is the vibration disease. The total share of the three types of the vibration disease amounts to 52 % of all diseases.

In the wood processing industry, the damage to hearing was the most frequent disease. In forestry, men and women in the same age group - 50 to 55 were the most frequently affected. The same is true for women working in the WPI; in men working in this sector most diseases were found in the last three categories, i.e. age above 45 years. Based on the available data, it can be concluded that the number of deceases developed differently depending on the duration of exposure and gender in both sectors, but most diseases occurred in workers exposed to short-term exposure (up to 10, i.e. 5 to 15 years - men in forestry). Men who work in WPI are an exception, as two maxima in the frequency chart of diseases were found there. In forestry, workers in timber logging process (except mobile equipment operators) are most highly affected by occupational diseases, i.e. workers assigned to a group of skilled workers in agriculture, forestry, fishing and hunting. In theWPI, the affected persons are those employed in other service facilities for wood and paper mills, such as skilled market oriented workers in agriculture, forestry, fishing and hunting.

One of the main factors influencing the development of occupational diseases in Slovakia is the disintegration of the health care system. This is obvious mainly in the neglected preventive health examinations, where it is often possible to identify a threat from an occupational disease. Only a few companies organize convalescent stays for their workers. Mainly in forestry, the development of occupational diseases was crucially influenced by the fact that the work is provided by contractors. The basic legislative rule relating to the Health and Safety at workplace in Slovakia (National Council of Slovak Republic No. 124/2006 Coll. on health and safety at work and amendments thereof) only refers to employees, but does not address the issue of HSW among traders and self-employed persons. Therefore, it is necessary to initiate a change in legislation that would include ensuring the safety and health of sole traders mainly in terms of organization, control and consequences solution.

**Acknowledgments -** Zahvala

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# Sawing Capacities in the Czech Republic

## Pilanski kapaciteti u Republici Češkoj

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**ABSTRACT •** *The author recapitulates the development of the sawmilling in the Czech Republic after the World War II, and describes the major investments in the nineties of the past century and since 2000 until today. The paper shows the main timber-processing plants bordering with the surrounding countries, which fundamentally affect the exports of the logs from the Czech Republic. In the next part the author presents the summary of roundwood cutting in the period 1991 to 2009, and describes the creation of the database of the important sawmill plants in the Czech Republic. These plants are then divided into 7 groups according to the size, and their list is available in Table 2. Subsequently the paper provides a general division of the sawmill plants into individual groups according to the used technology. Then the author compares the sawmill sawing of more than 50,000 m$^3$ of logs per year in the Czech Republic, Switzerland, Germany and Austria. The conclusion of the paper deals with the potential future development of the sawmill capacities in the Czech Republic and with the level of their expected concentration.*

***Key words:*** *Czech sawmilling, sawmill production, sawing capacities, log cutting technology*

**SAŽETAK •** *Autor prikazuje i analizira razvoj pilanarstva u Republici Češkoj nakon Drugoga svjetskog rata te opisuje kapitalne investicije 1990-ih godina i one od 2000. godine do danas. U radu se prikazuju glavna postrojenja za obradu drva smještena u blizini granice sa susjednim zemljama, koja znatno utječu na izvoz trupaca iz Republike Češke. U jednom dijelu rada autor daje sažeti pregled obrade oblog drva u razdoblju od 1991. do 2009. godine i opisuje stvaranje baze podataka o važnim pilanama u Republici Češkoj. Pilane su prema veličini podijeljene u sedam skupina, a njihov prikaz dan je u tablici 2. Nakon toga u radu se može pronaći općenita podjela pilana u skupine prema primijenjenoj tehnologiji obrade trupaca. Autor zatim uspoređuje postrojenja koja propiljuju više od 50 000 m$^3$ trupaca u godini u Republici Češkoj, Švicarskoj, Njemačkoj i Austriji. Zaključno, u radu se navode mogućnosti razvoja pilanskih kapaciteta u Republici Češkoj i predviđa stupanj njihova okrupnjavanja.*

***Ključne riječi:*** *češko pilanarstvo, pilanska proizvodnja, pilanski kapaciteti, tehnologija obrade drva*

### 1 INTRODUCTION
### 1. UVOD

After 1948, due to the nationalization of industry in our country, the sawmill production was also separated from the development in the Western Europe. No big sawmill plants larger than 200,000 m$^3$ of logs cut per year were established for a long time in the Czech Republic, and most of the production was aimed at the sawmill cutting ranging between 20,000 and 50,000 m$^3$ of logs per year. The first steps toward the bulk production in this field were made in the seventies of the 20$^{th}$ century (Ždírec, Vrbno pod Pradědem, Volary, Borohrádek); however, there was no massive onset of new sawmill technologies. A classic frame-saw technology with a very low level of automation played a major role. Similar development was recorded in the eighties of the 20$^{th}$ century, and it can be said that there was no development of the sawmill capacities through several generations, as used to be the case in western countries.

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In 1991, the first small sawmill plants were transferred into private hands due to a small wave of privatization and they started developing gradually. Nonetheless, the majority of the mid-sized sawmill plants remained within the associations of the former large woodworking plants, which were organized on a regional level and controlled centrally. Then within the frame of these associations, such plants were transferred into private ownerships through a large privatization.

Thereafter, the first entries of the foreign capital into this field were recorded in the independent Czech Republic. This was an investment project of the company named Schweighofer into the sawmill plants in Ždírec, and later in Planá u Mariánských Lázní (Pražan and Příkaský, 2007).

The first half of the nineties of the 20$^{th}$ century was the time of a serious chaos, and the then-unknown phenomenon of insolvency. This naturally brought in considerable problems in transformation of the forest economy for the newly founded corporations, which made the base of the timber trade.

Not sooner than after 2000, other investments into timber processing were made to enhance further development of the later bankrupt sawmill plant in Ptení – a company of Javořice a.s., and especially later via the largest investment into the sawmill plant in Paskov by an Austrian company of Mayr Melnhof.

Within the last 5 years, the situation has changed considerably in Central Europe, and the vicinity of our borders received new investments involving the resources of large timber logs cutting held by the following companies:

- Klausner Holz Sachsen in Kodersdorf (northern border with Germany)
- Holzindustrie Maresch in Retz (near the southern border with Austria)
- Ludwig Ziegler in Betzenmühle (near the western border with Germany)

In the Czech Republic this type of development has been simultaneously accompanied by an important investment project of Javořice a.s. in Ptení, by a further increase of the sawmill capacity in Ždírec (Stora Enso Timber), and by a new, very intensive construction of the sawmill in Chánovice (near Horažďovice) rendered by a German company of Haas Fertigbau.

All of these investment projects do naturally create a certain tension on the market of coniferous timber logs, and certainly because of that, some of the projects have never been implemented (Protivín, Northern Bohemia, Etc.). However, during the development of large sawmills, the sawmill plants of various capacities, being established for many years, have become subject to eradication (e.g. Šumperk, Vrbno, Volary, Jirkov, Mariánské Lázně, Vrchlabí, Letohrad, Jihlava, Etc.). Nevertheless, in the same period many – especially very small - sawmill plants were established with an insignificant total timber production (Pražan, Příkaský: 2007). The newest development also caused the closure of the first large-scale sawmill plant in the Czech Republic (Javořice a.s. in Ptení) in the beginning of 2009. On the other hand, a new sawmill plant was built in Čáslav (260,000 m$^3$ of logs cut per year).

## 2 SAWING OF LOGS
## 2. PILJENJE TRUPACA

Today the sawing of logs and production of timber may be determined from the sources of the Ministry of Agriculture of the Czech Republic stated in the report on the status of the forests and forest economy in the Czech Republic.

A summary of these data is presented in Table 1 below.

According to the information of the Ministry of Agriculture of the Czech Republic, the above data were determined based on the total roundwood exploitation in the Czech Republic, out of which the exports of the logs are deducted and to which the imports of the logs are added. Based on the ratio of the fiber, fuel and roundwood, the cuts are calculated additionally. According to the author, the amount of sawn logs in 2010 may be estimated to approximately 7,000,000 m$^3$.

## 3 IMPORTANT SAWMILL PLANTS
## 3. VAŽNA PILANSKA POSTROJENJA

In autumn 2009, the management of the Association of Woodworking Plants in the Czech Republic (hereinafter referred to as "SDP"), which represents

**Table 1** Sawing of logs and production of timber in thousands of cubic meters (m$^3$) (Ministry of Agriculture of the Czech Republic: 1991 – 2009)
**Tablica 1.** Piljenje trupaca i proizvodnja piljenica iskazani u tisućama metara kubičnih (m$^3$) (Ministarstvo poljoprivrede Češke Republike, 1991 – 2009)

| Year *Godina* | Sawing of logs *Piljenje trupaca* | Timber production *Proizvodnja piljenica* | Year *Godina* | Sawing of logs *Piljenje trupaca* | Timber production *Proizvodnja piljenica* |
|---|---|---|---|---|---|
| 1991 | 3,850 | 2,400 | 2001 | 6,600 | 3,889 |
| 1992 | 3,850 | 2,400 | 2002 | 6,441 | 3,800 |
| 1993 | 4,500 | 2,800 | 2003 | 6,500 | 3,805 |
| 1994 | 5,600 | 3,500 | 2004 | 6,800 | 3,940 |
| 1995 | 6,000 | 3,800 | 2005 | 6,900 | 4,003 |
| 1996 | 6,200 | 3,900 | 2006 | 8,650 | 5,080 |
| 1997 | 5,784 | 3,393 | 2007 | 8,700 | 5,454 |
| 1998 | 6,250 | 3,420 | 2008 | 7,650 | 4,636 |
| 1999 | 6,580 | 3,577 | 2009 | 6,700 | 4,048 |
| 2000 | 7,170 | 4,106 | | | |

**Table 2** Division of the Czech Republic sawmill plants processing coniferous and leafy timber according to the amount of logs sawn in 2009 (active as of December 31, 2009)
**Tablica 2.** Podjela čeških pilana koje prerađuju četinjače i listače prema količini propiljenih trupaca u 2009. godini (podaci od 31. prosinca 2009)

| **Sequence number** *Broj skupine* | **Size group in m³ of logs sawn per year** / *Veličina skupine iskazana količinom propiljenih trupaca* | **Group title** *Naziv skupine* | **Number of sawmill plants in the group** *Broj pilana u skupini* | **Total sawing of logs in thousands of m³** / *Ukupni prorez u tisućama m³* | **Percent of sawing, %** *Udjel u ukupnom prorezu svih pilana,%* | **Percent of the total number, %** *Udjel u ukupnom broju pilana, %* | **Average log sawing of the plant in thousands of m³ per year** / *Prosječni godišnji prorez pilane u tisućama m³* |
|---|---|---|---|---|---|---|---|
| 1 | 200,000 plus | super-large sawmill plants *supervelike pilane* | 4 | 2,850 | 40.1 | 0.4 | 712 |
| 2 | 50,000 – 200,000 | large sawmill plants *velike pilane* | 12 | 956 | 13.5 | 1.1 | 80 |
| 3 | 20,000 – 49,999 | large-medium sawmill plants *umjereno velike pilane* | 35 | 1,005 | 14.1 | 3.3 | 29 |
| 4 | 10,000 – 19,999 | mid-sized sawmill plants / *pilane srednje veličine* | 58 | 747 | 10,5 | 5.4 | 13 |
| 5 | 5,000 – 9,999 | small sawmill plants of category 2 / *male pilane 2. kategorije* | 88 | 565 | 8.0 | 8.3 | 6.4 |
| 6 | 2,500 – 4,999 | small sawmill plants of category 1 / *male pilane 1. kategorije* | 37 + 80* | 127 + 250* | 5.3 | 11.0 | 3.2 |
| 7 | 0 – 2,499 | very small sawmill plants *vrlo male pilane* | 750* | 600* | 8.5 | 70.5 | 0.8 |
| | Total / *Ukupno* | | 1,064* | 7,100** | 100 | 100 | 6.7 |

* estimate of the amount and roundwood consumption of the small and very small sawmill plants not included in the list of the sawmill plants and not detected by the research conducted by SDP / *procjenjuje količinu potrošnje oblog drva malih i vrlo malih postrojenja koja nisu uključena u listu pilanskih postrojenja i nisu uključena u istraživanja koja provodi SDP*
** assumed sawing of all plants in the Czech Republic derived from the report on the status of the forests (Ministry of Agriculture of the Czech Republic: 2008) and from the percentage of drop in the sawing between 2008 and 2009 (found from the research conducted by SDP) / *pretpostavlja količinu proreza svih pilana u Češkoj Republici prema izvješću o stanju šuma (Ministarstvo poljoprivrede Češke Republike, 2008) i prema postotku smanjenja proreza između 2008. i 2009. godine (utemeljeno na istraživanjima koja provodi SDP)*

primarily the small and mid-sized plants, organized an extensive opinion poll among its member firms with the objective to find their current cutting capacity during 2008 and 2009, their revenues, and their total number of employees.

Based on the verified data on the annual sawing of logs in the sawmill plants, decision was made to create a nationwide list of important sawmill plants in order to allow monitoring of the participation of the SDP firms in the total sawing in the Czech Republic. For the purpose of this task, a team was assembled, which verified and detected the locations and outputs of the larger sawmill plants in the Czech Republic from December 2009 to February 2010. The guidance was based on the documentation provided by the management of Terra Magazine, on the original summary of the sawmill plant activities, and on the private database of the sawmill plants created by certain professionals in this field in the Czech Republic. Most of the plants were contacted by telephone, and the sawing data were provided by the owners or responsible employees. For the purpose of comparison, the data from 2008 were also requested (if known and available). With regard to the practical impossibility to find the sawing data from the small and very small plants, the minimum borderline was determined as 2,500 m³ of log sawing per year. The list was created successfully and contained more than 230 sawmill plants.

Based on the analysis of this list, the sawmill plants were divided into size groups according to the amount of the log sawing. In order to complete the quantity calculation of all sawmill plants, a professional estimate was made of the quantity of the small and very small sawmill plants according to the experiences from the regions of the Czech Republic, and according to the detected numbers of the sawmill plants in Germany, Austria and Switzerland. The mobile sawmill plants operating during a year at various locations were not accounted for.

The division of all sawmill plants is shown in Table 2.

**Table 3** Comparison of the amount and of sawmill plants in Central Europe processing more than 50,000 m³ roundwood per year (Holzkurier 2010a, 2010b, 2009)
**Tablica 3.** Usporedba veličine proreza u pilanama Središnje Europe koje propiljuju više od 50 000 m³ u godini

| **Country** *Država* | **Number of firms** *Broj tvrtki* | **Number of sawmill plants (locations)** *Broj lokacija pilanskih postrojenja* | **Annual consumption of roundwood in thousands of m³ 2009** *Godišnja potrošnja trupaca u tisućama m³* | **Plan for 2010 in thousands of m³** / *Plan za 2010. u tisućama m³* | **% of sawing from the country total in 2009** / *Postotak proreza u ukupnom prorezu 2009.* |
|---|---|---|---|---|---|
| Austria / *Austrija* | 37 | 55 | 12,481 | 12,663 | 95 |
| Germany / *Njemačka* | 75 | 89 | 28,151 | 28,435 | 77 |
| Switzerland / *Švicarska* | 6 | 7 | 888 | 950 | 40 |
| Czech Republic *Republika Češka* | 15 | 16 | 3,806 | unknown | 54 |

## 4 DIVISION OF SAWMILL PLANTS ACCORDING TO LOG CUTTING TECHNOLOGY
## 4. PODJELA PILANA PREMA PRIMIJENJENOJ TEHNOLOGIJI

The division of sawmill plants in the Czech Republic was performed according to the amount of cubic meters (m³) of logs cut per year to fit into groups, which also partially correspond to the technological advancement of individual sawmill plants. (Friess, 2006).

Generally, the individual cutting capacity groups could be divided as follows:

Groups according to the annual sawing of logs in cubic meters (m³)

0 – 5,000:
very small sawmill plants with no mechanical equipment; very small sawmill plants with frame saws without sawmill ground floors; or simple band-saw plants;

2,500 – 5,000:
small sawmill plants with no mechanical equipment; or small sawmill plants with primitive mechanical equipment with no electric drive;

5,000 – 10,000:
smaller sawmill plants mostly with single-frame saws; or exceptionally band-saw plants with several individual saws;

10,000 – 20,000:
mid-sized sawmill plants with single-frame saws but mostly dual-frame saws; moderately mechanical mid-size sawmill plants with electric-drive conveyors, mostly working in one shift; or log band-saw plants combined with trimming saw or resaw;

20,000 – 50,000:
large-medium sawmill plants with dual-frame gang circular saws, automated with mechanical equipment, mostly working in two shifts; or in some cases, the frame-saw plants, also combined with lines for cutting small diameter roundwood;

50,000 – 200,000:
large sawmill plants with aggregate technologies, automated, working in two or three shifts; or in some cases aggregate lines with a line of frame-saws for cutting thick logs;

200,000 plus:
super-large sawmill plants of more than 1,000,000 m³ of logs cut per year, with very powerful aggregate technologies, fully automated, working in three or four shifts – usually these plants feature more than one aggregate line, but there are also single-line operations with such high output achieved by means of continuous production.

## 5 COMPARISON OF LARGE SAWMILLS IN THE CZECH REPUBLIC AND SURROUNDING COUNTRIES
## 5. USPOREDBA VELIKH PILANA U ČEŠKOJ I OBLIŽNJIM DRŽAVAMA

The creation of the list of sawmill plants in the Czech Republic and detection of their sawing in 2009 allowed the comparison of large and super-large sawmill plants in the Czech Republic with certain countries that feature sawmill plants sawing more than 50,000 m³ of roundwood per year – this comparison is shown in Table 3.

## 6 POTENTIAL FUTURE DEVELOPMENT OF CONCENTRATION OF CAPACITIES IN THE CZECH REPUBLIC
## 6. MOGUĆNOSTI RAZVOJA I OKRUPNJAVANJA PILANSKIH KAPACITETA U REPUBLICI ČEŠKOJ

As seen in Table 3, the Czech Republic has not yet reached such concentration of the sawing in large sawmill plants as for example Austria and Germany, but the Czech Republic has already superseded the plants in Switzerland. The total rapid increase of the sawing in the Czech Republic is not usually the order of the day because the surrounding countries rather import the timber logs from the Czech Republic than export, and the resources in the Czech Republic are continuously exploited to their maximum at permanently sustainable output.

Due to the above reasons, it may be said that the establishment of the additional large sawmill capacities with more than 500,000 m³ of logs processed per year may not be expected, and that otherwise the large shifts in the sawing may happen in the amounts of 20,000 – 100,000 m³ with a shift to the higher level of processing at the expense of the small ones. Generally, it may be concluded that approximately 50% of all coniferous roundwood in the Czech Republic is processed by small and mid-sized sawmill plants, so they still happen to be the basic processors of this raw material.

We may assume that the additional concentration would be coming at a slow rate, not as fast as hitherto, and that the levels of, for instance, Germany may be reached within 10 to 20 years. The gradual modernization and increase in work productivity will cause the improvements in sawing of certain mid-sized sawmill plants; however, due to the long-term insecure situation in purchasing raw materials, such modernization would not be happening so often, and several of such plants may again cease to exist because of high indebtedness created by investments into the process of modernization.

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# Međunarodno znanstveno savjetovanje *WoodEMA 2011*

U organizaciji Oddelka za lesarstvo Biotehniške fakultete Sveučilišta u Ljubljani i međunarodne asocijacije za ekonomiku i menadžment u preradi drva i proizvodnji namještaja WoodEMA, i.a., u Kozini (Slovenija) od 8. do 10. lipnja 2011. godine održano je 4. međunarodno znanstveno savjetovanje pod naslovom *WoodEMA 2011 - Development trends in economics and management in wood processing and furniture manufacturing*.

Za savjetovanje je na 34 rada prijavljeno 60 autora iz devet europskih zemalja i iz Sjedinjenih Američkih Država. Savjetovanju je nazočilo 30 autora.

S. Borkowski i R. Stasiak-Betlejewska (Poljska) održali su predavanje o stanju i trendovima na europskom tržištu drvnih proizvoda.

J. Drabek i M. Merkova (Slovačka) u svom su se radu bavili mogućnostima vrednovanja povrata investicija u ljudske potencijale.

K. Durkova (Slovačka) također se bavila ljudskim potencijalima i predstavila je rad s temom pogodnosti zaposlenika u drvoprerađivačkoj struci.

J. Dvoraček i H. Mat'ova (Slovačka) u svom su radu predstavili filozofiju *dizajna za sve*, odnosno izradu namještaja namijenjenu osobama s invaliditetom te obradili percepciju javnosti o takvom namještaju.

P. Gejdoš (Slovačka) predstavio je rad o uvođenju sustava ISO 9000 u drvoprerađivačku djelatnost u Slovačkoj.

B. Glavonjić, M. Nešić i P. Sretenović (Srbija) dali su prikaz socioekonomskog značenja proizvodnje drvenog ugljena u Srbiji.

K. Greger, K. Bičanić i D. Glumac (Hrvatska) predstavili su provođenje sustava upravljanja kvalitetom u proizvodnji namještaja.

S. Hasanić, S. Brdarević i M. Obučina (Bosna i Hercegovina) dali su prikaz kontrole kvalitete masivnih drvnih ploča primjenom dijagrama trošak–učinak.

*Predavanje prof. dr. sc. Denisa Jelačića*

*Prezentacija novog predsjednika WoodEMA izv. prof. dr. sc. Darka Motika*

M. Hitka, A. Hajdukova i M. Sirotiakova (Slovačka) u svom su se radu bavili motivacijom uposlenika u jednoj slovačkoj tvrtki.

D. Ivković, M. Nešić i B. Glavonjić (Srbija) dali su prikaz upravljanja proizvodnjom u površinskoj obradi drvnih proizvoda.

D. Jelačić (Hrvatska) predstavio je analizu motivirajućih čimbenika u uvjetima normalnoga gospodarskog okruženja i u uvjetima gospodarske krize.

M. Jošt, P. Grošelj, A. Zupančić i L. Oblak (Slovenija) predstavili su način razvoja u proizvodnji drvnih prozora primjenom metode Quality Function Deployment (QFD).

V. Kaputa, H. Paluš, J. Parobek i M. Šupin (Slovačka) predstavili su probleme koji se pojavljuju u određivanju troškova pri ugovaranju šumskih radova.

J. Kropivšek, B. Likar, P. Grošelj i M. Jošt (Slovenija) dali su prikaz gospodarske situacije u preradi drva i proizvodnji namještaja u Sloveniji.

A. Kusa, A. Zauškova i V. Pizano (Slovačka) predstavili su vrednovanje alata marketinškog miksa pri odabiru namještaja u Slovačkoj.

O. Kusy (Slovačka) osvrnuo se na način vrednovanja učinkovitosti procesa kontrolinga u poduzećima za preradu drva i proizvodnju namještaja.

Ž. Meloska, I. Petrovska i B. Anakiev (Makedonija) u svom su radu opisali trenutačno stanje i strategiju izvoza namještaja u Makedoniji.

M. Merkova i J. Drabek (Slovačka) prezentirali su mogućnosti učinka izravnih stranih ulaganja u Slovačku.

M. Moro, R. Ojurović, K. Šegotić, D. Motik i A. Pirc (Hrvatska) predstavili su raspodjelu investicija u preradi drva i proizvodnji namještaja u Hrvatskoj u razdoblju 2005 - 2009.

*Sudionici savjetovanja WoodEMA 2011*

*Na izletu u Postojnsku jamu*

N. Neykov, A. Dobrichkova i A. Petkov (Bugarska) prikazali su utjecaj međunarodne financijske krize na proizvodnju i prodaju drvnih proizvoda i namještaja u Bugarskoj.

R. Novakova i A. Tomankova (Slovačka) opisali su mogućnosti i načine dobivanja nepovratne financijske potpore u popularizaciji znanosti i tehnologije u drvoprerađivačkoj industriji.

R. Novakova (Slovačka) ujedno je predstavila rad s temom odnosa dodane vrijednosti za kupca i profita za proizvođača u preradi drva i proizvodnji namještaja.

L. Oblak, A. Zupančić, J. Kropivšek (Slovenija) prikazali su mogućnosti razvoja pojedinih specijaliziranih proizvodnji u slovenskoj proizvodnji namještaja.

H. Paluš i J. Parobek (Slovačka) dali su prikaz promjena u konkurentnosti pojedinih klastera u šumarstvu Slovačke.

S. Petrović i B. Glavonjić (Srbija) prikazali su standarde i certifikaciju drvnog ugljena i briketa od drvnog ugljena te njihov utjecaj na razvoj i ujednačavanje tržišta.

A. Pirc, D. Motik, M. Moro, K. Šegotić i V. Gašparić (Hrvatska) dali su prikaz odnosa ukupnog prihoda i zaposlenosti u drvnom sektoru Hrvatske.

V. Pizano, A. Kusa i A. Zauškova (Slovačka) predstavili su potencijal slovačkih drvnih poduzeća s obzirom na korištenje internetom radi približavanja potencijalnim kupcima.

M. Potkany (Slovačka) prikazao je metodologiju vrednovanja ekonomskih učinaka *outsourcinga* u preradi drva i proizvodnji namještaja.

P. Schwarzbauer, S. Weinfurter, T. Stern, W. Hubert, S. Koch, C. Ledl i L. Jazayeri-Thomas (Austrija) dali su detaljan prikaz simulacije potražnje drva u Austriji.

A. Sujova (Slovačka) u svom je radu predstavila pristupe restrukturiranju u preradi drva i proizvodnji namještaja u Slovačkoj.

A. Šatanova i L. Krajčirova (Slovačka) bavili su se vrednovanjem metoda ponude.

R. Vlosky (SAD) i A. Pirc (Hrvatska) u svom su radu dali usporedne pokazatelje proizvodnih profila poduzeća u SAD-u i Hrvatskoj.

S. Weinfurter i P. Schwarzbauer (Austrija) obradili su utjecaj kupaca drvnih proizvoda na šumska gospodarstva u Austriji.

A. Zauškova, A. Kusa i V. Pizano (Slovačka) u svom su radu dali prikaz audita inovacijskih procesa u malim i srednjim drvoprerađivačkim tvrtkama Slovačke.

Uz međunarodno znanstveno savjetovanje, prema ustaljenom redoslijedu, održana je i redovita generalna skupština WoodEMA asocijacije, koja je ove godina bila i izborna. Za predsjednika Asocijacije u razdoblju 1. siječnja 2012 – 31. prosinca 2013. izabran je izv. prof. dr. sc. Darko Motik, dok je za isto mandatno razdoblje za generalnog tajnika WoodEMA treći put zaredom izabran prof. dr. sc. Denis Jelačić.

Tijekom savjetovanja organizirani su stručni posjeti poduzeću za proizvodnju namještaja Brest u Cerknici te Postojnskoj jami.

Generalni tajnik WoodEMA, i.a.
prof. dr. sc. Denis Jelačić

# INSPIRACIJA, INOVACIJA, INTERZUM - 2011

„Tko još nije čuo da je Interzum spreman za tržišnu utrku?“ To su riječi kojima je na otvorenju sajma Chris McGachy, jedan od organizatora, pozdravio sve nazočne.

Interzum je, prema njegovim riječima, vodeći sajam vizionarske tehnologije i inovativnog dizajna na polju industrije, pokućstva i dizajna interijera. Godina 2011. predstavila je više od 1 400 izlagača iz 60 zemalja, a 70 % od 50 000 registriranih posjetitelja bilo je iz inozemstva. Te činjenice daju sajmu status ne samo regionalnoga već i svjetskog sajma.

Organizatori ističu da Köln kao grad domaćin nije samo grad već i osjećaj. Taj grad u svojemu svakodnevnom životu objedinjuje umjetnost, kulturu, posao, opuštanje i ono najvažnije - dobar stil života. Tim je adutima privukao velik broj kreativnih poslovnih ljudi i to je razlog više da “ugosti” jedan tako važan sajam kao što je Interzum.

Koncept sajma predstavljen je pod krilaticom *inspiracija, inovacija, interzum.* Kao i mnogih godina do sada, ove je godine ponovno predstavljeno ono najbolje u industriji namještaja i inetrijera, materijala, okova, repromaterijala i brojnih drugih segmenata. Inovacija i trgovački potencijali u sektoru na sajmu su maksimalno došli do izražaja, a javno se raspravljalo i o novim smjernicama nužnima za daljnji razvoj.

Vizualno lagan dizajn, aplikacije za pokućstvo i dizajn interijera, mogućnosti izravne aplikacije tiska


**Slika 1.** Plakat *Interzum 2011*


**Slika 2.** *Interzum 2011*, glavni ulaz

na elemente pokućstva, funkcionalne inovacije u okovima i spojnoj tehnici, tekstil i novi načini obrade kože, strojevi za obradu… samo su neki od mnogih tema koje je obuhvatio ovogodišnji Interzum.

## PREGLED TEMA NA INTERZUMU 2011

U sjeni nedavne svjetske ekonomske krize pokazala se potreba za raspravom o održivom razvoju industrije, i samim time i o donošenju nekih smjernica na tragu kojih bi se kreirale razvojne politike.

Doneseni su sljedeći zaključci.

- Održivi je dizajn etičan: društvena i socijalna senzibilnost, životni vijek proizvoda, proizvodnja, distribucija, konzumacija i reciklaža. To su postavke na kojima moramo temeljiti svaki dizajnerski projekt. Održivi je dizajn kompleksan: naš je svijet postao digitalan, a krilatica *povratak prirodi i jednostavnosti* stapa se s otkrićima i primjenom novih tehnologija.
- Priroda i tehnologija su u sinergiji.
- Održivi je dizajn ekološki osviješten: većina ljudski proizvedenih predmeta na neki način destablizira

**Slika 3.** *Interzum 2011*, konferencijska sala

**Slika 4.** Primjer printa na vratnom krilu

naš ekološki sustav, tj. moramo dizajnirati proizvode koji od procesa proizvodnje i konzumacije do samog odlaganja što manje utječu na ravnotežu tog sustava! Održivi je dizajn inovativan: dizajn nije samo bolji proizvod, tehnološki usavršen i oblikovno poboljšan. Dizajn je stvaranje novih navika i načela uz pomoć novih proizvoda.

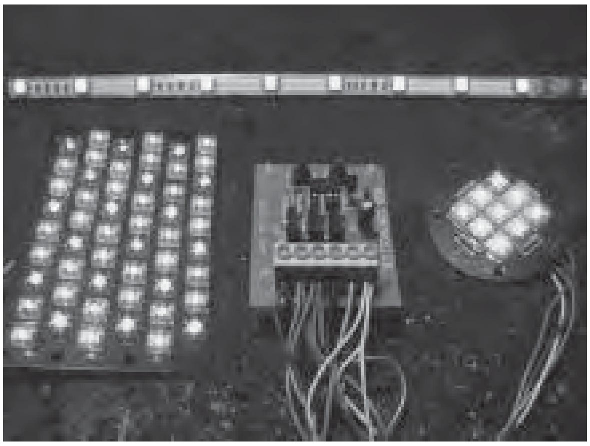
- Održivi je dizajn estetičan: odgovornost dizajnera je da svojim radom oblikuje estetski ugodne i prihvatljive oblike koji oplemenjuju naše okruženje.
- Održivi je dizajn autentičan: autentičnost proizvoda sociološki je izuzetno prihvatljiv koncept razvoja. Na korisnika utječe emocionalno, ali i izazivajući u njemu osjećaj pripadnosti ili ga korisnik povezuje s izvornim geografskim podrijetlom predmeta odnosno dizajnera. Time se pridonosi različitosti i unapređenju tradicija.

Lagane konstrukcijske ploče ponovno su bile apsolutni hit. Pokućstvo izrađeno od takvih ploča čvrsto je, čuva okoliš te je jednostavnije za transport.

Površine oplemenjene aplikacijom grafičkih otisaka individualiziraju neke industrijske procese i prilagođuju proizvod potrebama pojedinaca. To, kako su ga nazvali, „dodvoravanje“ kupcu postavlja nove izazove pred industriju jer time velike serije prilagođene ciljanoj populaciji gube na vrijednosti, a tržište dobiva nove zakonitosti. Industrija poprima neka obilježja obrtničkih radionica, pri čemu se prema načelu *just in time* proizvodi za individualnog naručitelja. Noviteti su usklađeni s nezaobilaznim trendom individualizma i raznolikosti, što u području vizualnih interpretacija doseže neslućene granice. Primjerice, na sajmu se moglo vidjeti mnogo individualnih i razigranih motiva i dijelova namještaja na kojima je otisnut logo tvrtke.

Ušteda energije, ekologičnost i održivi razvoj tri su glavne teme za inspiraciju. Uporaba niskoenergetske LED rasvjete svake sezone donosi nova iznenađenja, a s razvojem popratne industrije dodatno se otvara mnoštvo novih mogućnosti.

U svakom slučaju, izlagači na Interzumu ove su godine prikazali viziju za dizajn namještaja u budućnosti. Električni motori dobili su važne elemente koji idu u tom smjeru. Uporaba pokretnih sustava koji



**Slika 5.** RGB LED paneli i upravljačka jedinica

služe za otvaranje ladica ili vrata, spuštanje polica, podizanje radnih ploha ili prilagođivanje ojastučenih dijelova namještaja te daljnjim razvojem i neprestanim usavršavanjem omogućuju veću udobnost, praktičnost i funkcionalnost svakom korisniku.

Sajam, ako ga ne promatramo samo sa stručnoga gledišta, svakom posjetitelju otvara nove vidike i donosi inovacije o kojim prije nekoliko godina nismo ni razmišljali. Možda na temelju dojmova tih slučajnih posjetitelja možemo najbolje opisati sajam, a oni govore samo jedno: „Izvanredno.“

Sajam je bio tematski podijeljen na ove cjeline:

- priroda i interijer
- komponente i ergonomija
- oblici i dekoracije
- dijelovi i funkcije

**Slika 6.** Termakointerzum 2011, štand

- strojevi i tehnologija
- rasvjeta i inovacije
- trendovi
- nagrade *Interzum award: intelligent material &design.*

Da bismo što bolje dočarali atmosferu i događanja na sajmu, krenut ćemo od kraja.

## INTERZUM 2011: TRENDOVI

Visoka kvaliteta, zajedno s naprednim tehnologijama, uvjetovala je povećanje očekivanja u razvoju dizajna. Bez sumnje, dobar dizajn mora rezultirati kvalitetnijim i boljim proizvodom u svakoj novoj generaciji. Time dizajn i dizajner postaju bitan čimbenik u konkurentnosti na tržištu. Automatizacija proizvodnje prisiljava i dizajnera da bude „tehnološki osviješten" te da postupak prilikom razvoja proizvoda bude što jednostavniji.

Industrijski dizajneri i inženjeri, rade na razvojnim modelima čiji se dijelovi spojne tehnike, okovi i vodilice ne oblikuju samo kao funkcionalni dijelovi već oni postaju i estetska dogradnja cjelokupnog proizvoda. Integriranje tih sustava sistema u građevne jedinice namještaja povećavaju estetski i funkcionalni doživljaj gotovog proizvoda.

Možemo reći da trend više nije pojedinačni oblik ili boja, trend (unatoč tome što je riječ o pojedinim dijelovima za izgradnju sklopova) od ove godine postaje forma. Kao što je već navedeno, imperativ u današnjoj industriji postaje održivost i održivi razvoj. Održivi razvoj i ekologija zastupljeni su u svim inovacijama predstavljenima na ovogodišnjem sajmu. Uz unaprijeđenu tehnologiju, proizvođači naglašavaju ekološki način proizvodnje pojedine komponente, mogućnost njezine reciklaže i višenamjensku upotrebljivost u mnogim modelima u sklopu kojih se koristi.

Bitan čimbenik koji je naglašen u službenim priopćenjima, a mogao se primijetiti i u svakom razgovoru s proizvođačima i dobavljačima jest globalizacija tržišta. Svi ističu da prostor i vrijeme više nisu zapreka i da se uz pomoć globalne mreže dobavljača danas može u bilo koji dio svijeta u rekordno kratkom vremenu dostaviti bilo koji proizvod. Ako postoji zanimanje i osigurana su sredstva za implementaciju, postoje i kanali i alati kojima je sve ostvarivo. Postavlja se pitanje zašto se takva postavka stvari uvrštava u trendove? Odgovor se nameće sam po sebi jer u današnje vrijeme više nije bitno samo „načiniti inovaciju i uspostaviti lokalni trend". U današnje se vrijeme sve ostvaruje globalno, pa se samim time nameće neprestana potreba za komunikacijom i vremenom u kojemu se proces zbiva. Globalizacija pojedinačnog proizvoda postaje trend sam po sebi, kao i njezina implementacija. Raznolikost je ono što se ističe i za nju su bitne promjene. Tržište diktira tempo i potražnju, a protagonisti trendova pokazuju put kojim se treba kretati.

Što ostaje?

- lake ploče masivnog izgleda
- električni sustavi za ladice i pročelja
- antibakterijske površine
- „farmaceutske" ladice u kuhinjskom namještaju
- neprobojno staklo i staklene površine u kupaonicama i kuhinjama
- LED rasvjeta svih boja i oblika
- VOC neutralni adhezivi i boje
- višenamjenski sustavi za krevete, stolove i stolice
- plazma tehnologija za obradu rubova
- materijali za ojastučenje prilagodljivi klimi
- egzotični furniri
- dekorativni materijali s uzorcima drva i kamena
- prozračni i ergonomski oblikovani ležajevi - madraci
- strojevi koji se odlikuju velikom proizvodnom i energetskom učinkovitošću

Što dolazi?

- drvne ploče od brzorastućih vrsta biljaka, npr. od bambusa
- perolake drvne ploče
- drvo-plastični kompoziti
- materijali za vanjsku upotrebu velike otpornosti
- led diode u trakama
- promocija brendova u proizvođačkoj industriji
- inovacije u tehnologiji okova
- elastični furniri
- dekorativni materijali s fotografskim otiscima
- parketi od masivnog drva
- nanotehnologija u završnoj površinskoj obradi
- modularni višenamjenski namještaj

Iz priloženoga možemo vidjeti da valja ponoviti dobre stvari i da kvaliteta ostaje glavno obilježje trenda. Neki proizvodi i tehnologije opstaju na tržištu više

**Slika 7.** Prezentacija dekora za ojastučenje kao odjevnog modela

**Slika 8.** Hettich, trendovi u opremanju kuhinja

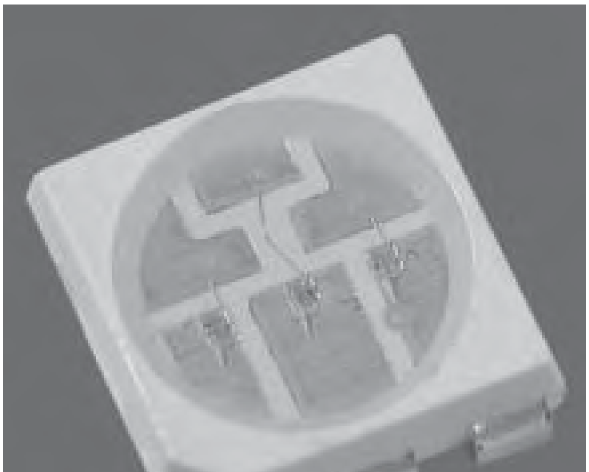
od 40 godina i još dugo neće dobiti ozbiljnu konkurenciju. Nasuprot tome inovacije koje se pojavljuju pokazuju toliku sposobnost prilagodbe da, osim što su sami po sebi nešto novo, imaju mogućnost stapanja s postojećim proizvodima.

## Rasvjeta i inovacije

Rasvjeta i rasvjetna tehnologija prešla je dug put od žarulje do LED diode.

**Slika 9.** RGB LED dioda s lećom

Pitanje kako rasvjetno tijelo uklopiti u interijer i proizvod tako da ono bude integralni dio cjeline ove je godine dobilo mnogo odgovora. Nanotehnologija u području LED rasvjete daje sve kvalitetnija rješenja, a rasvjetna tijela postaju sve manja. Uz činjenicu da se rasvjetna tijela smanjuju pojavljuje se paradoks da se njihova rasvjetna moć iz generacije u generaciju povećava. RGB LED (Red/crvena, Green/zelena, Blue/plava) tehnologija napravila je najveći iskorak. Sa samo nekoliko ampera dobiva se količina svjetla za koju se prije trošilo vrlo mnogo električne energije. LED to postiže diodama i lećama kroz koje svjetlost prolazi i tako se postiže velika disperzija. Dapače, ta disperzija vrlo jednostavno može biti kontrolirana malim korekcijama medija kroz koji svjetlost prolazi.




**Slika 10.** RGB LED dioda bez leće, tzv. modul

Jednobojna LED rasvjeta često je kritizirana zbog „hladne“ svjetlosti koje emitira. RGB LED mješanjem triju boja proizvodi bijelu svjetlost.

Neonska rasvjeta također nudi sve kreativnija rješenja, pogotovo u kuhinjama i radnim prostorima. Tanke, teško lomljive cijevi, s mogućnošću biranja spektra vidljive svjetlosti kojom se želi osvjetliti neki prostor vrlo su dobro rješenje.

## Strojevi i tehnologija

Adhezivi predstavljeni na Intezumu 2011 ozbiljno počinju konkurirati spojnim tehnologijama koje se koriste šivanjem. Čak je i nekoliko tvrtki koje se tradicionalno bave strojevima za šivanje počelo razvijati tehnologije spajanja bez vlakana. Adhezivi bazirani na vodenim disperzijama spajaju bez vidljivih šavova. Industrija u tome vidi potpuno novi smjer razvoja, posebice nove dizajnerske mogućnosti.

**Slika 11.** Stroj u procesu proizvodnje navlaka za madrace

Vlakno-konac, još je uvijek glavni spojni materijal pri šivanju i predviđa se da će proći još mnogo vremena prije negoli ljepilo zamijeni iglu i konac. CNC šivaći strojevi, robotizirane rubilice, automatski strojevi za proizvodnju madraca i ojastučenje te strojevi za proizvodnju madraca i kaučuk privukli su veliku pozornost zbog globalnih pozitivnih trendova glede tog materijala. Strojevi i tehnologija osnovna su polazišta za uspješnu proizvodnju i razvoj svake proizvodne tvrtke.

## Dijelovi i funkcije

Najopsežniji dio Interzuma 2011 činili su dijelovi elemenata i prateće funkcije koje ti mali dijelovi imaju. Zapravo, sve o čemu smo do sada pisali moglo bi se u nekom svom segmentu poistovjetiti s tom kategorijom. Sve vrste okova svih oblika i namjena, kotačići i kotači, spojna tehnika, rasvjeta, pametni okovi koji se koriste *bluetooth* tehnologijom, infracrveni senzori, računalna sučelja... Samo toj kategoriji trebalo bi posvetiti cijeli feljton da bismo dali pregled svega što se nudi. Organizatori su izjavili da „ta kategorija iz godine u godinu sve više nalikuje SF filmu nego sajmu“. Primjer toga su novi okovi koji u sebi objedinjuju *bluetooth* tehnologiju. Ukratko, to znači da je upravljanje njihovim funkcijama moguće putem bilo kojega komunikacijskog uređaja koji ima tu tehnologiju ugrađenu u svoj sustav. Primjerice, “skinete” program na svoj mobitel i


**Slika 12.** Prezentacija kotačića za uredski namješta

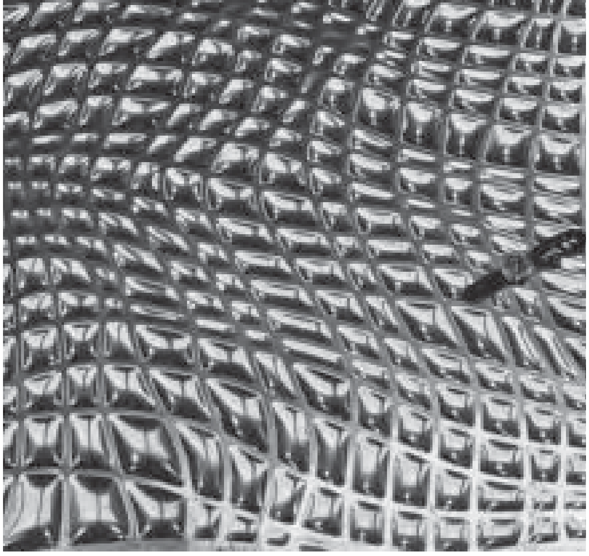
po kući otvarate i zatvarate vrata i ladice, podižete i spuštate krevet, stol, stolac, prilagođujete rasvjetu. Netko od izlagača u službenom se priopćenju i našalio primjetivši da "jedini problem u svemu tome nastaje ako vam netko hakira sustav".

Nanotehnologija i na tom području ima glavnu riječ, posebice kad je riječ o materijalima od kojih se izrađuje spojna tehnika. Unapređivanje metala, plastike i drugih materijala donosi uštedu, smanjuje dimenzije i povećava učinkovitost svakoga pojedinog elementa. Primjerice, tijela svornjaka izrađuju se od posebnih slitina koje su u svojoj mikrostrukturi porozne. Na taj se način štedi materijal potreban za izradu, a i cijena bi trebala pratiti uštedu materijala.

Računala i računalni programi već su zauzeli važno mjesto na sajmu, a tvrtki koje nude inovativne programe sve je više. Programi za obradu podataka, crtanje i vođenje procesa - sve se to nudilo na ovogodišnjem sajmu.

## Oblici i dekoracije

Unatoč svoj tehnologiji, vanjski je oblik ono što proizvod čini primamljivim. U ovoj su kategoriji objedinjeni baš svi proizvodi. Radi plasmana i proboja na


**Slika 13.** MDFi PVC u kombinaciji


**Slika 14.** *RE-Y-STONE*® dekorativne obloge

tržištu, svi „paze" na oblik prezentiranja svog uratka. Dizajneri su naporno radili i redizajnirali gotovo sve! Sve je dobilo nov oblik ili donijelo dodanu vrijednost i novu funkciju starom obliku. Prihvatnici, brave, stropni paneli, dekori za oblaganje ploča i inovacije u svim segmentima. Ističe se činjenica da je minula kriza sve proizvođače potaknula na razmišljanje i osmišljavanje novih proizvoda. Što je sve novo, teško je opisati riječima, to baš treba vidjeti.


**Slika 15.** Primjer dekora i alata kojim je dekor izađen (SIBU)


**Slika 16.** Rasvjetna tijela od savitljivog furnira

## Komponente i ergonomija

Spavanje i sjedenje osnovne su teme na koje se usmjerava industrija namještaja. Sati provedeni u uredskoj stolici tema su mnogih istraživanja provedenih na tom području. Kao i u drugim primjerima i ovdje je sveprisutna računalna tehnologija sa sustavima za nadzor i mjerenje. Oblik ne poprima samo estetsku nego i zdravstvenu funkciju. Oblici dobiveni pomnim istraživanjima ne samo da podupiru vaše tijelo, već i korigiraju položaj pri sjedenju ili ležanju. Senzori ugrađeni u samu konstrukciju šalju vam informacije o položaju tijela, težini tijela, prokrvljenosti udova, cirkulaciji tjelesnih tekućina.

Krevet je mjesto za odmor, ali i regeneraciju. *Smartwrap* koji ćemo spomenuti u sklopu nagrađenih inovacija uistinu podiže spavanje i ojastučeni namještaj na novu razinu. Spoj nanotehnologije, računalne tehnologije i tehnologije izrade kreveta i njegovih dijelova u medicinskoj i znanstvenoj primjeni sigurno imaju blistavu budućnost. Za privatnu upotrebu tu su klasični madraci-ležajevi i kreveti, uvelike poboljšani i materijalima i sitnim inovacijama uvedenima u proces proizvodnje.

Stolovi, radni, blagovaonički ili klupski nude mnoštvo inovacija. Ponovno su u upotrebi podizni mehanizmi, preklopni mehanizmi i izvlačni mehanizmi. Stol se može iz klupskog stolića preoblikovati u radnu površinu, i obrnuto. Višenamjensko svojstvo ključna je odrednica prilikom opisivanja dostignuća na tom području!

**Slika 17.** Bolnički krevet s ispunom od gela i ugrađenim senzorima

**Slika 18.** Gumeni ležajevi za izradu podnica kreveta

**Slika 19.** Primjer kliznih mehanizama za radne plohe

Višestruka namjena i kreativne ideje upravo su omogućeni kroz ideju inovativnog okova. Okov je u industriji namještaja davno prestao biti samo predmet povezivanja dviju ploha i postao je razvojna grana za sebe, čak je stekao tu prednost da se prvobitne plohe prilagođuju njemu kako bi zajedno činili novu i kreativnu cjelinu. Uz već navedene tvrtke, u *master* klasu okova ubraja se i tvrtka Häfele.

Uz glavno pravilo tvrtke - funkcionalnost s potpisom Häfele, predstavljene su brojne nove ideje. Kuhinja i dnevna soba mogu postati jedno. Dnevna se soba kada ogladnite pretvara u kuhinju, a kuhinja, kada vam se prispava u dnevnu sobu. Drugi razlog toga višenamjenskog

**Slika 20.** Häfele inovacije

namještaja je i današnja ograničenost stambenog prostora. U zemljama zapadne Europe trendo malih stanova, „spavaonica“, ponovno je u porastu. Električne klizne stijene, već dobro poznate minifiks mnogobrojne inovacije i poboljšanja, opet su nas nagnali na razmišljanje. Potreba za edukacijom stručnog osoblja u ulozi projektanata, tehnologa i dizajnera sve je bliža najužoj suradnji proizvođača i znanosti. MRSA ili lat. *Staphylococcus aureus*, bakterija koja često ostavlja trajne posljedice na bolesnike, sve je prisutnija u zajedničkim prostorima, posebice u sportskim dvoranama, ali i u ostalim javnim zgradama. Häfele je predstavio okov s antibakterijskom prevlakom Alsept, i time ponudio higijenski vrlo zanimljivu koncepciju - trajnu „preddezinfekciju“ površina najviše izloženih čestom dodiru s korisnicima objekata. Dakle, znanost i industrija u praktičnoj su kooperaciji.

### Priroda i interijer

Dovesti prirodu u interijer i životni prostor oblikovati prema prirodnim načelima - možemo li to nazvati pomodarstvom ili je stvarno riječ o održivom trendu? Vrijeme će pokazati.

Na sajmu je uočena jaka tendencija prema “iskrenosti” materijala. A kad je riječ o “iskrenosti”, prirodni su materijali najbolji. Među materijalima dominiraju drvo, staklo, keramika, kamen, neki metali kao što su nehrđajući čelik i do visokog sjaja lakirani MDF. U idućoj sezoni staklo će biti popularan materijal za pročelja i vrata kuhinjskih ormarića, regala i ormara. Tražit će se debelo staklo za gornje plohe stolova i mat staklo za prozirna vrata ormarića. U prostorima stana prevladava individualnost i umjerena decentnost bijele ili crne boje s naglašenim detaljima drva.

Prostori se povezuju u jedinstvene cjeline, nema jasno naznačenog prijelaza između, primjerice dnevnog boravka, blagovaonice i kuhinje. Kuhinje su samim time postale prošireni prostor i stilska poveznica s ostalim prostorima. Minimalizam u oblikovanju doveo je do još jačeg naglaska na materijalima i njihovim kombinacijama.

**Slika 21.** Priroda i interijer, kutak za okrepu

**Slika 22.** Izložbeni štand proizvođača furnira

U trendu su savitljivi furniri bez dodatne hidrotermičke obrade, 3D ploče, obloge od laminata koji opnaša doslovno sve prirodne površine, kao i furniri od vlakana banane, dekori od recikliranog papira. Može li to sve uistinu zamijeniti prirodne materijale u njihovu iskonskom obliku? Mogu li ti materijali imitirati onu energiju koju prenosi komad kamena obrađen u gazište stube ili hrastov pod impregniran uljem prirodnog podrijetla? Je li sintetika dosegnula tu razvojnu razinu da u sebi ne objedinjuje samo oblik i funkciju, već sa sobom donosi i dodatnu vrijednost u smislu poboljšanja kvalitete življenja?

Na kraju priče ne zaboravimo jedno: sve prije opisano i nabrojeno načinjeno je za čovjeka i prema njegovu sustavu vrijednosti. Čak i čovjek sam pokatkad zaboravi osnovnu namjenu svega i tada zastranjuje u nekim čudnim smjerovima. Donošenjem osnovnih postavki održivog dizajna Interzum 2011 aktivno se uključio u utrku za unapređenje življenja i održivog razvoja čovječanstva općenito. Neka te misli svakome budu vodilja u njegovu daljnjem radu, a svaka poslovna računica neka obuhvati i dobrobit za prirodu koja nam omogućuje život.

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Ivan Littvay, dipl. ing.
dr. sc. Danijela Domljan


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# DANIJELA DOMLJAN OBRANILA DOKTORSKI RAD

Danijela Domljan, magistrica dizajna, obranila je 18. svibnja 2011. godine na Šumarskom fakultetu Sveučilišta u Zagrebu doktorski rad s naslovom *Oblikovanje školskog namještaja kao preduvjet očuvanja zdravlja učenika*, pred povjerenstvom u sastavu prof. dr. sc. Boris Ljuljka, professor emeritus (Sveučilište u Zagrebu, Šumarski fakultet), prof. dr. sc. Ivica Grbac, redoviti profesor (Sveučilište u Zagrebu, Šumarski fakultet) i prof. dr. sc. Gordana Pavleković, dr. med., redovita profesorica (Sveučilište u Zagrebu, Medicinski fakultet, Škola narodnog zdravlja "Andrija Štampar") i time stekla akademski stupanj doktora znanosti s područja biotehničkih znanosti, znanstvenog polja drvne tehnologije, grane konstrukcije i oblikovanje proizvoda od drva. Mentor rada bio je prof. dr. sc. Ivica Grbac.

## PODACI IZ ŽIVOTOPISA

Danijela Domljan, rođ. Janković, rođena je 25. studenog 1971. u Zagrebu. Godine 1986. upisuje se u Školu za primijenjenu umjetnost i dizajn u Zagrebu, na Odjel unutrašnje arhitekture, gdje maturira 1990. u klasi profesora Vladimira Frgića. Iste godine upisuje, a 1996. godine diplomira na Interfakultetskom studiju dizajna pri Arhitektonskom fakultetu u Zagrebu, smjer Produkt dizajn, s temom *Sistem školskog namještaja. Didaktičko-odgojno sredstvo, radni stolić,* mentora Mladena Orešića. Od 1996. do 2004. zaposlena je u tvrtki Tvin d.d., Drvnoj industriji namještaja Virovitica – Predstavništvu Zagreb, u Odjelu za istraživanje, razvoj i racionalizaciju proizvoda. Od 2001. do 2003. radi kao vanjski suradnik u privatnoj školi Pomak, gdje drži vježbe za predmet Dizajnersko crtanje.

Godine 2001. upisuje poslijediplomski magistarski znanstveni studij na Šumarskom fakultetu, smjer Tehnologija finalnih proizvoda, 2006. prelazi na doktorski studij Drvna tehnologija, a 2008. prijavljuje doktorski rad s nazivom *Oblikovanje školskog namještaja kao preduvjet očuvanju zdravlja učenika*.

Nastavno djelovanje D. Domljan počinje u jesen 2003. na Šumarskom fakultetu Sveučilišta u Zagrebu u svojstvu stručne suradnice, a od ožujka 2004. godine izabrana je u suradničko zvanje asistentice na Drvnotehnološkom odsjeku, Zavodu za namještaj i drvne proizvode, gdje održava vježbe za kolegije Dizajn, Konstrukcije proizvoda od drva, Oblikovanje namještaja, Metodologija industrijskog dizajna i Interijer (Modul Dizajn, stari program). Prelaskom na bolonjski proces sudjeluje u kolegijima Oblikovanje namještaja, Metodologija industrijskog oblikovanja namještaja, Namještaj i opremanje prostora te Namještaj i zdravlje. Sudjelovala je u izradi novih nastavnih programa na Šumarskom fakultetu, za područje oblikovanja proizvoda od drva, te bila neposredna voditeljica na osam diplomskih i četiri završna rada s područja oblikovanja proizvoda od drva.

Od 2002. do 2006. sudjeluje kao istraživačica u interdisciplinarnim projektima Ministarstva znanosti obrazovanja i športa pod nazivom *Namještaj za sigurno, zdravo i udobno sjedenje i ležanje* (0068134), te od 2007. godine u projektu *Razvoj proizvoda od drva s ciljem očuvanja zdravlja* (068-0680720-0708) unutar programa *Novi materijali, procesi i proizvodi od drva*, (voditelj prof. dr. sc. Ivica Grbac), pri čemu se bavi problematikom sjedenja u obrazovnim institucijama i oblikovanjem školskog namještaja.

Članica je *Hrvatskog društva dizajnera* (HDD-a, od 1996), *Semera* – centra za umjetnički odgoj (članica Upravnog odbora, od 2000), *Hrvatskoga ergonomskog društva* (CES-a, od 2004), udruge *Odgoj PAžnje* (OPA) - udruge za promicanje vizualne kulture (od 2009), te suosnivačica i članica Vijeća *Zajednice za industrijski dizajn* pri *Centru za dizajn* u HGK (od 2010).

Članica je nekoliko stručnih povjerenstava i komisija u svojstvu dizajnera: članica povjerenstva za dodjelu nagrade Mobil optimum Ambienta (ZV) Zagreb (od 1996); članica Tehničke komisije za drvo, drvne proizvode i namještaj TK-8 za dodjelu nagrada Izvorno hrvatsko i Hrvatska kvaliteta pri HGK (od 2004); vanjska suradnica Povjerenstva za marketing i sajmove Udruženja drvno-prerađivačke industrije pri HGK (od 2005); članica Povjerenstva u natjecanju drvodjeljskih tehničara–dizajnera srednjih drvodjeljskih strukovnih škola RH (od 2000), članica Radne skupine za izradu Standarda kvalifikacije za drvodjeljskog tehničara–dizajnera u Obrazovnom sektoru šumarstvo, prerada i obrada drva pri ASO-u (od 2009), članica radne skupine projekta *Drvo je prvo* pri HGK i MRRSVG (od 2011), bila je i vanjska stručna suradnica Povjerenstva za pripremu i provedbu postupka nabave opreme interijera nekoliko tvrtki u RH, članica Povjerenstva za ocjenu nastavnog plana i programa za zanimanje drvodjeljski tehničar–dizajner srednjih drvodjeljskih strukovnih škola RH, smjer Obrada drva (1999 - 2000), članica komisije za selekciju radova za BIO 2000, Ljubljana (2000); članica Povjerenstva za izradu Nacionalne strategije dizajna (2007 - 2008), članica Povjerenstva za izradu Nacionalne strategije dizajna namještaja pri MRRSVG-u (2009 - 2010); članica Radne skupine i Ocjenjivačkog suda u natječaju za opremanje vrtića (HGK-HDD) (2009 - 2010); te voditeljica studije *Razvoj novih proizvoda u funkciji izvoza drvnog sektora – brand drvnog sektora*, za MPŠVG (2005).

Od 2004. godine članica je Povjerenstva za promidžbu Šumarskog fakulteta, u čijem sastavu organizira prezentacije na međunarodnim sajmovima i konferencijama (Ambienta i dr.), kao i na Smotrama Sveučilišta u Zagrebu (od 2002). Bila je suvoditeljica radionice i izložbe s temom *Daleki istok, dizajn stambenog prostora po principima feng shui*, u organizaciji I. klasične gimnazije i Semere (2001), te voditeljica radionica u organizaciji OPA-e s temom *Polica* (2009) i ASOO-a, s temom *Dizajnerski crtež* (2011).

Njezin profesionalni dizajnerski rad rezultirao je brojnim rješenjima u Tvinu, uz realizacije prijedloga razvoja novih programa i sustava uredskoga, školskoga i kućnog namještaja za serijsku i unikatnu proizvodnju, kao i samostalnim radovima na području industrijskog dizajna, projektiranja i opreme interijera te grafičkog oblikovanja. Izradila je nekolicinu projekata opremanja interijera u privatnim i javnim objektima, među kojima je i Projekt uređenja prostorija za oblikovanje proizvoda od drva – Dizajn studio na Šumarskom fakultetu u Zagrebu.

Godine 1994. kao studentica dobila je Rektorovu nagradu za *Sistem uredskog namještaja Owell*. Od 1990. godine s dizajnerskim rješenjima i projektima sudjeluje na nekolicini domaćih i međunarodnih izložbi, a profesionalno dizajnersko djelovanje okrunila je dvjema zlatnim medaljama, nekolicinom pohvala, priznanja i nagrada. Do sada je objavila više od 70 radova (41 znanstveni, 9 stručnih i 22 popularna rada), te održala više od 25 predavanja i posterskih prezentacija na znanstvenim i stručnim međunarodnim savjetovanjima i kongresima.

## PRIKAZ DOKTORSKOG RADA

Doktorski rad s naslovom *Oblikovanje školskog namještaja kao preduvjet očuvanja zdravlja učenika* sastoji se od 408 stranica (XVIII+390), te sadržava 114 slika, 218 tablica, 69 grafikona, 267 navoda citirane literature i jedan digitalni nosač zapisa s podacima i doktorskim radom u elektroničkom obliku.

Doktorski rad podijeljen je na osam poglavlja:

1. Uvod (4 str.),
2. Teorijske osnove i analiza problema (98 str.),
3. Temeljne postavke za istraživanje (3 str.),
4. Poligoni, uzorci, ispitanici i metode istraživanja (23 str.),
5. Rezultati istraživanja (134 str.),
6. Diskusija (54 str.),
7. Zaključak (2 str.),
8. Literatura (10 str.),

   Popis ilustracija,
   Popis tablica,
   Prilozi (30 str.).

Na početku rada navedeni su *Podaci za bibliografsku karticu* (na hrvatskome i engleskom jeziku), *Posveta, Sažetak, Sadržaj i Predgovor*, a na kraju rada su *Popis ilustracija* (slika i grafikona), *Popis tablica, Prilozi, Životopis* (na hrvatskome i engleskom jeziku) te *Popis objavljenih radova.*

### 1. Uvod

U *Uvodu* je kratko opisana problematika obrazovnog sustava i učenika u njemu. Upozorava se na to da promjene u sustavu nužno prate promjene u ponašanju i stajalištima mladih. Položaj tijela učenika, koji je već tradicionalno položaj sjedenja, više nije odgovarajući s obzirom na novonastale potrebe suvremenoga nastavnog procesa. Nužne su promjene koje se odnose i na oblikovanje školskog namještaja.

### 2. Dosadašnja istraživanja

Poglavlje *Dosadašnja istraživanja* drugo je poglavlje doktorskog rada u kojemu je osam potpoglavlja: *Povijesni pregled razvoja školskog sustava i namještaja*, *Suvremena škola i sukob tradicije s novim potrebama i zahtjevima*, *Rast i razvoj djece školskog uzrasta*, *Značaj antropometrije u oblikovanju školskog namještaja*, *Sjedenje u funkciji zdravlja učenika*, *Oblikovanje suvremene osnovne škole*, *Namještaj u osnovnim školama* te *Osvrt na dosadašnja istraživanja.*

To je poglavlje vrlo opsežno, ali važno jer je autorica time stvorila pretpostavke za izvrstan pregled područja i prikupila svu relevantnu literaturu. Tako opsežan pregled osobito je vrijedan jer su izneseni i kritički uspoređeni različiti teorijski pristupi i interdisciplinarna područja koja se bave srodnim temama i odnose se na učenike i namještaj. Na kraju je dan osvrt na dosadašnja istraživanja, i to kroz sva analizirana područja. Poglavlje završava uočenim i jasno detektiranim problemima koji se odnose na borbu suvremenih zahtjeva škole naspram tradicionalnih stajališta, na sekularne trendove rasta djece i dimenzije namještaja, na primjenu novih znanja o sjedenju, na investicije pri opremanju škola, na oblikovanje namještaja i okruženja za rad, na proizvodnu inertnost i dizajn za budućnost te postavljaju ključna pitanja oblikovanja novoga školskog namještaja. Navedeni problemi temelj su za postavljanje hipoteze i ciljeva istraživanja.

### 3. Temeljne postavke za istraživanje

U poglavlju *Temeljne postavke za istraživanje*, koje se sastoji od tri potpoglavlja (*Predmet istraživanja*, *Hipoteza* i *Cilj istraživanja*) definiran je predmet istraživanja te na odgovarajući način postavljena hipoteza i ciljevi rada. Predmet istraživanja jest oblikovanje suvremenoga školskog namještaja kao preduvjet očuvanja zdravlja učenika, odnosno oblikovanja odgovarajućega školskog stola i stolice kojima se dijete svakodnevno koristi u učionicama osnovne škole. Hipoteza rada je da postojeća opremljenost osnovnih škola nije odgovarajuća u smislu oblikovanja školskog namještaja i potreba korisnika (ergonomski, antropometrijski, funkcionalno), osobito su neodgovarajući stolovi i stolice, zbog čega učenici ne sjede sukladno prirodnim položajima ljudskog tijela te nastavnici imaju teškoća u provođenju nastavnog procesa. S obzirom na proizvođače, proces nabave i opremanja osnovnih škola nije odgovarajući, što se odražava u izostanku poštovanja brojnih zahtjeva glede oblikovanja te vrste proizvoda. Pravilno postavljena hipoteza omogućila je definiranje ciljeva istraživanja koji su se odnosili na utvrđivanje sukladnosti antropometrijskih veličina učenika od prvoga do osmog razreda i dimenzija namještaja u upotrebi, definiranje nepravilnosti u primjeni postojećega školskoga radnog namještaja u učionicama, utvrđivanje, na temelju karakterističnih položaja tijela učenika i njihova ponašanja na nastavnom satu, kao i mišljenja učenika i osoblja o postojećoj opremi, glavnih parametara za oblikovanje odgovarajućeg proizvoda koji omogućuje prirodne položaje tijela učenika, utvrđivanje prikladnosti postojećih oblikovno-konstrukcijskih rješenja školskog namještaja pri održavanju suvremenoga nastavnog sata te definiranje novih kriterija za optimalno oblikovanje, proizvodnju i plasman proizvoda koji bi omogućili zdrav i siguran položaj tijela učenika pri radu i odgovarajuće praćenje suvremene nastave. Glavni cilj istraživanja jest doprinos poboljšanju dizajna učenikova radnog mjesta u učionicama osnovnih škola, te postavljanje temelja za buduća istraživanja te problematike na području oblikovanja, konstruiranja, tehnologije izrade te uporabe novih materijala i njihove primjene.

**4. Poligoni, uzorci, ispitanici i metode istraživanja**

Poglavlje *Poligoni, uzorci, ispitanici i metode istraživanja* podijeljeno je na četiri istoimena dijela. U svakom se dijelu detaljno opisuju i objašnjavaju odabrani poligoni, uzorci i ispitanici s obzirom na primijenjene metode istraživanja. U istraživanju je sudjelovalo 79 osnovnih škola iz šest županija Republike Hrvatske (Zagrebačke, Primorsko-goranske, Splitsko-dalmatinske, Virovitičko-podravske i Osječko-baranjske te Grada Zagreba). Istraživanja su provedena s tri glavne skupine ispitanika: učenici (*u*), nastavnici (*n*) i proizvođači (*p*), na nekoliko razina i poligona (*P*), različitim metodama. Primijenjene su metode objektivnih mjerenja ispitanika–učenika (*Nu*=566; *P*=3) i uzoraka-namještaja – stolica (*Ns*=7, *P*=3) i stolova (*NS*=8, *P*=3), metoda anketiranja (*Nu*=255, *P*=3; *Nn*=371, *P*=64; *Np*=12, *P*=12) te metoda snimanja i promatranja ponašanja ispitanika–učenika (*Nu*=16, *P*=1).

**5. Rezultati istraživanja**

Peto poglavlje, *Rezultati istraživanja*, poglavlje je kojim je autorica sustavno prikazala rezultate i analizirala ih u zaokruženim i logički obrađenim cjelinama, podijeljenima prema metodama istraživanjima i odabranim ispitanicima. Dobiveni rezultati, podijeljeni u tri potpoglavlja: *Rezultati mjerenja ispitanika i uzoraka, Rezultati obrade anketnog upitnika*, *Rezultati promatranja, snimanja i fotografiranja* potvrdili su postavljenu hipotezu te pokazali da učenici ne mogu sjediti mirno, da sadašnja oprema i namještaj funkcionalnim dimenzijama ne odgovaraju antropometrijskim dimenzijama korisnika te da taj namještaj ne pomaže u održavanju zdravoga i tjelesno odgovarajućeg položaja na nastavnom satu. Poglavlje obiluje grafičkim prikazima, tablicama, grafikonima slikama i fotografijama, u ovisnosti o primijenjenim metodama obrade podataka (korišteni su statistički programi SPSS, Statistica 7.0, SAS, te Excell). Dokazano je da današnja oblikovno-konstrukcijska rješenja koja se primjenjuju u školama funkcionalnim dimenzijama ne odgovaraju antropometrijskim veličinama učenika niti propisanim dimenzijama u važećim normama, da svojom tvrdoćom, krutošću, nepomičnim i statičnim sklopovima pridonose još većem pomicanju tijela učenika, nemiru i vrpoljenju te ljuljanju na stolici i nerijetko padanju na leđa, što kratkotrajno i dugotrajno može imati velike posljedice za zdravlje. Nastavnici izražavaju nezadovoljstvo postojećim rješenjima namještaja, što se ponajprije odnosi na odlaganje pribora i torbi, nemogućnost jednostavnog razmještanja namještaja i stvaranja različitih tlocrtnih rasporeda u učionici, prilagođavanje individualnome i timskom radu i dr. Proizvođači izražavaju nezadovoljstvo postojećim procesima nabave i opremanja obrazovnih ustanova, a sadašnja rješenja oblikuju pojedinci ili grupe unutar tvrtke.

**6. Diskusija**

Poglavlje *Diskusija* podijeljeno je na pet potpoglavlja: *Analiza rezultata istraživanja, Vizija škole budućnosti – koncept novog školskog namještaja, Učionica iz snova, Oblikovanje idejnih rješenja* i *Implementacija inkluzivnog okruženja pomoću novooblikovanog namještaja*. U prvom potpoglavlju daje se osvrt i analiziraju rezultati istraživanja, dok se u idućima predlaže vizija škole budućnosti te definiraju potrebe i zahtjevi glede novoga školskog namještaja. U poglavlju su postavljene nove interdisciplinarne smjernice za oblikovanje školskog namještaja, poglavito u smislu zahtjeva o dizajnu (vizualnoj percepciji, estetici, funkciji, medicini, ergonomiji, pedagogiji, psihologiji, sociologiji, uporabi odgovarajućih materijala, tehnologiji izrade, ekologiji, cijeni i kvaliteti), te se daju nova rješenja i prijedlozi. Ciljevi idejnih rješenja koja se predlažu jesu smanjenje uočenih nedostataka, omogućavanje pravilnoga, udobnoga i sigurog rada te zaštitita zdravlja učenika.

**7. Zaključci**

U poglavlju *Zaključci* sažeto su prikazana glavna postignuća istraživanja: postojeća opremljenost osnovnih škola nije odgovarajuća sa stajališta oblikovanja učenikova radnog mjesta u učionici kojom se djeca dnevno koriste na nastavnom satu, osobito u smislu neusklađenosti antropometrijskih dimenzija učenika i funkcionalnih dimenzija namještaja, te se predlažu najmanje četiri razreda veličine pri opremanju školskih objekata. Pri radu se pojavljuje nepravilno držanje tijela učenika, nemirno sjedenje i dekoncentracija, bolovi u predjelu vrata, glave i leđa, kao i ozljede što se mora ukloniti odgovarajućim oblikovno-konstrukcijskim rješenjima koja omogućuju aktivne i sigurne promjene položaja tijela učenika. Postojeća rješenja nisu usklađena s novonastalim suvremenim potrebama nastavnog procesa, okruženje je nepoticajno za rad, a nastavnici imaju teškoća u provođenju nastavnog procesa, pa se predlaže da se namještaj za niže razrede oblikovno-konstrukcijski razlikuje od namještaja za starije učenike, što se ne odnosi samo na dimenzije, nego i na oblike, materijale, boje, funkciju, fleksibilnost i prilagodljivost te kognitivne i simboličke poruke. U procesu razvoja novih proizvoda moraju sudjelovati brojni stručnjaci interdisciplinarnih područja. Sadašnja rješenja školskog namještaja u Republici Hrvatskoj ne oblikuju interdisciplinarni timovi stručnjaka, manji se broj proizvođača koristi normama pri oblikovanju i konstruiranju te vrste proizvoda, pa se predlaže izrada vodiča ili pravilnika za opremanje školskih prostora koji detaljno definiraju obilježja namještaja (potrebne visinske razrede, izgled, konstrukciju, materijale, nadzor, uzorke) te olakšava proces oblikovanja i opremanja obrazovnih ustanova. Navode se glavni doprinosi rada i predlažu daljnja istraživanja usmjerena na dva glavna područja. Prvo se odnosi na implementaciju inkluzivnog okruženja uz pomoć novooblikovanog namještaja utemeljenoga na poznatim materijalima i konstrukcijama, a drugo na primjenu inovativnih konstrukcija i različitih materijala u oblikovanju novih proizvoda.

**8. Literatura**

Iz popisa literature vidi se temeljitost u proučavanju cjelokupnog razvoja školskog sustava i namještaja u njemu, problema i potreba suvremene škole, rasta i razvoja djece, sekularnih trendova te utjecaja na oblikovanje školskog namještaja, značenje antropometrije u oblikovanju školskog namještaja, kao i postojeće neusklađenosti dimenzija namještaja i učenika, biomehanike i ergonomije sjedenja te pojave umora, mišićno-koštanih poremećaja i bolova u leđima, ponašanja učenika pri sjedenju, projektiranja i opremanja školskih objekata, primjene normi za školski namještaj, kao i postojećih rješenja namještaja na tržištu i dr.

Posebno se ističe znanstveni doprinos rezultata istraživanja i buduća konkretna primjena u praksi. Predložena rješenja učeničkoga radnog mjesta bit će velika prevencija različitih bolesti uzrokovanih neodgovarajuće oblikovanim namještajem.

## OCJENA DISERTACIJE

Danijela Domljan u svom doktorskom radu s naslovom *Oblikovanje školskog namještaja kao preduvjet očuvanja zdravlja učenika* istražuje temu važnu za očuvanje zdravlja mlade populacije, kojoj do sada nije posvećeno dovoljno pozornosti ni u zemlji ni u svijetu. Temeljna pitanja na koja se u radu daje odgovor jesu čimbenici i zahtjevi učenika i nastavnika koji utječu na oblikovanje suvremenoga školskog namještaja te na pristup oblikovanju namještaja, opreme i cjelokupnog okruženja u učionici radi očuvanja zdravlja djece.

Način sagledavanja teme pokazuje interdiscplinaran odnos i širinu prepoznavanja problematike u oblikovanju školskog namještaja. Pravilno je uočeno i argumentirano da oblikovanje te vrste proizvoda nije jednostrano, naprotiv, indirektno je i direktno povezano s nekolicinom interdisciplinarnih čimbenika i zahtjeva koji postoje u suvremenome školskom okruženju, a utječu na ponašanje, stajališta i zdravlje mladih. To su razlozi za analizu razvoja školskog namještaja kroz povijest, kao i rezultata dosadašnjih istraživanja brojnih stručnjaka na području medicine, biomehanike, pedagogije, arhitekture, konstrukcija, procesa opreme obrazovnih objekata i dr. Jasno iskazani i postavljeni problemi proizašli iz navedene analize rezultirali su odgovarajuće postavljenom hipotezom i ciljevima rada.

Sve primijenjene metode istraživanja, u koje je uloženo mnogo truda, provedene su dobro i savjesno. Velika je pozornost pridana radu na terenu, u stvarnim uvjetima u kojima su odgovarajuće uočeni nedostaci postojećeg namještaja i opreme, što je rezultiralo obiljem podataka i slikovnih prikaza na kojima se temelje diskusija i zaključci.

Poglavlja u kojima se iznose rezultati istraživanja i diskusija o dobivenim rezultatima logično su podijeljena u zasebne cjeline prema redoslijedu istraživanja i uočenim problemima. Statistička obrada rezultata istraživanja korektno je provedena i jasno interpretirana. Na temelju dobivenih rezultata potvrđene su hipoteze i ciljevi te su postavljene nove interdisciplinarne smjernice u oblikovanju školskog namještaja u smislu dizajna (vizualne percepcije, estetike, funkcije, medicine, ergonomije, pedagogije, psihologije, sociologije, uporabe odgovarajućih materijala, tehnologije izrade, ekologije, cijene i kvalitete). Ciljevi novih rješenja koji se predlažu jesu smanjenje uočenih nedostataka, omogućavanje pravilnoga udobnog i sigurnog rada te zaštita zdravlja učenika.

Danijela Domljan svojim je radom pokazala da suvereno vlada navedenom problematikom, što se posebno vidi u pravilnom odabiru i primjeni različitih metoda, odabiru ispitanika iz različitih dobnih i ciljnih skupina te u odgovarajućem odabiru poligona istraživanja. Dobiveni su rezultati pravilno interpretirani, a zaključci jasni i konkretni. Rad je tehnički vrlo dobro opremljen, grafička je priprema prikaza pogodna za praćenje dobivenih rezultata, a metode statističke obrade rezultata istraživanja pravilno su odabrane i točno interpretirane. Obilje slikovnih prikaza, vlastitih crteža, skica, mentalnih mapa i fotografija s terena omogućuju jasno sagledavanje problematike. Analize ulaznih parametara za dizajn školskog namještaja, kao i idejna rješenja predložena u radu, temelj su za daljnji razvoj i proizvodnju suvremenih i inovativnih proizvoda.

Posebno treba istaknuti znanstveni doprinos rezultata istraživanja i konkretnu primjenu u praksi. Predložena i u modelima prikazana rješenja učeničkoga radnog mjesta bit će dobra prevencija različitih bolesti uzrokovanih neodgovarajuće oblikovanim namještajem.

prof. dr. sc. Ivica Grbac

# BALSA

## NAZIVI

Drvo trgovačkog naziva balsa pripada botaničkoj vrsti *Ochroma pyramidale* Urb. (sinonim *Ochroma lagopus* Sw.), iz porodice *Malvaceae* (potporodica *Bombacoideae*). Uz trgovački naziv balsa (Njemačka, SAD, Velika Britanija, Francuska, Nizozemska), postoje mnogi lokalni nazivi: tami (Bolivija); corkwood (Gvajana); cajeto; tanbor (Gvatemala); guano (Honduras); lano (Kolumbija); seibon butija (Kuba); gonote; maho (Meksiko); catillo (Nikaragva); topa (Peru); balsahout (Surinam); tacarigua (Venezuela); enea, pung (Kostarika); lanero (Kuba); polak (Honduras, Gvatemala, Nikaragva). Ime balsa španjolska je riječ za splav.

## NALAZIŠTE

Balsa je prirodno rasprostranjena u tropskim kišnim šumama srednjega i sjevernog dijela Južne Amerike, od Bolivije, Perua, Južnog Meksika do Brazila, osobito u Ekvadoru, na zapadnim Indijskim otocima te u Africi (Kamerun) i jugoistočnoj Aziji (Java). Tipično nalazište balse su niže nadmorske visine, posebice na aluvijalnim plodnim tlima pokraj vodotoka. Raste na čistinama i sječinama, a kultivira se i na plantažama. Dok u prirodi rastu otprilike 2 – 3 stabla po hektaru, u plantažnom je uzgoju gustoća stabala 50 – 100 po hektaru. Danas na tržište dolazi oko 60 % balse uzgojene na plantažama.

## STABLO

Balsa je brzorastuća listača. U optimalnim uvjetima na plantaži stabla za 6 do 7 godina mogu narasti do 24 m visoko, sa srednjim promjerom od 75 cm na prsnoj visini. Prirodno uzgojena stabla visoka su od 18 do 27 m, a prsnog su promjera od 75 do 120 cm. Visina čistog debla iznosi od 10 do 15 m. Debla su pravilna, cilindrična oblika. Kora je mekana, siva, u starosti izbrazdana, debljine 1,3 cm.

## DRVO

### Makroskopska obilježja

Drvo balse rastresito je porozno, grube teksture i s dobro vidljivim porama. Srž drva obično je bijela ili siva, a bjeljika se bojom neznatno razlikuje od srži. Granica goda je neuočljiva, a pokatkad je uočljiva zbog promjene udjela pora.

### Mikroskopska obilježja

Traheje su velike i dobro vidljive, pretežno u malim skupinama, obično u kratkim radijalnim nizovima (2–3 traheje). Na 1 mm$^2$ nalaze se 1–2 traheje. Prosječni tangenti promjer traheja iznosi 130...215...260 μm. Volumni udio traheja je od 3,0 do 4,5 %. Ploča perforacije članaka traheja jednostavna je.

Aksijalni je parenhim apotrahealni i paratrahealni. Aporatehalni je parenhim difuznog rasporeda. Paratrahealni je aksijalni parenhim oskudan ili vazicentričan. Volumni udio parenhima iznosi oko 74 %.

Drvni traci sastoje se od dvaju ili više različitih tipova stanica (heterocelularni), s izrazito kvadratičnim ili uspravnim stanicama na rubnim dijelovima traka. Širina trakova je 24...95...135 μm. Visina trakova je od 200 do 3 500 μm, a gustoća trakova iznosi 2...3...4 na 1 mm. Volumni udio trakova u građi drva je oko 17–19 %.

Drvna su vlakanca tankostjena. Prosječna je duljina vlakanaca 1690...2170...3600 μm, promjer lumena 4,8 ... 11,1 .. .18,7 μm, a dvostruka debljina staničnih stijenki 1,8 ... 3,2 ... 6,2 μm. Volumni udio vlakanaca je oko 4 %.

### Fizikalna svojstva

| | |
|---|---|
| Gustoća standardno suhog drva $\rho_o$ | 50...130... 410 kg/m$^3$ |
| Gustoća prosušenog drva $\rho_{12-15}$ | 70...160...440 kg/m$^3$ |
| Gustoća sirovog drva $\rho_s$ | 270 – 360 kg/m$^3$ |
| Poroznost | oko 91 % |
| Radijalno utezanje $\beta_r$ | 1,8 – 3,0 % |
| Tangentno utezanje $\beta_t$ | 3,5 – 5,3 % |
| Volumno utezanje $\beta_v$ | 6 – 9 % |

### Mehanička svojstva

| | |
|---|---|
| Čvrstoća na tlak | 3,5...9,4...27 MPa |
| Čvrstoća na vlak, paralelno s vlakancima | do 75 MPa |
| Čvrstoća na vlak, okomito na vlakanca | oko 1 MPa |
| Čvrstoća na savijanje | 5,3...19...39 MPa |
| Čvrstoća na smik | oko 1,1 MPa |
| Tvrdoća (prema Brinellu), paralelno s vlakancima | 0,3...0,7...1,2 MPa |
| okomito na vlakanca | 0,2 – 0,3 MPa |
| Modul elastičnosti | 1,1...2,6...6,0 GPa |

## TEHNOLOŠKA SVOJSTVA

### Obradivost

Zbog vrlo male gustoće drvo balse teško se obrađuje. Rezanje i ljuštenje drva ne preporučuje se. Vijci i čavli lako se koriste, no drvo je previše mekano da bi ih trajno čvrsto držalo. Dobro se lijepi i površinski obrađuje.

### Sušenje

Suši se dobro. Sirovo drvo balse ima izuzetno visok sadržaj vode. Potrebno ga je sušiti odmah nakon rušenja da bi se izbjegla pojava raspucavanja i skorjelosti. Prirodno sušenje ima prednost pred umjetnim. Sušenje u sušionici zahtijeva posebnu vještinu i brigu zbog velikog rizika od pojave skorjelosti ili pregrijavanja drva.

### Trajnost

Drvo je slabo do izrazito slabo trajno. Bjeljika i srž slabo su otporne na insekte, termite i gljive uzročnice truleži. Bjeljika je vrlo permeabilna.

### Uporaba

Drvo balse vrlo je male gustoće i služi za gradnju splavi, čamaca i pojasa za spašavanje, za toplinsku i akustičnu izloaciju, gradnju zrakoplova i sanduka te za proizvodnju plutača. Sporedni proizvod je vuna od sjemenaka koja se upotrebljava za punjenje jastuka i madraca.

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izv. prof. dr. sc. Jelena Trajković
doc. dr. sc. Bogoslav Šefc

### ERRATA CORRIGE

U radu "The influence of solvent content in liquefied wood and of the addition of condensed tannin on bonding quality" objavljenom u broju 2/2011 napravljena je pogreška u jednadžbi (1). Jednadžba treba glasiti $TAR = \left(\frac{W_1 - W_2}{W_3}\right) \cdot 100\%$. Uredništvo se ispričava autorima i čitateljstvu na nenamjernom propustu.

In the paper named "The influence of solvent content in liquefied wood and of the addition of condensed tannin on bonding quality" published in No. 2, 2011 the equation (1) is not correct. The correct equation is $TAR = \left(\frac{W_1 - W_2}{W_3}\right) \cdot 100\%$. Editorial office apologizes to authors and readers for unintentional error.

## Upute autorima

Sve autore molimo da prije predaje rukopisa pažljivo prouče sljedeća pravila. To će poboljšati suradnju urednika i autora te pridonijeti skraćenju razdoblja od predaje do objavljivanja radova. Rukopisi koji budu odstupali od ovih odredbi i ne budu udovoljavali formalnim zahtjevima bit će vraćeni autorima radi ispravaka, i to prije razmatranja i recenzije.

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Časopis "Drvna industrija" objavljuje izvorne znanstvene i pregledne radove, prethodna priopćenja, stručne radove, izlaganja sa savjetovanja, stručne obavijesti, bibliografske radove, preglede te ostale priloge s područja iskorištavanja šuma, biologije, kemije, fizike i tehnologije drva, pulpe i papira te drvnih proizvoda, uključivši i proizvodnu, upravljačku i tržišnu problematiku u drvnoj industriji.

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Znanstveni i stručni radovi objavljuju se na hrvatskome uz širi sažetak na engleskome ili njemačkome, ili se pak rad objavljuje na engleskome ili njemačkome, s proširenim sažetkom na hrvatskom jeziku. Naslovi i svi važni rezultati trebaju biti dani dvojezično. Ostali se članci uglavnom objavljuju na hrvatskome. Uredništvo osigurava inozemnim autorima prijevod na hrvatski. Znanstveni i stručni radovi podliježu temeljitoj recenziji bar dvaju izabranih recenzenata. Izbor recenzenata i odluku o klasifikaciji i prihvaćanju članka (prema preporukama recenzenata) donosi Urednički odbor.

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Autori su potpuno odgovorni za svoje priloge. Podrazumijeva se da je autor pribavio dozvolu za objavljivanje dijelova teksta što je već negdje drugdje objavljen, te da objavljivanje članka ne ugrožava prava pojedinca ili pravne osobe. Radovi moraju izvještavati o istinitim znanstvenim ili tehničkim postignućima. Autori su odgovorni za terminološku i metrološku usklađenost svojih priloga.

Radovi se, u dva tiskana primjerka i u elektronskom zapisu, šalju na adresu:

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### Rukopisi

Predani rukopisi smiju sadržavati najviše 15 jednostrano pisanih DIN A4 listova s dvostrukim proredom (30 redaka na stranici), uključivši i tablice, slike i popis literature, dodatke i ostale priloge. Dulje članke je preporučljivo podijeliti u dva ili više nastavaka.

Tekst treba biti napisan u MS Wordu, u normalnom stilu bez dodatnog uređenja teksta. Uredništvo prihvaća elektronski zapis na disketi, CD-u ili putem elektronske pošte.

Prva stranica poslanog rada treba sadržavati puni naslov, ime(na) i prezime(na) autora, podatke o zaposlenju (ustanova, grad i država), te sažetak s ključnim riječima (približno 1/2 DIN A4 stranice, u obliku bibliografskog sažetka).

Znanstveni i stručni radovi na sljedećim stranicama trebaju imati i naslov, prošireni sažetak i ključne riječi na jeziku različitom od onoga na kojem je pisan tekst članka (npr. za članak pisan na engleskome ili njemačkome naslov, prošireni sažetak i ključne riječi trebaju biti na hrvatskome, i obratno). Prošireni sažetak (približno 1 1/2 stranice DIN A4), uz rezultate, trebao bi omogućiti čitatelju koji se ne služi jezikom kojim je pisan članak potpuno razumijevanje cilja rada, osnovnih odrednica pokusa, rezultata s bitnim obrazloženjima te autorovih zaključaka.

Posljednja stranica sadrži titule, zanimanje, zvanje i adresu (svakog) autora, s naznakom osobe s kojom će Uredništvo biti u vezi.

Znanstveni i stručni radovi moraju biti sažeti i precizni, uz izbjegavanje dugačkih uvoda. Osnovna poglavlja trebaju biti označena odgovarajućim podnaslovima. Napomene se ispisuju na dnu pripadajuće stranice, a obrojčuju se susljedno. One koje se odnose na naslov označuju se zvjezdicom, a ostale natpisnim (uzdignutim) arapskim brojkama. Napomene koje se odnose na tablice pišu se ispod tablice, a označavaju se uzdignutim malim pisanim slovima abecednim redom.

Latinska imena pisana kosim slovima trebaju biti podcrtana.

**U uvodu** treba definirati problem i, koliko je moguće, predočiti granice postojećih spoznaja, tako da se čitateljima koji se ne bave područjem o kojemu je riječ omogući razumijevanje namjera autora.

**Materijal i metode** trebaju biti što preciznije opisane da omoguće drugim znanstvenicima obnavljanje pokusa. Glavni eksperimentalni podaci trebaju biti dvojezično navedeni.

**Rezultati** trebaju obuhvatiti samo materijal koji se izravno odnosi na predmet. Obvezatna je primjena metričkog sustava. Preporučuju se SI jedinice. Rjeđe rabljene fizikalne vrijednosti, simboli i jedinice trebaju biti objašnjeni pri prvom spominjanju u tekstu. Za pisanje formula koristiti Equation Editor (program za pisanje formula unutar MS Worda). Jedinice se pišu normalnim (uspravnim) slovima, a fizikalni simboli i faktori kosim slovima. Formule se susljedno obrojčavaju arapskim brojkama u zagradama, npr. (1) na kraju retka.

Broj slika mora biti ograničen na samo one koje su prijeko potrebne za pojašnjenje teksta. Isti podaci ne smiju biti navedeni u tablici i na slici. Slike i tablice trebaju biti zasebno obrojčene arapskim brojkama, a u tekstu se na njih upućuje jasnim naznakama ("tablica 1" ili "slika 1"). Naznaka željenog položaja tablice ili slike u tekstu treba biti navedena na margini. Svaka tablica i slika treba biti prikazana na zasebnom listu, a njihovi naslovi moraju biti tiskani na posebnim listovima, i to redoslijedom. Naslovi, zaglavlja, legende i sav ostali tekst u slikama i tablicama treba biti pisan hrvatskim i engleskim ili hrvatskim i njemačkim jezikom.

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Primjeri:

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*Wilson, J.W.; Wellwood, R.W. 1965: Intra-increment chemical properties of certain western canadian coniferous species. U: W. A. Cote, Jr. (Ed.): Cellular Ultrastructure of Woody Plants. Syracuse, N.Y., Syracuse Univ. Press, pp. 551- 559.*

Ostale publikacije (brošure, studije itd.):

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Web stranice:

****1997: "Guide to Punctuation" (online), University of Sussex, www.informatics.sussex.ac.uk/department/docs/punctuation/node 00.html. First published 1997 (Pristupljeno 27. siječnja 2010).*

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