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From Editor’s desk

„U nauci se moramo baviti stvarima, a ne osobama.”
Marija Kiri

Kovid je doneo velike promene u nauci i obrazovanju. U izvesnoj meri smo svi bili prinuđeni da aktiviramo *on line* forme učenja, obrazovanja, posla, biznisa, konferencija, što je dovelo do promena i u drugim aspektima života pojedinaca i društva. Smanjenje komunikacije se negativno odrazilo na istraživanje i razmenu ideja, pa je i zainteresovanost za klasične forme iznošenja rezultata istraživanja, kao što je publikovanje u časopisima, opalo i usporilo se. Upravo iz tog razloga, sa izvesnim zakašnjenjima predstavljamo vam novi broja časopisa.

Kao i u prethodnom periodu, novi broj časopisa *Safety Engineering* ostaje fokusiran na teme inženjerstva zaštite, zaštite na radu, zaštite od požara sa posebnim osvrtom na: zaštitu zaposlenih od elektromagnetnih polja u visokonaponskim energetskim postrojenjima, analizu povreda na radu, monitoring životne sredine, kao i na moguće aspekte upotrebe informacionih tehnologija u post-Covid eri.

” In science, we must be interested in things, not people.”
Marie Curie

Covid has had a significant impact on science and education. We were all compelled to use online resources for learning, teaching, our business and conferences, which changed other facets of lives of individuals and society as well. The decline in communication had a negative impact on research and the exchange of ideas, so interest in traditional methods of presenting research findings, such as publication in journals, has declined. For this reason, we finally bring to you a new journal issue.

As in previous issues, the new issue of *Safety Engineering* journal focuses on safety engineering, occupational safety, and fire protection with a particular emphasis on employee protection from electromagnetic fields in high-voltage power plants, analysis of work injuries, environmental monitoring, but also on potential applications of the use of information technologies in the post-Covid era.

On behalf of the editors
Prof. Dr. Dejan Krstić

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POWER FREQUENCY ELECTROMAGNETIC FIELD EXPOSURE ASSESSMENT DURING 500-750 KV SUBSTATION MAINTENANCE

Abstract: *The increase in extreme and ultra-high voltage power grid facilities is associated with the impact on employees of harmful and dangerous occupational environment factors, such as electromagnetic fields. At the places of employment for electrical staff, power frequency electric and magnetic fields may surpass allowable limit values. The purpose of this study was to conduct a hygienic assessment of power frequency electric and magnetic fields in 500-750 kV substation workplaces and to design staff protection proposals. The study was conducted at electrotechnical staff workplaces of five open switchgear, some of which are work current or voltage transformers inspection, disconnector maintenance, reading electrical appliances at the ground, etc. The paper presents the results of power frequency electric and magnetic field measurements.*

Key words: power frequency electric and magnetic fields, open switchgear, personal protective equipment.

INTRODUCTION

The staff working in the vicinity of power transmission elements and distribution systems (extremely- and ultra-high voltage overhead transmission lines and open switch gears) are exposed to power frequency (50 Hz) electric (EF) and magnetic (MF) field high levels, often are over than permissible limit values (PLV) [1], [2]. All substation territory includes, as a rule, several different voltage classes of open switchgear and various high-voltage equipment due to the possibility of worker exposure to varying EF and MF levels.

In accordance with the Russian Federation hygienic standards, EF PLV is 5 kV/m during the working day, PLV from 5 to 20 kV/m depending on the exposure time and the maximum PLV is 25 kV/m (up to 10 minutes per shift) [3]. MF PLV of whole-body exposure is 100 μT for the entire working shift and for time exposure less than 8 hours is determined by interpolation curve within different time intervals [3]. When time MF exposure is less than 1 h, PLV is 2 mT for whole-body exposure.

Meanwhile, according to International Hygienic Requirements Directive 2013/35/EU and ICNIRP 2010 the minimum requirement for EF occupational exposure is 10 kV/m (limiting the internal EF below the exposure limit values and spark discharges) [4]. Below 20 kV/m the internal EF does not exceed the exposure limit values and annoying spark discharges are prevented, provided protection measures [4]. The magnetic flux density of occupational exposure is 1 mT related to sensory effects [4] and 6 mT related to electric stimulation of peripheral and autonomous nerve tissues in the head and trunk [4].

Hygienic standards regulate occupational electromagnetic safety by means of working time, equipment distance limitation, and collective or personal (PPE) protective equipment use [6]. In case of EF is higher than 25 kV/m the use of PPE is obligatory all working day [3].

PPE includes conductive clothing (coveralls or jackets, trousers/semi-coveralls forming a one-piece garment) and conductive component parts (head protection – hoods and helmets, gloves and boots). All PPE parts must be connected to provide electrical continuity and a reduction of EF inside PPE [9].

The goal of this study was power frequency electric and magnetic field hygienic assessment at workplaces during equipment maintenance in 500-750 kV substations and the design of staff protection proposals.

MATERIALS AND METHODS

The study was carried out in 5 open switchgears including workplaces of the electrotechnical staff while performing work tasks such as going around to the 500-750 kV open switchgears, current or voltage transformers inspection, disconnector maintenance and reading electrical appliances at the ground, etc. (Figure 1).

EF and MF levels are assessed by the methodology of Methodical Requirements 4.3.2491-09 “Hygienic assessment of power frequency (50 Hz) electric and magnetic fields at occupational conditions” at height 0.5 m, 1.5 m and 1.7 m from the ground at each point [12].

EF and MF were measured by a portable electric field analyzer EFA-300 and EHP-50F (Narda, USA) with a calibrated isotropic electric probe and optical interface for connection to the PC.

Measurement results present as maximum values, means (measured values arithmetic average), standard deviations and medians (50th %iles), and quartiles (25th, 75th, 95th %iles).

There were 1057 measurement points in three 500 kV open switchgears and 671 measured points in 750 kV open switchgears.

Figure 1. *The example of electric and magnetic field measurement in open switchgear*

RESULTS

Table 1 shows 500 kV open switchgears EF measurement results at 1.7 m. Figure 2 shows the share (%) of EF levels of different values in each 500-750 kV open switchgear territory.

EF maximum values range of all substations were from 18.70 to 22.20 kV/m, which was more than 4 times higher PLV [3]. At the same time, the mean, median and 75th %iles values of EF were over 5 kV/m (≤ 10 kV/m).

EF PLV excess for the entire working shift (5 kV/m) for the 1st substation (Table 1) was registered in 35 of 54 points (65%). The share of EF levels 5 to 10 kV/m was 48%, 10 to 15 kV/m – 13%, and from 15 to 20 kV/m – less than 4% of total measurement points (Figure 2).

On 2nd substation, EF PLV excess for all work days (5 kV/m) was registered in 351 of 413 points (85%). The share of EF levels from 5 to 10 kV/m was 59%, from 10 to 15 kV/m – 22%, from 15 to 20 kV/m – 2%, over 20 kV/m – less than 2% of total measurement points (Figure 2).

EF PLV (5 kV/m) excess was registered in 331 of 590 points (56%) for 3rd substation. The share of EF values from 5 to 10 kV/m was 47%, from 10 to 15 kV/m – 8%, from 15 to 20 kV/m – about 1% of total measurement points (Figure 2).

Table 1. *Electric field in 500 kV open switchgears (means and standard deviations; quartiles (25th, 50th, and 75th %iles and 95th %iles; height – 1.7 m*

Switchgear	1 (54 points)	2 (413 points)	3 (590 points)	all (1057 points)
Electric field (kV/m) Mean	6.56	8.26	5.38	6.57
Electric field (kV/m) Standard Deviation	4.03	3.56	3.28	3.70
Electric field (kV/m) 25th %ile	2.93	5.70	2.40	4.30
Electric field (kV/m) Median	5.90	7.80	5.50	6.40
Electric field (kV/m) 75th %ile	8.53	10.00	7.70	8.70
Electric field (kV/m) 95th %ile	13.74	14.18	10.96	12.20
Electric field (kV/m) Peak	18.70	22.20	19.40	22.20

The total trend for observed substations shows PLV exceedances in more than 55% of measurement points individually and 68% considering all measurement points (1057). The main proportion of points were from 5 to 10 kV/m EF values (at least 45% for each substation and 52% for all measurement points). The lowest number of points was from 15 to 20 kV/m (1-4%).

The measured magnetic flux density in 500 kV open switchgears did not exceed the hygienic standard for the entire work shift (100 μT) [3].

Results of 750 kV open switchgears EF measurements in 2 substations are present in Table 2. In all substations, the maximum EF was over 30.00 kV/m. EF maximum level range for all substations was from 30.80 to 34.00 kV/m, with a higher PLV was more than 6.5 times [3]. At the same time, mean and median EF values were over 5 kV/m (≤ 15 kV/m), and 75th % percentile EF values – over 10 kV/m.

In 1st substation (Table 2), EF PLV excess for the working shift (5 kV/m) was registered in 233 of 324 points (72%). EF share from 5 to 10 kV/m was 35%, from 10 to 15 kV/m – 25 %, from 15 to 20 kV/m – 7%, from 20 to 25 kV/m – 2%, from 25 to 30 kV/m – 2%, over 30 kV/m – less than 1% of total measurement points (Figure 2).

Table 2. *Electric field in 750 kV open switchgears (means and standard deviations; quartiles (25th, 50th, and 75th %iles and 95th %iles); height – 1.7 m*

Switchgear	1 (324 points)	2 (347 points)	all (671 points)
Electric field (kV/m) Mean	8.40	12.05	10.29
Electric field (kV/m) Standard Deviation	5.87	7.13	6.80
Electric field (kV/m) 25th %ile	3.90	6.85	5.80
Electric field (kV/m) Median	8.10	11.60	9.50
Electric field (kV/m) 75th %ile	11.70	15.85	13.90
Electric field (kV/m) 95th %ile	18.26	25.24	23.90
Electric field (kV/m) Peak	30.80	34.00	34.00

EF PLV (5 kV/m) excess for the 2nd substation was registered in 289 of 347 points (83%). The share of EF levels from 5 to 10 kV/m was 24%, from 10 to 15 kV/m – 30 %, from 15 to 20 kV/m – 12%, from 20 to 25 kV/m – 11%, from 25 to 30 kV/m – 4%, over 30 kV/m – above 2% of total measurement points (Figure 2).

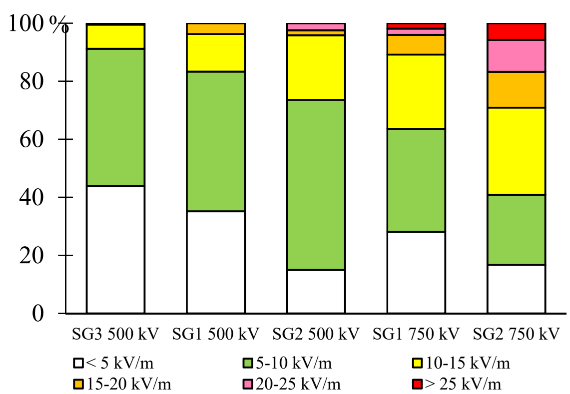

Figure 2. *The share (%) of EF levels of different values on each open switchgear territory*

Equal dependency of PLV excess shows for more than 70% of measurement points separately and 78% considering all measurement points (671) in 750 kV substations.

EF levels from 5 to 10 kV/m were the main fraction of points (at least 20% for each substation and 30% for all measurement points), which is less than in 500 kV substation. Least number of points was over 30 kV/m (1-2%).

Measured MF in 750 kV open switchgears also did not exceed the hygienic standard for the entire work shift [3].

CONCLUSION

The results of the present research are similar to other studies, for example, EF occupational exposure measurement in 400 kV substation during main transformer inspection, maintenance of operating device of disconnector or maintenance of operating device of circuit breaker showed the average levels 0.2–24.5 kV/m in Finland [1].

Other research evaluated extremely low-frequency electromagnetic field occupational exposure by performing tour inspection close to transformers and distribution power lines [10]. In 500 kV areas, EF levels at 71.98 % of the total measured 590 spots were above 5 kV/m (national occupational standard of China) and the maximum level was 14 kV/m [13].

EF and MF were evaluated in 8 electrical transformation stations in the North-East counties of Romania showing 4.0-26.0 kV/m at 380-kV Installation [14].

Differences between the present results and other literature data may be due to the different dimensions of the equipment for different voltages and open switchgears area sizes.

In this way, the allowable time for the staff to stay in a 500 kV substation is no more than 10 minutes per shift, and in a 750 kV substation the use of PPE is obligatory all working day [3]. In accordance with MF measurements, in 500-750 kV substations no work time limits for personnel are required [3].

Electrical staff protection from EF hazard effects is organizational and technical measures, time limits including as mentioned above.

Maintaining electromagnetic safety requires keeping employees safely away from conductive areas and organizing the workplace. The purpose of these measures is to install warning barriers at workplaces with EF exceeding 25 kV/m because the main proportion of points in all open switchgears was from 5 to 10 kV/m EF levels (working time is not more than 3 hours).

However, the most optimal way to protect the staff against EF's negative effects is PPE use. The staff using PPE can be in open switchgears for the duration of the work shift without time limits.

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BIOGRAPHY of the first author

Sergey Perov was born in Moscow, USSR, in 1980. He received a diploma in biomedical engineering from Bauman Moscow State Technical University, a Ph.D. degree in Radiobiology from the Lomonosov State University, Faculty of Biology and Doctor of Science from Research Institute of Occupational Health. His main areas of research include EMF occupational and general public exposure evaluation, assessment of personal protective equipment from EMF, biological effects of EMF different frequency ranges, and human health EMF effects. He is currently working as a head of the electromagnetic fields laboratory at the Izmerov Research Institute of Occupational Health.

PROCENA IZLOŽENOSTI ELEKTROMAGNETNOM POLJU TOKOM ODRŽAVANJA OPREME NA TRAFOSTANICAMA 500-750 KV

Perov Sergei, Tatyana Konshina, Alexey Dremin

Rezime: *Intenziteti električnog i magnetnog polja na radnim mestima elektrotehničkog osoblja mogu premašiti dozvoljene granične vrednosti koje zahtevaju poštovanje propisanih vrednosti elektromagnetne bezbednosti za profesionalnu izloženost na radu. Cilj ove studije bio je procena intenziteta električnih i magnetnih polja industrijske učestanosti na radnim mestima u elektroenergetskim postrojenjima i definisanje predloga za zaštitu osoblja. Studija je rađena na 5 otvorenih elektro energetskih rasklopnih postrojenja koja su obuhvatala radna mesta elektrotehničkog osoblja pri obavljanju radnih zadataka kao što su obilazak otvorenih uklopnih uređaja 500-750 kV, pregled strujnih ili naponskih transformatora, održavanje rastavljača i fiksiranje električnih uređaja u zemlji i dr. U radu su prikazani rezultati merenja intenziteta električnog i magnetnog polja.*

Ključne reči: postrojenja industrijske učestanosti, električna i magnetna polja, otvoreni rasklopni uređaji, lična zaštitna oprema.

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ANALYSIS OF OCCUPATIONAL ACCIDENTS IN THE REPUBLIC OF SERBIA FOR THE PERIOD 2015-2019

Abstract: *Occupational accidents have a significant impact on integrity in the workplace, but also cause high costs for the system of social security in the country. The main purpose of this research was to analyse the number of occupational accidents in Serbia (officially recorded) during the 2015-2019 period, in the working environment and working conditions with the aim to describe the state of working conditions in the country. Due to data incompatibility, index numbers by time and indicator were calculated. The number of total and fatal accidents increased from 2015 to 2019 with certain stagnation regarding the number of fatal accidents in 2019. The two economic sectors with the highest overall number of occupational accidents and fatalities were construction and manufacturing. The main causes of fatal work injuries were slip-trips and falls, which are some of the most common causes in construction and manufacturing.*

Key words: occupational accident, safety, accident statistics.

INTRODUCTION

Due to the Resolution on the Accession of the Republic of Serbia to the European Union, requests for implementing the system of occupational health and safety tailored to the contemporary market conditions of the economy in the EU have emerged. The Strategy of occupational health and safety in the Republic of Serbia [1] promoted the following: the implementation of the principles for prevention of occupational accidents and professional illnesses, the active participation of the occupational medicine services, the implementation of work provider's responsibility principles regarding occupational health and safety regulations, the involvement of employee representatives concerning occupational health and safety (the occupational health and safety committee), the introduction of special occupational insurance for determining compensation arising from occupational accidents and professional illnesses, implementing health and safety in the school curriculum, introducing a general register of occupational accidents and professional illnesses, continual education/training of specialists and officials responsible for occupational health and safety and other officials, promotion of the culture of prevention and examples of good practice, as well as fundamental requirements in this area..

According to the number of occupational accidents or the level of incidence, Serbia is placed in the middle of EU countries scale. However, this should be viewed with some caution, considering the fact that the methodology of data collection and processing has not been fully implemented [2]. Prevention of occupational accidents and illnesses will lead to fewer interruptions and production delays, and it will lower the total cost of production. Additionally, if the company's policy requires the use of adequate safety equipment, ensuring a suitable work environment and its proper maintenance, this will lead to the improvement of productivity and quality of work, and will reduce the risk concerning the health and safety of employees. One way of changing the approach is to indicate that the investment in the development and implementation of the system for evaluating and preventing workplace accidents is a strategic decision that will improve the productivity and competition of Serbian businesses. The costs associated with occupational accidents are compensation to the employee for job-related damages, material damage, production delays and disturbances in the work organization, hiring other employees as substitutes for the injured ones, equipment replacement, etc. Investing in occupational health and safety entails improving working conditions and occupational health and safety, purchasing new equipment, replacing hazardous chemicals with safer or less harmful alternatives, purchasing products and personal protective equipment, and so on. Two-thirds of these expenses are concentrated in four highly risky fields of work (agriculture, construction industry, manufacturing and transport). The costs are equally divided into the costs of short-term injury effects (medical costs and wages) and long-term injury effects of more serious cases (permanent disabilities and deaths). The investment in occupational health and safety contributes to the well-being of employees and is profitable. According to the evaluation, investing in this field can result in a higher percentage of cost refunds, on average 2.2 % [3]. Statistical analysis of occupational accidents is an effective method of describing and evaluating hazardous working conditions in any country. It can be used for determining country-wide priorities that are related to the application of rules of prevention and are crucial in determining the indicators of working conditions [4].

This research focuses on the analysis of the data of occupational fatalities and the total number of occupational accidents between 2015 and 2019 in Serbia including an effort to present the statistics of occupational accidents in Serbia through comparison by using ESAW methodology [2].

MATERIALS AND METHODS

From 2015 to 2019 the registered number of employees in Serbia was 2074494 ± 68470 on average, out of whom 55 % were men. The dominant type of businesses in Serbia were micro (84 %), small (around 12 %), and medium-sized businesses (around 3 %) during the 2015-2019 period, which includes 60 % of employees on average (20 % in businesses employing less than 10 people, 18 % in companies employing 10-49 people and 22 % employed in medium-sized companies). Out of all the companies in Serbia, during the period of analysis, 18 % belonged to the manufacturing, 9% to the construction industry, 35 % to retail and wholesale trade and 27 % to service businesses [5-9]. The key role in providing and applying monitoring of health and safety measures in the workplace in Serbia belongs to the Labor Inspectorate as a part of the Ministry of Labor, Employment, Veteran and Social Policy. Besides monitoring the application of the Occupational Health and Safety Act, the Labor Inspectorate also monitors the application of other regulations regarding measures and security norms as well as occupational health and safety, technical measures related to occupational health and safety, standards and commonly acknowledged measures concerning the issues in the field of occupational health and safety [1]. By 2018, the concept that was used for recording occupational accidents was unchanged from the 1960s. Only since 2019 have occupational accidents been analysed by the new methodology which is in compliance with ESAW methodology [2]. Due to this methodology, there is a record of information regarding occupational accidents within the EU, which allows comparison of data of the countries that are a part of the EU and the analysis of occupational accidents to enable improvement in the field of occupational health and safety. The insight in the general database enables not only the inspection of the comparing data regarding occupational accidents but also following the trends in the field of occupational health and safety, including taking appropriate measures for the prevention of accidents.

In Serbia, employers are required by law to notify the Labor Inspectorate and the responsible police department, both in person and in writing, immediately or within 24 hours of the accident occurring, including any fatal, collective, or heavy occupational accident or injury that prevents an employee from working more than three days in a row. Different state institutions publish their own data concerning occupational accidents. The most detailed and reliable database of fatal and heavy occupational accidents can be obtained by the Labor Inspectorate, whereas relatively updated data of the total number of occupational accidents can be obtained by the Directorate for Safety and Health at Work which is a part of Ministry of Labor, Employment, Veteran and Social Policy [10-14]. According to Serbian laws, an occupational accident is defined as any injury, illness, or death that occurred as a consequence of an occupational accident, which is defined as any unexpected or unplanned event. It also includes any act of violence committed at work or in connection with a workplace, causing an illness or fatal accident to the insured person, which occurred immediately or within a year. The term "employee" is also used to refer to people who have a formal contract of employment, which is a relationship of employment with an employer for a specific or indefinite amount of time, and persons who perform temporary and occasional jobs under a work contract or contract of temporary employment; persons who run business individually or are founders of enterprises or entrepreneur's shops, as well as persons who undertake agricultural activities and are registered in the Central Registry of Compulsory Social Insurance.

The main data regarding occupational accidents used in this analysis are taken from the Report on the work of the Labor Inspectorate and the Directorate for Safety and Health at Work under the Ministry of Labor, Employment, Veteran and Social Policy of the Republic of Serbia dating from 2015 to 2019. Information about the accidents that occur while commuting to work and workplace accidents involving self-employed individuals are not fully available, thus they are not included in the analysis. Despite similar methodologies of data collecting and processing included by the public institutions, they do not always refer to the same reference population of employees. If the same reference population is not used for obtaining all data sources, the incident rate cannot be determined (in an attempt to avoid incorrect conclusions). Therefore, index numbers, whether regarding the annual or indication base, are more adequate and advantageous for the report. It should be emphasized that the index number is defined as the ratio between the number of occupational accidents in a certain year (from 2015 to 2019) and the number of them in 2019 (which is taken as the reference year because that was the first time ESAW methodology was used in Serbia) or as the ratio between the number of occupational accidents in the observed group compared to the reference group (which varies according to the analysis). The index number eliminates the questions regarding data comparison obtained from different institutions as it directly shows the trend of occupational accidents and their frequency. Besides this, concerning e.g. economic activity and the age group, there are differences between data obtained from different sources. Nevertheless, prior to this analysis, data was grouped by taking into account the incidence only regarding the most common occupations. The analysis includes the number of fatalities and the total number of occupational accidents between 2015 and 2019, in accordance with ESAW variables [2], economic activity, and the cause of the accident (deviation).

RESULTS AND DISCUSSION

The numbers and the incidence rate of the total number of occupational and fatal accidents in Serbia between 2015 and 2019 are shown in Table 1. The results show the general trend of the increasing number and incidence rate of total and fatal accidents between 2015 and 2019. The number of total occupational accidents and the incidence rate has its maximum in 2019, while all of these indicators have the maximum in 2018 regarding fatal accidents, after which there is certain stabilization of the observed indicators. In the period of analysis, fatal accidents were approximately at 0.46% regarding the total number of occupational accidents, with the values fluctuating around this figure randomly.

Table 1. *Total and fatal accidents and corresponding mean ($\bar{x}$) and standard deviation (s) values, and incidence rates for total and fatal accidents in Serbia, between 2015 and 2019*

Year	Total accidents		Fatal accidents	
	Number	Incidence rates[a]	Number	Incidence rates[a]
2015	7539	377.7	38	1.90
2016	8591	427.5	42	2.09
2017	9535	462.3	39	1.89
2018	9882	463.7	53	2.49
2019	12709	584.8	49	2.25
$\bar{x}$± s	9651 ± 1732		44 ± 6	

[a] The incidence rate is defined as the number of accidents at work per 100000 employed persons.

Comparison of the occupational accident incidence rate in Serbia to those in other countries EU-28 is affected by differences in definitions of occupational accidents as well as other methodological issues. However, keeping in mind all the limitations, it can be observed that the total accidents in Serbia in the period from 2015 to 2019 were substantially lower than the average value of the incidence rate for E-28 for the period of analysis, having a value of around 1600. On the other hand, fatal incidence rates in Serbia were significantly higher than the average values of the fatal incidence rates for EU-28 whose values are around 1.6. Serbia is, according to the fatal incidence rate within the period of analysis, in the same range as Hungary, Italy and Latvia, which is around 2.1 on average. The risk of occupational accidents in small companies is higher than in bigger ones. Therefore, a larger number of occupational accidents may be expected in Serbia. Although the distribution of the size of the companies in Serbia does not differ significantly from the average of EU-28, in which there is around 65 % of employees in micro, small or medium-sized companies, Serbia has a tendency to show higher rates of fatal incidence rate in comparison to EU-28, whereas the fatal incidence rates EU-28 constantly decreased, as well as the rates of total accidents [15]. Besides this, there has been a decrease in fatal incident rates in Serbia in 2019 compared to the previous years, mostly due to the increase in the number of employees, and also because of the fact that the number of fatal accidents fluctuated around the medium value during the period of analysis. These findings could be explained by the fact that most companies in Serbia achieved a low level of prevention regarding occupational health and safety. This is primarily because of economic factors, poor employee education in this area, and the fact that 40% of employees work for businesses with fewer than 50 employees. In Serbia, the 2013-2017 Occupational Health and Safety Strategy, as well as the 2018-2021 Strategy, are being implemented, with the focus on constant improvement in this field through applying rules and regulations regarding occupational health and safety, mutual collaboration between employers and employees, raising awareness, improving knowledge and skills, specifically establishing work ethics and creating preconditions for well-being at work as well as the quality of life and health at work. The mission is to establish a system for fulfilling safe working conditions that enable a decrease in the number of occupational accidents as much as possible. The mission is aimed at all the business subjects in Serbia, especially in the sector of small and medium companies and entrepreneurs. However, these efforts have not completely fulfilled their purpose during the period of analysis, so the number of total occupational accidents in Serbia during those 5 years was on the increase reaching its peak in 2019 in terms of both the number of accidents and the incidence rate. The index numbers by time (2019 is the reference value representing 100%), which include the analysis according to fields of work (economic activities) are shown in Tables 2 and 3, for fatal accidents and total accidents respectively.

The rates of variation - all index numbers of economic activities electricity, gas, steam and air conditioning supply and other service activities were higher than or equal to one, whereas the variation rates regarding economic activities agriculture, forestry and fishing, water supply, sewerage, waste management and remediation activities and wholesale and retail trade were lower than or equal to one. Regarding the remaining economic activities, the index numbers were either higher or lower than 1 during the whole period of analysis. Furthermore, it can be deduced that the economic activity construction had the lowest variation coefficient (17%), whereas other service activities had the highest value (69%) during the 5 years of analysis.

Table 2. *Mean ($\bar{x}$) and standard deviation (s) for the numbers of fatal accidents and index numbers according to economic activity in Serbia, between 2015 and 2019*

Economic activity	$\bar{x} \pm s$	2015	2016	2017	2018	2019
Index number by time						
Agriculture, forestry and fishing	5 ± 2	56	44	56	44	100
Manufacturing	9 ± 4	63	113	100	200	100
Electricity, gas, steam and air conditioning supply	1 ± 0	100	100	200	200	100
Water supply, sewerage, waste management and remediation activities	3 ± 1	50	25	50	100	100
Construction	17 ± 3	79	116	79	79	100
Wholesale and retail trade	3 ± 1	100	50	25	75	100
Transportation and storage	3 ± 1	67	67	133	100	100
Other service activities	3 ± 2	400	100	200	600	100
Index number by economic activity						
Agriculture, forestry and fishing		33	18	33	27	47
Manufacturing		33	41	53	90	42
Electricity, gas, steam and air conditioning supply		7	5	13	13	5
Water supply, sewerage, waste management and remediation activities		13	5	13	27	21
Construction		100	100	100	100	100
Wholesale and retail trade		27	9	7	20	21
Transportation and storage		13	9	27	20	16
Other service activities		27	5	13	40	5

Table 3. *Mean ($\bar{x}$) and standard deviation (s) for the numbers of total accidents and index numbers according to economic activity in Serbia, between 2015 and 2019*

Economic activity	$\bar{x} \pm s$	2015	2016	2017	2018	2019
Index number by time						
Agriculture, forestry and fishing	323 ± 80	151	95	167	177	100
Manufacturing	3030 ± 547	69	63	65	74	100
Electricity, gas, steam and air conditioning supply	632 ± 179	43	90	108	116	100
Water supply, sewerage, waste management and remediation activities	434 ± 185	23	59	54	92	100
Construction	515 ± 217	24	71	91	47	100
Wholesale and retail trade	830 ± 196	56	123	120	104	100
Transportation and storage	747 ± 140	56	75	92	89	100
Administrative and support service activities	496 ± 154	80	74	37	108	100
Public administration and defence, compulsory social security	295 ± 199	17	22	72	30	100
Education	417 ± 155	58	39	44	51	100
Human health and social work activities	962 ± 206	67	54	74	65	100
Other service activities	969 ± 142	69	75	71	72	100
Index number by economic activity						
Agriculture, forestry and fishing		189	41	55	114	30
Manufacturing		1504	471	376	836	527
Electricity, gas, steam and air conditioning supply		158	114	106	221	90
Water supply, sewerage, waste management and remediation activities		80	71	51	167	86
Construction		100	100	100	100	100
Wholesale and retail trade		249	185	140	236	107
Transportation and storage		271	124	118	223	117
Administrative and support service activities		266	84	33	185	80
Public administration and defence, compulsory social security		56	24	63	50	79
Education		221	51	45	100	92
Human health and social work activities		476	133	140	240	173
Other service activities		461	172	126	249	161

Taking into account the index numbers by time for total accidents between 2015 and 2019 (Table 3), it can be concluded that economic activities agriculture, forestry and fishing and wholesale and retail trade had all the values above 1 except in 2016 and 2015 when they were lower, respectively. In contrast, all other economic activities had values below 1, throughout the entire analysis period, with the exception of the provision of electricity, gas, steam, and air conditioning, administration, and transportation. This is another confirmation that 2019 has been a very unfavourable year regarding the number of total occupational accidents in Serbia, which requires future investigation into the root cause.

Similarly to the data concerning fatal occupational accidents, the manufacturing activity showed the lowest coefficient of variation (18%). However, different findings regarding the highest value were reported. According to these results, construction, mandatory social security, water supply, sewerage, waste management, and remediation activities were the activities with the highest variation coefficient during the analysis period (67%, 43%, and 42%, respectively).

Index numbers by economic activities regarding fatal occupational activities show that all the economic activities had values less than 1, independently of the observed year (Table 2). Therefore, the activity construction (taken as the referent value 1 or 100 %) can be regarded as the economic activity with the highest number of fatal occupational activities during the period of analysis, after which come the following activities - manufacturing (10-67% less), agriculture, forestry and fishing (67–82% less), which represents a certain kind of relevance regarding fatal occupational accidents. However, it is not possible to define a general pattern of relevant significance regarding these activities in the course of time as their development was not continual from 2015 to 2019. Other economic activities have lower index values by about 85-95% during most of the years in comparison to the reference activity construction, so they can be regarded as the activities with the least influence on fatal occupational activities. Nevertheless, due to the analysis of index numbers of total accidents according to economic activities, there is a different view, which can be seen in Table 3: manufacturing was the activity that showed the highest index numbers independently from the observed year (270-1400% above construction activity), followed by human health and social work activities, wholesale and retail trade, transportation and storage and other service activities, which had higher index numbers compared to the reference activity 33-376%, 7-149%, 17-171% and 26-361%, respectively. The other activities are at least 79% exposed below the construction index numbers. The activities of public administration and defence, and compulsory social security had index numbers lower than 1 during the whole period of analysis, specifically less by 21-76% compared to the reference activity. The other economic activities during the period of analysis had higher or lower values compared to the construction activity.

As in most other countries EU-28 [15], construction is the economic activity that accounts for the highest number of fatal occupational accidents in Serbia, although it is not the activity in which a high number of persons are employed [16-20]. It is important to emphasize that the activity construction in Serbia accounts for about 7% on average regarding the total number of employees during the period of analysis, while services add to this by around 50% [5-9]. Fatal occupational accidents in the activity of construction, during the period of analysis make up approximately around 40 % of all fatal occupational accidents. The reason for such a high rate of occupational accidents in construction activity, both in Serbia and other countries, comes as a result of the four most common dangers or risks: falls, caught-in/between, struck-by, and electrocution hazards, which are defined through Construction Focus Four programme established by Occupational Safety and Health Administration [21]. Another factor is the failure of employees in the construction sector to recognize and manage pertinent safety risks. This directly increases the likelihood of accidents, catastrophic safety incidents, and accidental exposure to dangers [22, 23]. Unfortunately, some research shows that employees might not recognize up to 57% of safety dangers in a typical working environment [22-26].

Besides these objective reasons, another factor that contributes to a high number of fatal occupational accidents in construction activity, as well as to a large number of total fatal accidents and total number of occupational accidents, is the inefficient measure implementation defined by Occupational Health and Safety Strategy in the Republic of Serbia introduced for the period 2013-2017 [27], and further for 2018-2022 [1]. This, including other factors, is related to the introduction of the occupational accident prevention principle, the principle of work organizer responsibilities for the implementation of occupational health and safety measures, the introduction of a general register of occupational accidents, continual education/training of persons responsible for health and safety in the workplace as well as other persons and promotion of the culture of prevention and examples of good practice in the field of health and safety at work. However, none of the aforementioned strategies for reducing the number of occupational accidents have been successful during the period of analysis because, as previously stated, there was not a decrease in fatal occupational accidents until 2018. In the meantime, in 2019 there was a certain decline in the number of fatal accidents, which will be analysed in detail during the following years regarding its stabilization and confirmation. Manufacturing ranks second in Serbia in terms of fatal occupational accidents, despite being (at least 44%) lower than the level of construction activity. Besides these two activities, agriculture, transport, trade and other service activities also showed a significant contribution to the number of fatal occupational accidents. Thus, these activities should be additionally analysed. All of this is in accordance with countries of EU-28, where agriculture, construction industry, manufacturing and transportation are the most significant activities regarding the number of occupational accidents [15]. It is important to emphasize that there were no fatal occupational accidents during the analysed period in the activities of administrative and support service activities, public administration and defence, compulsory social security, education and human health and social work activities (listed in Table 3; therefore they are not listed in Table 2. From 2015 to 2019 it can be found that the final number of fatal and total occupational accidents in the construction activity would be much more predictable considering the fact that its variation coefficient was the lowest. On the other hand, the activities such as water supply, sewerage, waste management and remediation and other service activities – regarding fatal accidents as well as the activities public administration and defence, compulsory social security – and also the total number of occupational accidents, had the highest variation coefficients and were much less predictable. In terms of fatal occupational accidents, the reference year of 2019 was best for the following activities: electricity, gas, steam, and air conditioning supply, but the worst for construction activity. In terms of the overall number of occupational accidents, however, the reference year of 2019 was the worst. In contrast to manufacturing activity, 2019 was the best year for forestry, fishing, and agriculture. Index numbers by the cause of the accident (deviation) are shown in Table 4.

Table 4. *Mean ($\bar{x}$) and standard deviation (s) for the numbers of fatal accidents and index numbers according to accident cause (deviation) in Serbia, between 2015 and 2019*

Accident cause (deviation)	$\bar{x} \pm s$	2015	2016	2017	2018	2019
Index number by time						
Electrical problems, explosion, fire	7 ± 2	333	200	267	233	100
Overflow, overturn, leak, flow, vaporization, emission	2 ± 0	100	50	50	100	100
Breakage, bursting, splitting, slipping, fall, collapse of material agent	12 ± 3	56	81	56	94	100
Loss of control of machine, means of transport or handling equipment, hand-held tool, object, animal	8 ± 3	30	90	60	120	100
Slipping-Stumbling and falling-Fall of persons	15 ± 2	78	72	83	94	100
Index number by deviation						
Electrical problems, explosion, fire		71	46	53	41	17
Overflow, overturn, leak, flow, vaporization, emission		14	8	7	12	11
Breakage, bursting, splitting, slipping, fall, collapse of material agent		64	100	60	88	89
Loss of control of machine, means of transport or handling equipment, hand-held tool, object, animal		21	69	40	71	56
Slipping-Stumbling and falling-Fall of persons		100	100	100	100	100

Table 4 provides insights into fatal occupational accidents caused by electrical problems, explosions, and fire showing index numbers by time higher than 1 which is 100-233% more in comparison to the reference year. On the other hand, the accidents caused by breakage, bursting, splitting, slipping, fall, collapse of material agent and slipping-stumbling and falling-fall of persons, show index numbers less than 1 during the whole period of analysis, whereas the rest of the aforementioned factors had higher or lower values during the analysis period. The largest number of fatal accidents in the analysis period is caused by slipping-stumbling and falling-fall of persons, on average 15 ± 2, which represents around 34 % of total accidents. The variation coefficient with the accidents caused by loss of control of machine, means of transport or handling equipment, hand-held tool, object, or animal, was the highest (40%), whereas regarding slip-ping-stumbling and falling-fall of persons was the lowest (12%). Interestingly, it can be noticed that with all the recorded causes of fatal accidents, index numbers according to the cause of the accident were lower than 1 in comparison to the cause observed in reference to slipping-stumbling and falling-fall of persons, except in 2018 at breakage, bursting, splitting, slipping, fall, and collapse of material agent. Also, it can be concluded that fatal occupational accidents caused by slipping-stumbling and falling-fall of persons, were by far the most common causes throughout the entire analysis period. The lowest index numbers according to the cause, independently of the observed year, were the result of overflow, overturn, leak, flow, vaporization, and emission, at least 86% below the reference cause. As previously stated, the most significant economic activity regarding fatal occupational accidents is construction. Therefore, it can be expected that in this particular activity accidents like slipping-stumbling and falling-fall of persons and breakage, bursting, splitting, slipping, fall, and collapse of material agents, according to the results, cause most occupational fatal accidents. Also, a no less significant activity when it comes to the stated causes of occupational accidents involves manufacturing, the activity which, among the rest, includes monotonous work and repetition, the placement of objects, inexperience, frequent (and tolerated) risky behaviour as well as poor maintenance of the premises and equipment [28]. Besides the aforementioned, a significant number of occupational accidents is caused by non-reading and non-understanding the manual, the lack of protective clothes and shoes, psychophysical conditions (rush, stress, lack of concentration), unfavourable environmental factors, irregular handling, as well as not easily used or badly constructed machine parts [29].

CONCLUSION

There has been no pattern in the change of index numbers by time during the analysed period (2015-2019) for either of the factors (economic activity and the cause of the accident). Thus, it can be presumed that the numbers occurred more or less randomly with the evident increase of fatal occupational accidents during the analysed period, which is primarily caused by unsuccessfully implemented strategies, that would contribute to a significant decrease in fatal occupational accidents from 2015 to 2019. Besides this, considering the situation in the EU, it is expected that in Serbia the share of small and medium-sized companies will continue to rise, as well as that flexible production will be more and more present, and the outcome could, unfortunately, be that the occupational accidents indicators could deteriorate if urgent precautions are not undertaken.

Some of the precautions should be as follows: a) the implementation of (already significant) number of laws that define minimum requirements for occupational health and safety in Serbia – most accidents could be prevented through the implementation of the existing regulations and rational use of the resources; b) the development of the regulations for reporting minor occupational accidents concerning the fact that the results indicated bad reporting regarding these types- of accidents and c) the development of a well-defined statistical methodology on data collecting and processing along with creating a general register of occupational accidents for official records, which is a general trend for EU organizations – to have comparable data as the statistical data and analyses can (and should) be used for further strategy development regarding occupational accidents.

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ANALIZA POVREDA NA RADU U SRBIJI ZA PERIOD 2015-2019

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Rezime: *Povrede na radu imaju značajan uticaj na integritet na radnom mestu, ali i uzrokuju visoke troškove za sistem socijalne zaštite. Osnovna svrha ovog istraživanja bila je analiza broja povreda na radu u Srbiji (zvanično evidentiranih) u periodu 2015-2019, u radnom okruženju i uslovima koji se odnose na radnu snagu, u pokušaju da se prikaže stanje uslova rada. Zbog nekompatibilnosti podataka, izračunati su indeksi po vremenu i indikatoru. Broj ukupnih povreda i povreda sa smrtnim ishodom se povećao od 2015. do 2019. godine uz izvesnu stagnaciju u odnosu na broj povreda sa smrtnim ishodom u 2019. Građevinarstvo i proizvodnja su bile najvažnije privredne delatnosti po ukupnom broju povreda na radu i broju smrtno stradalih. Glavni uzroci povreda na radu sa smrtnim ishodom bili su klizanje-spoticanje i pad, kao jedno od najčešćih uzroka u građevinarstvu i proizvodnji.*

Ključne reči: povreda na radu, bezbednost na radu, statistika povreda na radu

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SAFETY SYSTEM MANAGEMENT BY ANALYSING OCCUPATIONAL INJURIES AND USING INDICATORS OF STATE

Abstract: *The occupational safety and health management system requires constant upgrades and analyses of the current state. Work environment indicators need to be monitored in order to ensure safe work conditions. Previous analysis has shown that problems are more prominent in specific administrative districts in Serbia. This paper discusses the number of total, minor, and major occupational injuries at the national level, the number of occupational injuries in the Nišava District, and the relation between the number of reported injuries and closed injury cases by the public attorney's office in Niš.*

Key words: management system, indicators, occupational injuries, Heinrich pyramid, preventive engineering

INTRODUCTION

Preventive engineering, based on the analysis of preventive safety measures needs to include both conventional prevention activities and identification of safety risks. Timely elimination of causes of occupational injury depends on the system for reporting risk situations that occurred (Berry, 2004) but did not result in a risk event. The Heinrich pyramid is used in different economic branches to investigate the causes of disrupting the safety system (Dujman, 2017), even though it was originally intended for use in industrial production. Application of such statistical analyses suggests that an emergency or a risk event is preceded by hundreds of situations (Milovanović, 2011) in which undesired effects were avoided. The purpose of these analyses is to emphasise the need for monitoring the number of situations with compromised safety.

ANALYSIS OF THE NUMBER OF OCCUPATIONAL INJURIES

The data on the number of injuries published in Labour Reports are classified into multiple categories. The available data include incidence of occupational injuries, types of injuries, severity of injuries, and share of injuries by economic activity, city, and administrative district. The number of injuries in administrative districts is dependent on the functioning of the occupational safety system management to a lesser extent and on economic development to a greater extent.

Analysis of the total number of occupational injuries

The analysis of the total number of occupational injuries shows that there are serious deficiencies in the functioning of the occupational safety system in Serbia. The number of injuries also depends on economic development, so it is understandable that statistical data changed significantly in the period when the number of new factories, small companies, and artisanal businesses considerably increased. The situation is similar in the surrounding countries, but much better in developed EU countries. Figure 1 shows the total number of occupational injuries at the national level for a period of eight consecutive years.

Figure 1. *Number of occupational injuries in Serbia*

The growing trend of the total number of occupational injuries peaked in 2019; however, the Labour Report for 2019 does not state any reason for such a high number.

Analysis of occupational injury severity

Minor occupational injuries by far outnumber major injuries either at work or during the commute. Figure 2 shows the number of minor injuries from 2015 through 2022.

Figure 2. *Number of minor injuries*

When comparing Figure 1 with Figure 2, it is apparent that the curves for the total number of occupational injuries and minor injuries are similarly shaped. Again, the upsurge in minor injuries occurred in 2019, which influenced the similarity between the two curves. Major and fatal injuries are presented together in the Labour

Reports and given as a single number, which is not in keeping with EU standards.
Figure 3 shows the number of major commuting injuries, while Figure 4 shows the number of major injuries at work.

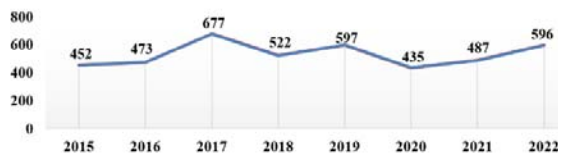

Figure 3. *Number of major injuries while commuting*

The data indicate that most major commuting injuries occurred in 2017 and the fewest in 2020. The reduction of these injuries in 2020 and 2021 also influenced the similarity between the curves in Figure 1 and Figure 2, but it needs to be stressed that this fact suggests a lower degree of occupational safety during that period.

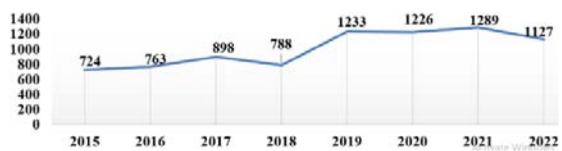

Figure 4. *Number of major injuries at work*

The growing trend of major occupational injuries warrants the proper implementation of preventive and corrective safety measures. The official data do not provide enough elements to correct the management system, because separate data on the number of fatal injuries are not available. The data only directly confirms that the situation has sharply deteriorated since 2019. The average number of major injuries over the first four-year period (2015-2018) was 794, only to increase over the subsequent period (2019-2022) by as much as 50% and reach 1,219 injuries.

ANALYSIS OF THE NUMBER OF OCCUPATIONAL INJURIES IN THE NIŠAVA DISTRICT

The analysis of the total number of occupational injuries shows that there are significant differences in safety management between specific Serbian administrative districts (Malenović-Nikolić, 2023). The data presented in the Labour Report for 2022 reveal the three most prominent administrative districts according to the total number of injuries – the City of Belgrade (5,720), the South Bačka District (3,202), and the Nišava District (1,576).

Table 1 shows the number of criminal charges filed with the public attorney's offices throughout Serbia for failure to implement occupational safety and health measures.

Table 1. *Number of filed criminal charges and number of closed cases*

City	*filed* 2020	*filed* 2021	*closed* 2020	*closed* 2021
Aranđelovac	10	24	15	18
Bačka Palanka	11	19	21	19
Beograd	83	144	106	93
Bečej	10	5	4	7
Valjevo	36	49	21	37
Vranje	19	19	7	24
Vršac	3	1	6	4
Gornji Milanovac	0	8	2	3
Zaječar	7	15	9	5
Zrenjanin	12	27	11	17
Jagodina	17	15	16	8
Kikinda	10	5	6	12
Kragujevac	24	21	23	32
Kraljevo	65	40	65	49
Kruševac	73	78	77	57
Lazarevac	1	1	1	2
Leskovac	23	17	28	17
Loznica	29	21	32	17
Mladenovac	7	1	6	2
Negotin	2	1	3	2
Niš	**29**	**25**	**53**	**35**
Novi Pazar	22	34	31	21
Novi Sad	87	93	40	92
Obrenovac	5	5	2	4
Pančevo	2	8	4	6
Paraćin	3	4	6	5
Pirot	39	41	45	19
Požarevac	15	22	20	16
Požega	1	5	4	1
Preševo	1	0	0	0
Prijepolje	2	7	2	5
Prokuplje	4	10	8	5
Raška	7	1	11	12
Ruma	6	10	9	11
Senta	9	12	11	11
Sjenica	2	0	0	0
Smederevo	7	5	6	7
Sombor	4	3	15	4
Srem. Mitrovica	7	3	4	5
Subotica	54	67	80	46
Trstenik	12	5	16	2
Užice	14	28	19	18
Čačak	16	28	23	32
Šabac	25	13	29	31
Total	815	940	897	940

The Nišava District is the focus of this paper because of the conspicuously lower activity of inspectorates and attorneys' offices compared with some smaller cities (shaded fields in Table 1). The Labour Reports present these data as sourced from the Serbian National Health

Insurance Fund, the Public Attorney's Office, and the Ministry of Justice.

Table 1 shows the number of closed cases by the public attorney's offices throughout Serbia regarding the failure to implement occupational safety and health measures.

The data show that the inspectorates and public attorney's offices in Subotica and Kruševac had the most closed cases.

Analysis of work results of inspectorates

The analysis of the number of criminal charges filed with public attorney's offices in Serbia for failure to implement occupational safety and health measures resulting in fatal, major, and collective occupational injuries and of the outcomes of proceedings following the charges paints a clearer picture of how occupational safety preventive measures are implemented.

Figure 5 shows a comparison of data taken from the Labour Reports for the Nišava District concerning (I) the number of filed criminal charges, (II) the number of closed cases, and (III) the number of cases closed in a different manner pursuant to the Law on Misdemeanours (warning notices, request denials, dismissals, and release from responsibility of the accused).

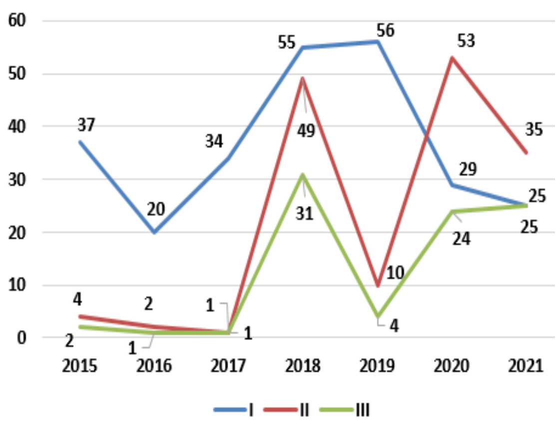

Figure 5. *Work results of inspectorates*

The analysis of data in Figure 5 shows that a significant number of cases were closed in 2018 and 2020 and that the period from 2015 through 2017 was characterized by a surprisingly small number of closed cases, fewer than three on average. Another cause for concern is the number of criminal charges filed with the public attorney's office in Niš, where the maximum number is 56, even though the Nišava District has the third-highest number of major occupational injuries. The results of the analysis indicate that more work is required on preventive safety measures, and even more work on repressive measures, in order to establish an adequate worker safety management system. The data show that the inspectorates and public attorney's offices in Subotica and Kruševac had the most closed cases.

ANALYSIS OF OCCUPATIONAL SAFETY SYSTEM MANAGEMENT

Occupational safety system management using the principles of preventive engineering involves the analysis of risk events that did not result in occupational injuries. Heinrich pyramid is a suitable basis for the analysis of real problems, as it can be adjusted to present the number of (I) fatal injuries, (II) major injuries, (III) minor injuries, (IV) and avoided injuries during risk events (near misses). Its application facilitates the identification of potentially hazardous events and the proper record keeping for the number, causes, and effects of recorded problems in the work environment. The safety system will function properly and more easily with orderly statistical records of risk situations. Detailed records of risk situations create conditions to clearly identify the causes of occupational injuries, eliminate the elements that endanger workers' health, and reduce the level of risk.

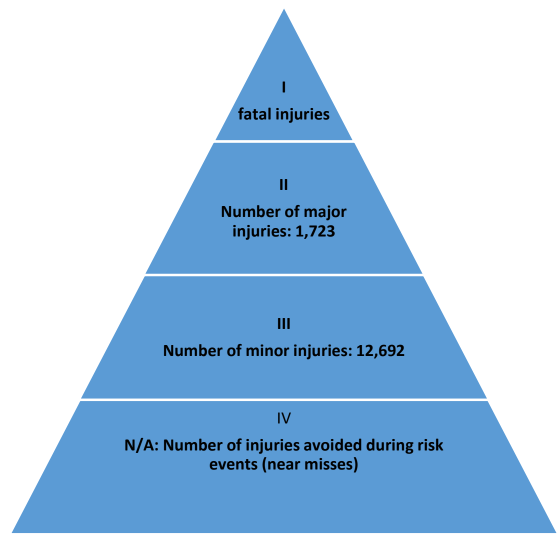

Figure 6. *Heinrich pyramid of occupational injuries*

Injuries may be directly or indirectly caused by oversights in the functioning of the occupational safety system and failures to implement preventive safety measures. Direct causes of injuries include absence or non-performance of preventive maintenance, disregard of maintenance, or malfunctions due to ignored warnings, whereas indirect causes include maintenance errors. The problems that can produce the highest level of risk and most likely cause fatal injuries should take priority.

CONCLUSION

The use of indicators of the state of the work environment is an important step towards improving the management system. The exact ratio of the number of major and minor injuries is impossible to determine because data on major injuries are presented together with fatal injuries. In addition, the presentation of unified data on the number of major and fatal injuries is not in keeping with European standards. Another issue to be tackled is the definition of the number of risk situations in which an occupational injury was avoided. Orderly record keeping and inputs in the Heinrich pyramid segments are prerequisites for improving the occupational safety system. Regular preventive inspection (daily, weekly, monthly, quarterly, biannually, and yearly) and registration of individual data on the number of fatal injuries and near misses can help present a clearer picture of how to preserve workers' health and increase their safety.

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BIOGRAPHY

Jelena Malenović-Nikolić was born in Knjaževac, Serbia, in 1974. She received a diploma in environmental protection engineering and the Magister of technical sciences degree from the University of Nis, Faculty of Occupational Safety.
She obtained a Ph.D. in Mining Engineering, Special Scientific field: Occupational Safety and Environmental Protection, from the University of Belgrade, Faculty of Mining and Geology, Special Scientific field: Occupational Safety and Environmental Protection. Her main areas of research include environmental protection, energy, environmental management, environmental security, etc. She is currently working as an assistant professor at the Faculty of Occupational Safety, University of Niš.

UPRVLJNJE SISTEMOM ZAŠTITE BAZIRNO NA ANALIZI POVREDA NA RADU I PRIMENI INDIKATORA STANJA

Jelena Malenović-Nikolić, Dejan Krstić, Lidija Milošević, Ivana Ilić-Krstić, Milan Lukić

Rezime: *Sistem upravljnja bezbenošću i zdravljem na radu zahteva konstantno unapređivanje i analizu postojećeg stanja. Praćenje indiktora kvaliteta radne sredine treba vršiti s ciljem da se stvore uslovi bezbedni uslovi rada. Anlizom je utvrđeno da su problemi izraženiji u pojedinim uprvnim okruzima Srbije. U radu se razmatra broj ukupnih, lakih i teških povreda na radu, na nacionlnom nivou, broj povreda na radu u Niškom okrugu i odnos broja prijavljenih povreda i rešenih predmeta niškog tužilaštva.*

Ključne reči: sistem upravljanja, indikatori, povrede na radu, Hajnrihova pirmida, preventivno inženjerstvo

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SMART TECHNOLOGY-BASED SAFE TOURISM IN THE POST-COVID-19 ERA

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Abstract: *The tourism sector is heavily influenced by the ongoing coronavirus pandemic, due to strict government measures including travel restrictions and, on the other side, psychological factors, such as fear and anxiety that together have caused a sharp decline in this sector. However, it is identified that state-of-the-art smart technology has huge potential when it comes to post-COVID tourism revival. Therefore, in this paper, we examine how the synergy of the following concepts can be adopted for the purpose of increasing work safety in sectors based on live human interaction: Artificial Intelligence (AI), Augmented Reality (AR), blockchain, Internet of Things (IoT) and smartphone applications. As an outcome, three case studies relying on them are proposed and evaluated: 1) smart tourist scheduling 2) gamified sightseeing with fitness elements 3) safe public events. They aim to provide engaging, content-rich, but safe tourism at the same time under novel, pandemic-related circumstances.*

Keywords: protection of employees, mobile applications, Internet of Things (IoT), deep learning, blockchain.

INTRODUCTION

The ongoing coronavirus pandemic dramatically impacts the tourism sector [1, 2], as safety becomes a major concern. Due to a huge number of new cases and high death rate in many countries [3], government responses are quite restrictive [1-8], applying measures [3] such as total lockdown, public event prohibition or limiting the number of participants, forbidding travel outside the boarders and closing hospitality objects. On the other side, policies aiming to reduce infection among employees, such as working from home and reducing open hours were counter-productive in sectors that are mainly based on live human interaction, such as tourism and hospitality [7, 8]. Later, the requirement of a green certificate as proof of vaccination or a negative COVID-19 test made traveling and event attendance even more demanding. Additionally, negative psychological effects of the current situation, such as fear and anxiety have also contributed to the overall decline of tourism and related sectors [4, 5]. Therefore, an enormous number of events, travels, accommodation and flight reservations have been cancelled worldwide [1, 2]. It is not only that the number of tourists has decreased significantly, but the current situation has shown many negative side-effects as well, such as the number of jobs lost in the tourism and hospitality sector [1, 2]. Due to the dramatic impact of pandemic on almost any aspect related to everyday life - including work, transportation, interaction and other regular activities, the period after the outbreak of coronavirus is often referred to as the post-COVID era [7].

However, it has been identified that safety engineering, relying on smart digital technology is crucial for improving employee safety in both outdoor and indoor working environments [5-9]. This way, the revival of sectors based on human interaction within on-the-spot activities becomes a reality even under these new circumstances. This work focuses on leveraging Artificial Intelligence (AI), Augmented Reality (AR), blockchain, Internet of Things (IoT) and smartphones as key enablers of novel scenarios aiming safe tourism. Fig. 1 depicts the notable use cases involving these technological concepts in the context of the COVID-19 pandemic, inspired by [7].

Figure 1. *Smart technology for post-COVID tourism revival and notable use cases (illustration).*

AR aims to make the on-site tourist experience more engaging, providing additional content, based on current context. IoT relies on affordable, small-size and low-consumption devices which are interconnected and equipped with various sensors used for acquiring enormous amounts of heterogeneous data from the environment. The collected data is further analysed in order to detect the events that occur within the environment, while actuator IoT devices execute the action in this context, to respond to the changes. AI enables the extraction of useful knowledge and patterns from huge amounts of data in order to make predictions of relevant aspects of previously unseen observations, enabling smarter decision-making based on these predictions. On the other side, blockchain, originally coming from the world of finance, enables storing information about the executed transactions permanently, in an immutable manner.

In this paper, we adopt the synergy involving these state-of-the-art digital technologies with the aim to enable safe, but content-rich tourism in the post-COVID era at the same time. As an outcome, three case studies built upon by extending the work from [9] are developed and evaluated from various perspectives.

BACKGROUND AND RELATED WORK

Augmented reality using AR.js

The main idea of augmented reality (AR) technology consists of merging realistic images coming from the camera stream with additional, overlayed multimedia content, such as text, sounds, images and 3D models. Moreover, these objects can be interactive, so user input, such as touch/click can trigger their actions or change, such as animation sequence. We make use of AR in order to make the self-guided sightseeing experience richer and more engaging while avoiding interactions that involve a huge number of persons. There are different implementations of AR frameworks and technologies aimed at various devices – from gaming consoles to mobile phones. In this paper, the focus is on mobile augmented reality due to smartphone portability and affordability, so additional equipment is not needed, which is suitable for tourism-related scenarios.

In this paper, the case study application is developed AR.js [10], which represents a resource-efficient, lightweight, widely compatible web-based, mobile-friendly framework for JavaScript, offering a set of features necessary for mobile AR. Two major AR paradigms are covered by this framework: 1) location-based [11] – objects appear/disappear depending on current GPS location 2) marker-based [12] - objects will show up after the detection of pre-defined barcode-alike markers. Furthermore, AR.js also provides capabilities for drawing 3D primitives (cubes, spheres and others); transformations of 3D objects; and loading of externally stored 3D models and their animation. AR.js encapsulates the capabilities of several other frameworks into a simple, higher-level Application Programming Interface (API), implemented as a set of special HTML elements and JavaScript classes. Its syntax is quite intuitive, but still very expressive, enabling the development of sophisticated AR applications in just several lines of code.

In [13], a marker-based mobile AR approach to sightseeing in the city of Niš was presented. When the visitor points the camera to the years written on the Monument to the Liberators of Niš, additional objects pop up – both relevant textual info and multimedia (audio and images), depicting the events related to the liberation of Niš. On the other side, a similar approach to AR-supported museum visits can be found in [14], using QR codes, instead of year numbers as markers.

Deep learning in PyTorch

Deep learning refers to an approach in artificial intelligence that makes use of artificial neural networks that contain multiple computation layers (known as *hidden* layers) between their input and output [15]. The role of these layers is to help extract features from raw data at the input, in order to make as good as possible prediction of the target variable in some specific context. When it comes to supervised learning techniques, the so-called deep neural networks can be efficiently trained on a set of correctly labelled observations (train set) in order to make accurate predictions on previously unseen data (test set). Each layer contains a set of computational units, the so-called artificial neurons, which are adjusted iteratively during training in order to make as closest as possible predictions. Loss function is used to estimate the distance between the predicted value and the expected outcome during training. The learning rate parameter tells how much to adjust the model weights using the optimizer with respect to the previously calculated error value.

In this paper, we leverage the PyTorch [16] framework for deep learning in Python, introduced by Facebook in 2016. It covers three main aspects that enable the implementation of deep learning-based predictive models [16, 17]: 1) high-level specification of neural network architecture 2) tensor-based arithmetic operations and their manipulation 3) representation of datasets. Due to its object-oriented approach, clear syntax and solid performance, it is becoming more and more popular, especially in scientific works.

In [18], PyTorch was used for the prediction of two aspects related to ultramarathon running - regression for run distance and classification for injury prediction. Moreover, it was also used for yoga pose detection based on images leveraging a convolutional neural network (CNN) for image classification in the same paper [18]. On the other side, in [19], hotel booking cancellation and tourist number prediction using RapidMiner were presented.

Blockchain and smart contracts

Blockchain enables decentralized transaction execution and storage of corresponding records, holding relevant information about them (such as source account, destination account, amount transferred and timestamp) [20]. As an outcome of the transaction, virtual digital tokens are exchanged among different parties with the purpose of buying a service or acquirement of ownership over either physical or intangible assets. Distributed ledger is used in this context for transaction data storage purposes and represents an append-only sequence of data blocks. The storage is provided publicly, in an anonymous, immutable, and trackable manner without intermediary, relying on a large network of peer nodes [20, 21]. However, when a transaction is executed, nodes within the network have to confirm it relying on the protocol for consensus, making it extremely difficult to tamper it [20, 21]. Despite the fact that initial applications of blockchain were mostly in the area of finance and trading, this technology has been widely adopted nowadays in order to enable novel usage scenarios, especially since the rise of the Ethereum blockchain platform, together with smart contracts in JavaScript-alike Solidity language. In the world of blockchain, the smart contract represents executable software code that defines the protocol required for the realization of transactions relying on the targeted platform [20, 21]. They describe the business logic behind them, changes that should be made as an outcome of the transaction and which data should be kept within the blockchain. Even before the current pandemic, blockchain and smart contracts have been considered as enablers of many healthcare-related scenarios, especially in the case of record keeping and their access across different organizations [22]. In this paper, we use the Ethereum blockchain and Solidity smart contract synergy to check green certificate validity at public event entrances and keep the proof of presence in order to trace contacts in case when potentially infected persons were present and notify the other participants.

SAFE TOURIST SCHEDULING LEVERAGING DEEP LEARNING MULTI-OBJECTIVE OPTIMIZATION

Avoiding large queues and crowded places, especially indoors, is highly beneficial for safe tourism, as it contributes to COVID-19 spread reduction. Therefore, one of the common government responses to novel circumstances is putting limits on the maximum number of persons inside closed spaces and in case of public gatherings, even outdoors. However, this safety measure has a negative impact on tourism and sightseeing, especially when it comes to museum and gallery tours. In that context, the aim of this case study is to enable smart tourist scheduling, aiming to reduce the risk of coronavirus infection during the tour. The idea is to generate recommendations for safe sightseeing and show them to tourists via mobile app, taking into account several factors relevant to the COVID-19 pandemic. For that purpose, we adopt the approach for proactive planning leveraging deep learning-based prediction and linear optimization, as approved in case of pandemic resource planning scenarios [23].

Deep learning in PyTorch is leveraged for prediction of two aspects considered during tourist scheduling: 1) number of tourists that will visit some location and 2) tour cancellation prediction. The first one is treated as a regression problem, while the second is considered a binary classification.

The aim of the first predictive model is to estimate the number of tourists that would visit some location within the destination, taking historical data about visitor count and external factors like number of COVID-19 cases and average daily temperature as input. In Table 1, the layout of the dataset header can be seen (the output and dependent variable are gray). When it comes to tourist count data used as input for the training of predictive models, a camera-equipped Raspberry Pi executing computer vision script for human body detection is used for that purpose [24].

Table 1. *Visitor number predictor dataset*

COVID -19 cases	Temp.	Month	Day	Hour	Location	Visitor [num]

For regression, we used a deep neural network with the following architecture: input layer – 6 nodes (corresponding to the number of input variables); 3 hidden layers – 45 nodes each, rectified linear unit (ReLU) activation function; output – one linear node. For training such a neural network, we rely on the Adam optimizer and mean squared error loss function, while the value of the learning rate was 0.01. We decided to rely on the Adam optimizer due to fast computation time while it requires fewer parameters for tuning than others [18].

On the other side, the second predictive model has a goal to predict whether a tourist is likely to cancel the visit or not, considering the COVID-19 case number, price of ticket or reservation, season and number of persons within the reservation. In this context, for binary classification, we use a similar neural network, with several modifications: sigmoid activation function in the output layer, stochastic gradient descent optimizer, binary cross entropy loss function and learning rate 0.003. The header of the dataset used for the second predictive model is shown in Table 2.

Table 2. *Tour cancellation predictions*

COVID -19 cases	Season	Number of persons	Price	Location	Cancel [yes/no]

For particular tourist-oriented location l, the total estimated count of visitors $tourists_l$ is calculated as the difference between the outcome of the first predictive model for that location $predicted_l$ and the count of all reservations that will be cancelled multiplied by a number of persons involved:

$$predicted_l - \sum_{i \in N} cancelled_l[i] \cdot num\_persons_l[i] = tourists_l \quad (1)$$

Finally, once the tourist number estimate is known, multi-objective tourist allocation can be performed, relying on the Pymoo [25] framework for Python. For this problem, we observe the decision variable of transfers between tourist locations, denoted as $x[i,j]$, where L is the set of considered locations, i represents the index of the source location, while j is the index of target location (where tourists should go). For source destinations, the approximation is made with respect to the tourist's closest GPS location. This variable takes value 1 in case the tourist at current location i is advised to visit location j. When it comes to allocation, there is a constraint that the current number of tourists at each target location $tourists[j]$ including the new visitors should be lower than the maximum number of persons allowed for that place *max_allowed[j]*:

$$tourists[j] + \sum_{i \in L} tourists[i] \cdot x[i,j] \le max\_allowed[j], j \in L \quad (2)$$

However, there are two objective functions – infection risk reduction and overall tourist commuting time minimization. The first one aims to keep the COVID-19 infection risk for location *j* as low as possible. Infection risk is defined as the ratio between the number of visitors *toursists[j]* and the size of the location, expressed in square meters (*size[j]*), given as:

$$minimize \sum_{i,j \in L} \frac{x[i,j] \cdot tourists[i] + tourists[j]}{size[j]} \quad (3)$$

On the other side, another objective function has a goal to minimize the estimated transportation time required to travel (denoted as *duration*) from one location to another, as longer trips in public and group transportation increase the risk of infection as well:

$$minimize \sum_{i,j \in L} duration[i,j] \cdot x[i,j] \quad (4)$$

Furthermore, the values obtained as the outcome of optimization process (decision variable *x[i,j]*) are interpreted as recommendations, so for the user currently on location *i*, the recommendation for the next visit is location *j*. The workflow of this case study is depicted in Fig. 2.

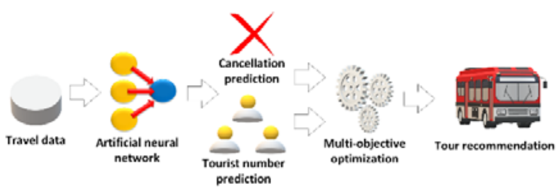

Figure 2. *Smart tourist scheduling leveraging deep-learning and multi-objective optimization workflow*

AR-ENABLED APPROACH TO GAMIFIED SIGHTSEEING

In traditional tourism, a group of travelers usually follows a tourist guide giving the necessary information and additional details about the visited destination and its sights, such as buildings and monuments. However, in the post-COVID era, gathering of large groups is considered quite problematic due to infection risk, so an adequate alternative to the traditional approach is needed, in order to ensure equivalent self-guided experience [7]. In this case study, the goal is to adopt mobile AR technology not only to change the role of the human guide by the mobile app but also to provide an additional motivational factor in the form of gamification for tourists, promoting local craftmanship and physical activity, making the overall experience more engaging and entertaining.

This case study leverages both location- and marker-based approaches to augmented reality relying on smartphones, their cameras and GPS sensors. While traversing the tourist destination, at specific locations of interest, especially near buildings of importance and monuments, several types of interactive 3D objects pop up over the camera stream. The first type is *info objects*, which represent location-triggered animated 3D models aiming to depict some important historical or cultural event, relevant to the tourist destination. Furthermore, the user is redirected to a page providing textual info about the location by clicking or touching one of these objects. Another type of location-based object is question boxes, which give the opportunity to the tourists for collecting points, which can be later used for discount coupons. When clicked, they redirect to the input form where the user can answer the destination-related question, usually about history and culture, based on information provided by info objects. These questions are either to fill in the gap in sentences with correct word or multiple-choice. Each correct answer brings points, which are accumulated for a given e-mail address. Later, users are able to claim prizes for a given amount of points, selecting one of the traditional local craftsmanship products, such as wine, chocolate and cheese. The prizes are received in the form of digital coupons via tourist-provided e-mail.

Fig. 3, 4, and 5 give representative screenshots of AR-enabled mobile app for a gamified tourism experience. Fig. 3a shows a 3D model of Sebastokrator Momčilo with knight guards popping up at the entrance of his fortress (Momčilov Grad) in Pirot, Serbia. Clicking on the 3D model, the user is redirected to the info page, stating that the Seabstokrator built Pirot Fortress in the 14th century and the name of his legendary horse was Jabučilo [26], as can be seen in Fig 3b.

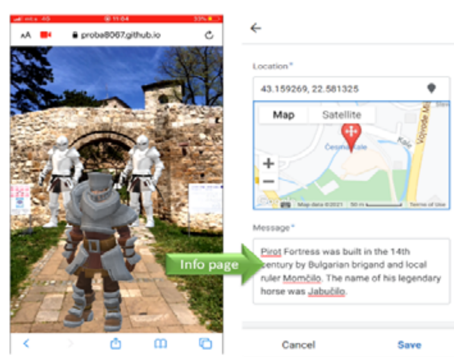

Figure 3. *Location-based AR for tourism: a) 3D historical reconstruction b) info page*

Moreover, Fig. 4a shows a 3D question box that appears in Kazandžijsko Sokače, Niš, Serbia, while arriving close to the Monument of Stevan Sremac and Kalča. This box redirects to the question form (Fig. 4b), where the user has to respond from which book/movie this character comes from (referring to "Ivkova Slava"). Finally, Fig. 4c shows the prize selection screen.

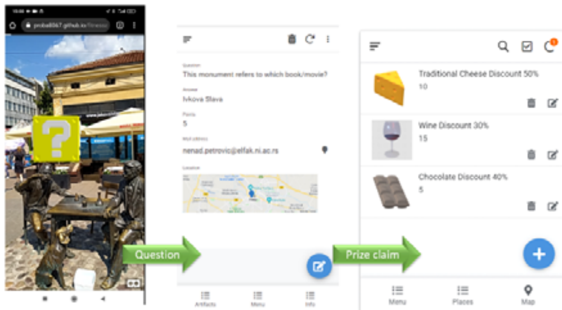

Figure 4. *Elements of gamification in AR sightseeing app: a) question box object b) question responding c) prize selection*

Furthermore, this app includes two more gamification elements, related to the promotion of physical activity, which is also one of the aspects relevant to health in the post-pandemic era, especially after long-term quarantine periods. While exploring the tourist destination, the user is also rewarded for the calories burnt between the last two 3D objects discovered. In this context, we also leverage deep learning-based regression for energy spending prediction, based on dataset from [27]. In Table III, the layout of the dataset is depicted.

Table 3. *Dataset for predicting the burnt calories*

Activity type	Weight [kg]	Duration [min]	Calories burnt [kcal]

The assumed type of activity is walking, while the duration required for passing between two interactive 3D objects is considered as input, together with user-provided weight. The predicted value of calories burnt is divided by 100 and added to the sum of accumulated points.

Additionally, the third gamification element is also related to physical activity and relies on marker-based AR. The goal of this element is to enable safe exercise instructions without the involvement of large groups. Additionally, it is assumed that near locations of importance, QR code markers printed on paper are placed. When the camera is pointed at them, each marker shows a 3D animated model of a yoga instructor showing a distinct exercise pose. After that, the user is able to provide a picture of himself/herself repeating the exercise. In case that pose is correct, a certain amount of points will be collected. For pose correctness classification, a convolutional neural network (CNN) was used, as described in [18]. The neural network is able to recognize 5 different yoga poses and is trained on a publicly available dataset from [28]. Its input is images of size 256x256 and it contains 5 convolutional layers followed by max-pooling layers performing downsampling, to reduce the size of the feature map and increase processing speed. On the other side, the classification part consists of 4 fully connected layers with ReLU activation and 5 softmax nodes in the output, as it performs multiclass distinction into 5 categories.

Fig. 5 shows the screenshots of the marker-based part.

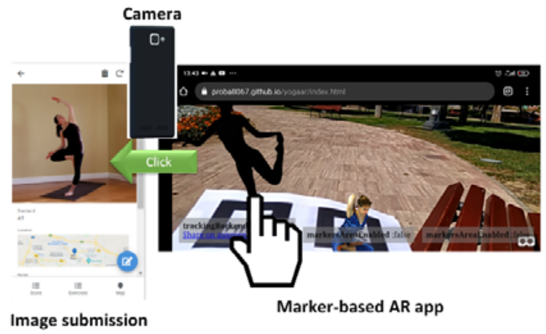

Figure 5. *Marker-based AR to support physical activity*

Fig. 6 depicts an overview of the AR application workflow used in this case study. Its architecture is based on the works from [18, 29]. Several different technologies were adopted as described: 1) AR.js – for location – and marker-based mobile AR; 2) AppSheet – a codeless platform for multiplatform mobile applications, used for the creation of info pages and input forms (questions and image submission) relying on Google Sheets for data storage; 3) AppsScript - a framework for integration of Google's services built upon JavaScript, leveraged for trigger-based backend business logic (checking the question answers, uploading pose images, score calculation, prize claim, coupon generation and delivery via e-mail) 4) Flask [30] – providing the interface to the PyTorch predictive models (calories burn prediction and yoga pose classification) via HTTP requests which are sent from AppsScript.

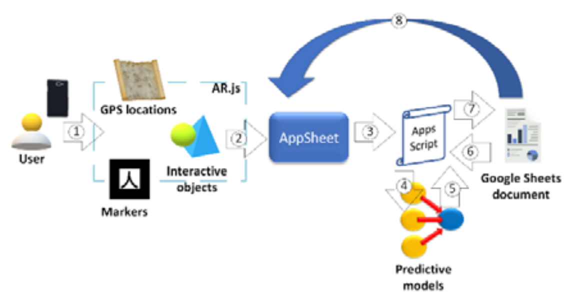

Figure 6. *Gamified AR-enabled sightseeing workflow: 1) Touch/click on 3D model 2) Redirection to info pages, questions and input forms 3) Apps Script trigger activation 4) HTTP requests via Flask API containing predictive model input 5) Prediction outcome 6) Retrieval of stored data 7) Storing new data 8) Update view*

SAFE PUBLIC EVENTS USING IOT AND BLOCKCHAIN

When it comes to post-COVID tourism, culture and entertainment-related events, such as gallery and museum expositions, concerts, theatre and cinema, indoor safety is of utmost importance. In this context, governments of many countries around the world are imposing specific requirements for entering closed-space public events, such as a green certificate. Pre-requisites for such documents are often a negative coronavirus test, vaccination proof, or the presence of healed COVID-19 within the health record's disease history. However, checking the validity of green certificates manually by approved personnel is not only time-consuming but could also cause large waiting queues at the entrance, which increases the risk of coronavirus infection as well. Moreover, if later turns out that some of the event participants were infected, in order to reduce further spread of coronavirus, it is highly beneficial to inform the attendants about that.

Therefore, in this case study, we introduce an IoT-based system for automated check of compliance with indoor safety conditions, in order to speed up the procedure and avoid crowd. For this purpose, we rely on an affordable, small-size, low-consuming Arduino Uno microcontroller equipped with an RC522 RFID reader. Moreover, the Ethereum blockchain in synergy with Solidity smart contracts is adopted for vaccination record checks and contact tracing.

The workflow of the proposed system is illustrated in Fig. 7. First, the person who enters the event, provides an RFID tag, either in the form of a distinct card or integrated with a smartphone. Furthermore, based on tag ID, it is checked if disease history containing COVID, vaccination, or test record with valid duration (depending on the specific country) exists on the Ethereum blockchain. In case that check is passed, the entrance opens, otherwise, it remains closed, preventing the person from entering. Additionally, the the number of persons present in this location is counted and leveraged for the creation of the dataset from Table I. Storage and retrieval of green certificate data is implemented in the form of Solidity smart contracts, based on [8, 9]. For vaccination records, the relevant data is kept, such as dates of first, second and booster doses, type of vaccine and validity duration. Similarly, for coronavirus tests, type (such as quick antigen, PCR) and duration are also relevant. Moreover, for each person who passed the check, the presence record for the purpose of contact tracing is stored on the blockchain, which contains the location ID, tag ID, phone number and timestamp. In case of a positive coronavirus test for at least one of the attendants during the next 7 days, all the people who attended the event together will be informed via SMS that risky interaction might have occurred on that day. The storage and retrieval of contact tracing records are done in a similar way, as in the case of green certificate-related data.

Figure 7. *Event safety check workflow*

RESULTS AND EVALUATION

This section describes the experiments used for the evaluation of the previously presented case studies, considering various relevant aspects. The experiment execution environment mainly relies on free cloud resources. When it comes to the execution of Python components (predictions and scheduling), we rely on cloud resources offered by Google Collab [31]. It is both a development and runtime environment, allowing to leveraging of high-performance GPUs which accelerate the training phase of deep learning models significantly. On the other side, for the AR app, the GitHub Pages [32] service was used for deployment. Additionally, business logic and mobile app input forms are executed on Google Cloud infrastructure offered within the free plan of AppSheet and Apps Script. For blockchain-related experimentation, we make use of Ganache [33], an Ethereum blockchain simulation environment running on the local computer (laptop equipped with quad-core i7 CPU and 16GB of DDR4 RAM).

Table 4 summarizes the results of experiments from the perspective of two metrics: execution time for various processing steps and prediction quality. The first column represents the name of the case study to which the experiment refers to. However, the second column shows the aspect that was evaluated within the experiment. The third column shows the metric used for the evaluation of the selected aspect. Finally, the last column presents the value achieved for the selected metric, as the average result obtained in 100 experiments.

In what follows, the achieved results shown in Table 4 will be discussed for each of the case studies. For the first one, the calories burn prediction model shows high performance (low mean relative error), which is suitable even for more sophisticated fitness-related use cases. However, the processing time in the reward claim scenario is longer than 1 second considering the usage of the remote mail server responsible for sending prize coupons, which is still acceptable as it does not depend on real-time user interaction. Furthermore, the smart tourist scheduling case study achieves faster processing times more appropriate for real-time (which is a must here) together with satisfactory prediction quality - low relative error for regression-based tourist number prediction and high accuracy for classification-based reservation cancellation prediction. Finally, the last scenario shows slower response times, mainly dependent on the limitations of the underlying blockchain infrastructure itself when it comes to data retrieval as a compromise for other desirable features at the same time, such as traceability.

Table 4. *Case study evaluation*

Case study	Aspect	Metric	Value
Gamfied sightseeing	Question check	Execution time [s]	0.571
	Reward claim		2.27
	Calories burnt prediction	Execution time [s]	0.615
		Mean Relative Error [%]	7
Smart scheduling	Tourist number prediction	Execution time [s]	0.127
		Mean Relative Error [%]	14
	Cancellation prediction	Execution time [s]	0.241
		Accuracy [%]	89
	Multi-objective optimization	Execution time [s]	0.012
IoT/Block chain	Contact tracing - notification	Execution time [s]	70.41
	Green certificate check	Retrieval time [s]	8.42

CONCLUSION AND FUTURE WORKS

According to the results achieved for the presented case studies, it can be confirmed that state-of-the-art smart technology effectively provides support to tourism and related sectors in the post-pandemic era, contributing to their revival. Additionally, the adoption of open-source and free-of-charge software and affordable, widely compatible hardware platforms is promising, especially when it comes to countries under development. Moreover, the fast prototyping using the combination of the proposed technologies is also beneficial to early adopters as well, such as regions relying entirely on tourism. However, the main limitation of the current work is the lack of a framework for imposing data privacy policies on the involved users when it comes to contact tracing and green certificate scenarios.

In the future, it is planned to focus on safe air quality control and regulation mechanisms relying on IoT and artificial intelligence, in order to further reduce the risk of COVID-19 transmission, especially indoors, which would contribute to the revival of large-scale public events. Finally, we will also aim to enable the adoption of country-specific privacy preservation policies based on data anonymization before storing it on the blockchain.

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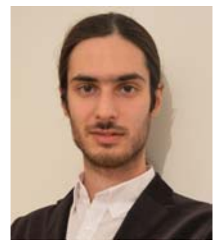
BIOGRAPHY of the first author



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BEZBEDAN TURIZAN U DOBA KORONAVIRUSA OSLANJAJUĆI SE NA PAMETNE TEHNOLOGIJE

Nenad Petrović, Vasja Roblek, Maša Radenković, Valentina Nejković, Nino Papachashvili

Rezime: *Turizam je jedna od najugroženiji grana za vreme trenutne pandemije koronavirusa, s obzirom na stroge mere bezbednosti u mnogim državama, koje ograničavaju putovanja, ali i psiholoških faktora (poput straha i anksioznosti) sa druge strane. Međutim, takozvane "pametne" digitalne tehnologije pokazuju veliki potencijal, što se tiče oporavka turizma u novonastalim okolnostima. Prema tome, ovaj rad razmatra kako je moguće primeniti sinergiju sledećih koncepata u tu svrhu: veštačka inteligencija, proširena stvarnost, blokčejn, internet stvari i pametni telefoni. Kao ishod, predstavljene su i evaluirane tri studije slučaja: 1) pametno raspoređivanje turista 2) primena gejmifikacije i mobilne proširene stvarnosti za interaktivan obilazak znamenitosti 3) bezbedna javna okupljanja. Cilj ovih studija slučaja je da obezbede ne samo bezbedan, već i sadržajan obilazak turističkih destinacija upotrebom pametnih tehnologija.*

Ključne reči: zaštita zaposlenih, mobilne aplikacije, internet stvari, duboko učenje, blokčejn.

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ENVIRONMENTAL MONITORING AND CONTEMPORARY ORGANIZATION

Abstract: *There is a continual need to monitor all activities carried out within the environmental management framework. However, to monitor any activity, constant data collection, i.e. monitoring, is required. Responsible environmental management means adequate monitoring, which implies the process of collecting data not only on the state of the environment but also on the ecological efficiency of a contemporary organization, law enforcement, and implementation of strategies, programs and plans. In addition to the operationalization of basic research terms, the paper also considers the importance of the application of environmental monitoring instruments by a contemporary organization.*

Key words: environmental management, modern organization, environmental monitoring

INTRODUCTION

The literature review shows that the most common risk in the workplace and the natural environment that can affect the safety of both is industrial pollution as a consequence of non-compliance with safety standards in industrial production, high-risk industrial processes and handling of toxic and radioactive materials, all of which can cause accidents, breakdowns and large-scale pollution on the affected territory and beyond [1]. For adequate environmental management, it is necessary to conduct proper environmental monitoring activities and apply appropriate legal instruments. Monitoring is carried out by systematic observation of indicator values, that is, by observing negative effects on the environment, the state of the environment, measures and activities undertaken with the aim of reducing negative impacts and increasing the level of environmental quality. Environmental management at the level of modern organizations which can be major or minor polluters depending on the activities they are dealing with is an integral part of the environmental management system. Organizations should mobilize all employees and adapt their systems, strategies, resources and structure to all environmental management system-related requirements. In the context of this work, systematic and comprehensive monitoring of the environment is a prerequisite for reliable determination of the status of various environmental media, but also the environmental performance of modern organizational processes, as a basis for planning the use of environmental resources and effective integrated management of the environment. The responsibility for the establishment and execution of this type of monitoring usually rests with an organization that has an established environmental management system, through the adoption of an annual monitoring program and the provision of conditions for its implementation.

CONCEPTUAL AND THEORETICAL APPROACH

Environmental management

Regarding the conceptual definition of environmental management, the terms "ecological management" or "eco-management" are also used today, although the term "environmental management" is used more frequently in foreign literature.

In our country, both terms have a similar meaning and refer to several management activities related to ecology, and therefore to the environment. If we look at the differences between these two concepts, we can see that the term "environmental management" is related to management when solving problems that are directly related to the environment, specifically to water, air, waste, etc. (waste management, water resources management, etc.). On the other hand, the term "ecological management" is used in the management of individual economic entities to achieve compliance with all requirements related to the state and conditions of the environment through economic activities [2].

There is no generally accepted and universal definition of environmental management due to the breadth and variety of topics. However, ecological management is determined by characteristic goals, so it could be said that it represents an environmental protection management system, which aims to establish a systematized and unified approach in industry and other branches and which ensures that environmental reasons become an integral part of business strategy and practice. If management is taken to refer to the process by which economic or other activity is planned, organized, coordinated, and controlled, then ecological management refers to the process by which economic or other activity in the field of ecology is planned, organized, coordinated, and controlled in an ecological way, or by which goals in the domain of ecology are achieved [3].

Environmental management in the broadest sense can be defined as a discipline focusing on the relationship between humans and the environment [4]. Management represents the aspiration to eliminate negative tendencies and influences in relation to the environment and human health. Managing the environment means carrying out basic strategic activities that determine the means and define the protection criteria as well as the directions of environmental development [5]. Environmental management is a technique used to manage environmental processes. It defines what is environmentally friendly as well as what is an environmental, economic, social, and technological barrier to improving the protection process [6].

Contemporary organization

The very notion of an organization is derived from the Greek word *organon*, which literally means a tool, a device. An organization is a group of two or more people working in a structured way to achieve one or more goals. The following elements that characterize each organization are listed in the literature: organizations are social entities (consisting of two or more persons); they are carefully structured to get the job done efficiently; they are goal-oriented and have the resources that members of the organization will use; organizations have management that directs all other elements (people, resources) towards achieving goals. The concept of organization is not static but changes over time in each environment [7].

The growing complexity of business, the emphasized interdependence of phenomena, and the exponential growth of knowledge create the conditions for the development of the modern theory of organization. With the development of computer systems and quantitative methods, as well as system theory, there is a modern theory of organization, where the organization and its parts are observed according to the principles of the systems approach. The systemic approach views the organization as an open system, made up of subsystems, parts, and processes that achieve balance through regulation. Modern organizations, whether economic or non-economic, require constant management actions to operate and develop in the complex and dynamic environment [7]. Larger organizations are complex to manage, as they need to invest more energy to coordinate their departments, require enormous resources, and are slow to respond to changes in the environment.

All successful economies today generally have large private sectors that adapt to changes in the environment. Internal coordination in companies is more efficient and that is why they are growing, unlike small interdependent companies. An efficient bureaucracy with the superior skills of its employees is a new intellectual tool.

The emergence of information technologies was necessary for the development of modern organizational schemes. The pattern of creating modern organizations is based on an explicit analysis of the problem. Raising "the model from the level of the subconscious, they made it available for verification and improvement" [8]. This is the very foundation of modern organizations. Every contemporary organization is affected by the environment in which it operates. One of the definitions of the environment is "the system of forces that surround the organization and affect the way it functions as well as the access to its resources" [9]. The organizational environment is usually divided into internal (the totality of connections and relations between and within the company's resources) and external (individuals or groups of organizations that are outside the organization but are also in direct interaction with it) [10]. Organization as a structure is a feature of all social systems that differ from natural systems in their characteristics. Natural and social systems represent a dynamic system whose parts are in a variable relationship based on the principle of feedback [11]. Whether they are small organizations or companies with their autonomous units (departments), all activities and processes that take place within them, as well as products, have a certain impact on the environment in one of the phases of the life cycle.

CONTEMPORARY ORGANIZATION AND THE ENVIRONMENTAL ASPECTS

When introducing the ISO 14000 standard, it is important to consider the relationship between environmental aspects, environmental impact, and its control systems. Elements of activities, products, and services of a contemporary organization that interacts with the environment are called environmental aspects [12]. The term "environmental aspect" itself should be understood as an aspect through which an organization affects or may affect the environment (for example, the environmental aspect "wastewater discharge" implies that an organization may have an impact on the environment, i.e. pollute watercourses, land, etc.). Environmental impact is defined as any environmental change, improvement, or deterioration, that is entirely or partially a consequence of the activities of the organization, its products, or its services [13]. A modern organization needs to identify the environmental aspects that it can manage and those that it impacts. Aspects of the environment that are harmonized with national normative acts in the field of environmental protection and that are included in the management procedure in environmental protection are the following [12]: waste generation; wastewater discharge; rainwater discharge; air emission sources; exhaust emissions from cars; chemical operations; water use operations; energy operations; use of natural resources; cessation of product production; and waste disposal.

Table 1. *Examples of connections between activities, aspects, and environmental impact* [4,13]

Activity, product, or service	Aspect	Consequences of environmental impact
Product: Paper printing	Emission of organic solvents into the atmosphere	Air pollution by organic solvents
Activity: Transport of dangerous substances	Potential spill of dangerous substances in case of an accident	Pollution of land/water, endangered biodiversity
Service: Supply of settlements with hot water (district heating)	Combustion of fossil fuels	Emission of harmful gases

Activities related to the products and services of an organization produce environmental impacts (positive or negative). All these environmental impacts, as well as any changes in them, are defined by the standard. The elements of the control system are designed and applied according to the aspects of the organization's environment and environmental impact [8].

At some stage in their life cycle, almost all products, services, and activities have a certain impact on the environment (local, regional, or global). To determine the interaction of products and processes of the organization with the environment, it is necessary to [12]:

- select the categories of products and services of the organization;
- identify environmental aspects for each product category;
- assess the significance of the environmental impact for each identified aspect;
- define measures to eliminate, reduce, and/or manage risks.

ENVIRONMENTAL MONITORING INSTRUMENTS

The primary objectives of environmental monitoring are warning of danger and prevention of unwanted consequences for the environment and monitoring of already occurring changes to prevent further negative impact on the environment. Monitoring can refer to environmental components (air, water, soil, biodiversity) or to economic activities that affect the environment (industry, energy, agriculture, transport, and tourism). Specific research institutions at the national and local level, in accordance with their legally established competences, perform this type of monitoring. All industrial plants that represent a source of environmental pollution have the obligation to monitor the impact of their activities on the environment. They also monitor the effectiveness of the applied measures to prevent, create, or minimize the level of pollution. They are also obliged to prepare a monitoring plan, keep regular records, and submit reports to the competent institution in charge of managing the national environmental information system. From all national environmental information systems, data and information are consolidated and integrated into international systems. To include individual national reports on the state of the environment in a single report on the state of the environment in Europe, it is very important to establish a unique methodology for monitoring the state of the environment based on indicators as indicators of the state of a phenomenon [4].

According to the methodology of the European Environment Agency, the determination of environmental quality indicators is based on the relationship between the environment and human activity. These relationships are represented by indicators that "depict cause-and-effect relationships and represent the basis of the DPSIR methodology" (Ibid., p. 81).

The DPSIR methodology follows selected indicators based on which it gives an assessment of the state of the environment, as well as a definition of goals and a proposal for further measures to improve the current state. The methodology considers five groups of indicators [14]:

- indicators of driving factors (D);
- indicators of pressures on the environment (P);
- the state of environmental condition (S);
- impact indicators (I);
- indicators of reactions to the existing state of the environment (R).

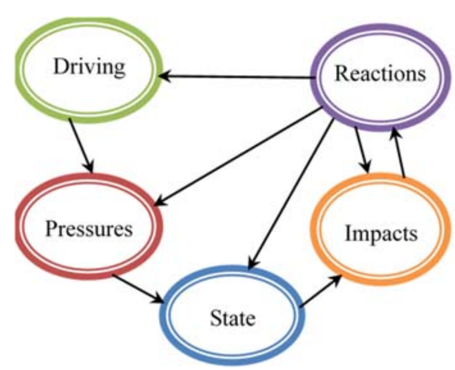

Figure 1. *DPSIR framework [14]*

According to the DPSIR framework, there is a chain of causal links starting with driving forces (economic sectors, human activities, social and demographic conditions), through pressures caused by human activities (emissions, waste, resource use), to the state (physical, chemical, and biological phenomena in certain areas) and impacts as a cause-and-effect relationship (systems, human health, and functions). Ultimately, they lead to reactions (setting priorities, setting goals, indicators). Describing the causal chain from driving forces to impacts and reactions is a complex task and tends to be divided into subtasks (for example considering pressure-state relationships) [14].

On the other hand, the approach of a contemporary organization to environmental monitoring does not have to be based only on the DPSIR framework, but also on some others, of which PSR and DSR stand out. The PSR model was developed in the seventies of the 20th century, for the purposes of data organization in the field of the Canadian environment, and over time it began to be used in OECD (*Organization for Economic Cooperation and Development*) practice, namely in the working group for environmental conditions [15]. The PSR model represents a concept according to which anthropogenic activities generate pressures on the environment that result in changes in the state of the quality of environmental elements. Society reacts to observed changes in the state of the quality of environmental elements in different ways, starting from the change in the nature and intensity of the pressures it generates to the implementation of various plans for the protection and improvement of the quality of the environment. The usefulness of the PSR model is recognized at the global level, and the model can be applied at the supranational, national, regional or local level [16].

The DSR model was developed by the United Nations Commission on Sustainable Development (UNCSD) as part of a wider program related to the development and structuring of 134 indicators of sustainable development into a coherent system with units related to driving forces, states and reactions of society [17]. With this model, the category of pressures is contained within the framework of driving factors, and in this way it gives enough importance to economic, social and institutional indicators. The DSR model can be understood as a matrix in which the indicators are grouped horizontally into three basic units, while the vertical axis contains the basic components of sustainable development - social, ecological and environmental development [18].

No less important is the fact that, in addition to complementary methodological frameworks, the modern organization needs to harmonize the environmental monitoring system with the overall safety system of the given organization, with an emphasis on both safety and business continuity [19].

CONCLUSION

It is an inevitable fact that there is a close cause-and-effect relationship between a contemporary organization and the environment. All contemporary organizations considered a source of environmental pollution are responsible for monitoring, regular observation, measurement and evaluation of environmental parameters, changes in the quality and quantity of the environment, the emission of pollutants and the use of natural resources. They also monitor the effectiveness of applied measures for the prevention, occurrence or minimization of the pollution level. Their responsibility is as well the preparation of the monitoring plan, keeping regular records and submission of reports to the reference bodies responsible for the management of the national environmental information system.

It is clear that today's organizations operate in a turbulent market environment with pronounced dynamic competition. In such economic conditions, the choice and implementation of an adequate competitive strategy is a guiding star of a modern organization to run a successful business. In addition to environmental trends and strong global competition that exert excessive pressure on managers to channel their organizational activities towards the continuous development of key competencies in order to strengthen their market positions, it is necessary to direct organizational activities towards harmonizing their development with the ecological order in nature.

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MONITORING ŽIVOTNE SREDINE I SAVREMENA ORGANIZACIJA

Mirjana Galjak

Rezime: *Sve aktivnosti koje se sprovode u okviru upravljanja životnom sredinom potrebno je da se kontinuirano i adekvatno prate. Da bi se pratila bilo koja aktivnost neophodno je konstantno prikupljanje podataka odnosno monitoring. Odgovorno upravljanje životnom sredinom podrazumeva adekvatan monitoring koji predstavlja ne samo proces prikupljanja podataka o stanju životne sredine, već i podatke o ekološkoj efikasnosti savremene organizacije, sprovođenje zakona, implementaciju strategija, programa i planova. U radu se, pored operacionalizacije osnovnih istraživačkih pojmova, razmatra i značaj primene instrumenata za monitoring životne sredine u savremenim organizacijama..*

Ključne reči: upravljanje, životna sredina, savremena organizacija, monitoring

BOOK REVIEW- PRIKAZ KNJIGE

U knjizi **„Osnove prava i zakonodavstvo zaštite zdravlja i sigurnosti na radu"** autora prof. dr Marinka Đ. Učura, Cvetana Kovača, Ane Šijaković i dr Ivane Krišto nalaze se korisni i originalni sadržaji o osnovama prava i zakonodavstva zaštite zdravlja i sigurnosti na radu posmatrani u međunarodnim i nacionalnim okvirima.

U aktivnostima brojnih subjekata svakodnevno se uspostavljaju i razvijaju odnosi čiji sadržaj čine prava, obaveze i odgovornosti tih subjekata, koji se, u najširem smislu reči, mogu smatrati odnosima sigurnosti, a onda i odnosima zaštite zdravlja na radu. Istraživačku pažnju autori usmeravaju na tri područja tih odnosa: prvo područje odnosi se na donošenje pravnih propisa kojima su navedeni odnosi uređuju; drugo područje odnosi se na realizaciju pravnih pravila na snazi; a treće područje se odnosi na nadzor primene (prakse) i ostvarivanja onoga što je propisano.

U kompleksnoj multidisciplinarnoj i interdisciplinarnoj oblasti zaštite zdravlja i sigurnosti na radu teško je naći pravu meru za kazivanje o pojmovima, kategorijama, institutima i odnosima koji, u najvećem delu, tu oblast određuju. Dugogodišnja iskustva u teoriji i praksi, autori su koristili da nađu pravu meru između jednog i drugog. Bitna determinanta u koncepciji i sadržaju ove knjige su programi po kojima se realizuje predmet/kurs *Osnove prava i zakonodavstvo sigurnosti* na visokim školama, fakultetima, veleučilištima i sveučilištima (univerzitetima prim.aut.) u Republici Hrvatskoj.

U prvom delu publikacije predstavljen je kratak istorijski osvrt zaštite na radu, da bi se na temelju upoznavanja prošlosti bolje razumela sadašnjost u stvaranju, primeni, nadzoru odnosno kontroli primene prava. U tom delu elaborirane su nomotehničke pretpostavke u stvaranju propisa sigurnosti na radu i zaštite zdravlja na radu, o klasifikaciji propisa, posebno o donosiocima propisa različitog imena, nadležnosti, postupka, sadržaja, prostornog i vremenskog važenja donesenih propisa itd.

Pored toga, opisani su heteronomni propisi u Hrvatskoj (o Ustavu države – „zakonu nad zakonima"), zakoni i brojni podzakonski dokumenti kojima se uređuju sigurnost na radu i zaštita zdravlja na radu i zaštita životne sredine. To se odnosi i na autonomne opšte normativne akte u tim odnosima (kolektivni ugovor, procena rizika, pravilnik o zaštiti na radu, odluke s opštom normama i druge osnivačke akte, statute, pravila i druge). Takođe, čitaoci mogu da se upoznaju sa fenomenom osnovnih ljudskih prava i sloboda, kao i prava na rad i u vezi sa radom.

U drugom delu *"Zakonodavstvo sigurnosti na radu i zaštite zdravlja na radu"* sadržaj se odnosi na: pojmove i odnose, nomotehniku u pravu zaštite na radu, subjekte u ovim odnosima (prava i obaveze poslodavaca, radnika i drugih subjekata). Izvori prava zaštite na radu su konvencije MOR-a, direktive EU, nacionalno zakonodavstvo o sigurnosti na radu i zaštiti zdravlja na radu, autonomni opšti normativni akti i drugi izvori.

Treći deo je posvećen državnom inspektoratu, sudskoj praksi; statistici povreda na radu i profesionalnih bolesti na međunarodnom nivou (statistika povreda na radu MOR-a i evropska statistika povreda na radu); nacionalna statistika povreda na radu i profesionalnih bolesti, dok su četvrti i peti deo rezervisani za popis literature i priloge (ogledni primeri autonomnih akata poslodavca, pravilnika o zaštiti na radu, „Evropskog i nacionalnog plana zaštite zdravlja i sigurnosti na radu".

Posebnost dela *Prilozi,* a i čitavog udžbenika je u nekoliko metodičkih novosti koje štampani udžbenik proširuju i povezuju sa elektronskim izvorima korišćenjem mobilnih uređaja bliskim različitim generacijama čitaoca. Naime, kao dodatak tekstu (u prilozima) koriste se kodovi za brzi pristup (QR kodovi) koji čitaoce povezuju sa digitalnim izvorima, omogućuju detaljnije istraživanje i pomažu pri shvatanju izloženog gradiva.

Ovim rukopisom autori žele da istaknu značaj zakonodavstva u svakodnevnom radu brojnih subjekata u još brojnijim odnosima u proizvodnji u najširem smislu reči, a koji se odnose na sigurnost na radu i zaštitu zdravlja na radu. Pravna regulativa, propisi i praksa stalno se menjaju, a sve te promene zahtevaju odgovarajuće odgovore. Autori su odgovorili na ovaj istraživački izazov stvarajući vredno štivo namenjeno svima koji se, posredno ili neposredno, bave ovom problematikom: studentima, stručnjacima zaštite na radu, poverenicima zaštite na radu, poslodavcima i njihovim predstavnicima, radnicima, radničkim sindikatima, lekarima specijalistima medicine rada, inspektorima, sudijama, veštacima, advokatima itd.