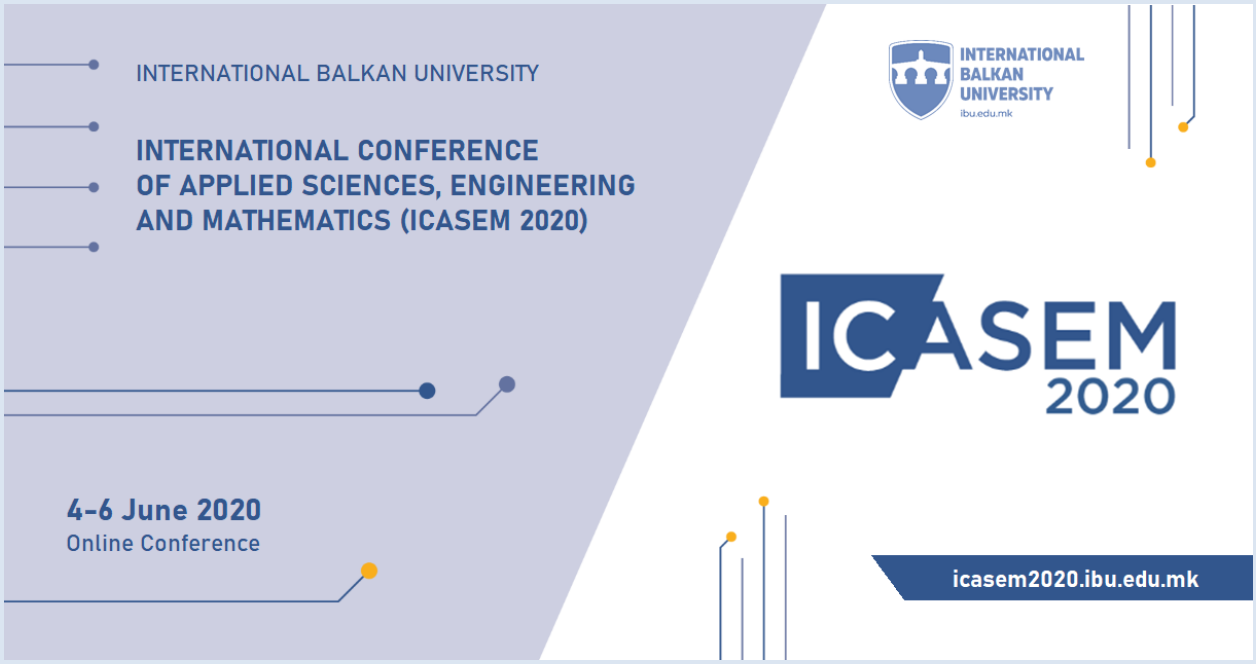

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Texas A&M University, Qatar

Utilizing Machine Learning for Planning Unsupervised Future Cellular Networks

Prof. Dr. Nicholas Kathijotes

International Ocean Institute, Cyprus

Climate Change and Rainwater Management – Rain Cities

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Keynote Speaker

Prof. Dr. Ali Ghrayeb

Texas A&M University, Qatar

Utilizing Machine Learning for Planning Unsupervised Future Cellular Networks

Reducing the cost of deploying cellular networks is of great interest to all concerned parties, including service providers and users. Such cost can be associated with operation (OPEX) or capital (CAPEX). Towards achieving this goal, the wireless industry is moving towards zero-touch cellular networks, i.e., zero human intervention. The need for having unsupervised (i.e., automated) cellular networks is aligned with the vision of having a dynamic cellular architecture, enabled by the use of mobile equipment (e.g., unmanned aerial vehicle base stations), which gives the architecture flexibility to adapt quickly and frequently to service demands. To this end, the concept of self-organizing network (SON) has been established and added to the list of 5G/6G key enabling technologies that aim at automating the processes of planning, configuration, management, and healing cellular networks. Among these processes, radio access network (RAN) planning has received special attention, since it decides on the required radio resources and the equipment to deploy, which directly affects CAPEX. Motivated by the above, we present in this talk a framework that aims at developing an unsupervised planning process that provides the essential planning parameters of cellular networks, including the minimum number of required base stations (BSs), their positions, coverage, and antenna radiation patterns, while taking into consideration the inter-cell interference and satisfying capacity, coverage and transmit power constraints. We make use of the statistical machine learning (SML) theory to solve the problem at hand. The core idea of SML is that the planning parameters are treated as random variables. The parameters that maximize the corresponding joint probability distribution, conditioned on observation of users' positions, are learned or inferred using Gibbs sampling theory and Bayes theory. The inference process involves linking the observations and the planning parameters through a probabilistic model (i.e., a problem formulation) which yields a Dirichlet process. Through several numerical examples, we show that the performance of the proposed framework is superior to two existing main planning approaches, including the k-mean based approach. We also demonstrate how our approach can leverage existing cellular infrastructures into the new design.

Biography

Ali Ghrayeb received the Ph.D. degree in electrical engineering from The University of Arizona, Tucson, AZ, USA, in 2000. He is currently a Professor with the department of Electrical and Computer Engineering, Texas A&M University at Qatar. Prior to his current position, he was a tenured professor in the Electrical and Computer Engineering Department, Concordia University, Montreal, QC, Canada. He has co-authored two books and published over 200 journal and conference papers. His research interests include wireless and mobile communications, physical layer security, massive MIMO, wireless cooperative networks, and visible light communications. He was a recipient/co-recipient of several best paper awards. He served as an instructor/co instructor in many technical tutorials at several major IEEE conferences. He served as the Executive Chair of the 2016 IEEE WCNC Conference. He currently serves as a member of the IEEE ComSoc Conferences Council, a member of the IEEE GITC Committee, and a member of the IEEE WCNC Steering Committee. He served in different editorial capacities for a number of IEEE transactions journals. He is an IEEE Fellow.

Keynote Speaker

Prof. Dr. Nicholas Kathijotes

International Ocean Institute, Cyprus

Climate Change and Rainwater Management – Rain Cities

Climate change is already having wide-ranging consequences for human health, the environment and economies across Europe. Southern and central Europe are seeing more frequent heat waves, forest fires and droughts. The Mediterranean area is becoming drier, making it even more vulnerable to drought and wildfires. Most of the water problems due to climatic changes such as floods, droughts and water shortages are related to rainwater. This concludes that proper rainwater management promises a huge potential for the control or the solution of these problems. As many countries suffer from floods and drought, such disasters can become a blessing with proper rainwater management. This presentation outlines the development of water management technologies from the ancient times up to the most modern smart methods.

Biography

Dr. Nicholas Kathijotes is an experienced International senior consultant and academic with a demonstrated history of working in the higher education industry. Skilled in Water Resources and Wastewater Management, Blue Economy infrastructure, Ocean protection and Climate Change. Strong US education professional with a Doctorate focused in Environmental Engineering from the University of Architecture, Civil Engineering and Geodesy (UACEG) BG. Numerous keynote invitations to international events on topics of interest with emphases on Blue Economy, Blue Technology management and Blue infrastructure. Dr. Nicholas Kathijotes received his first degree in Civil Engineering (BSCE), from the University of Massachusetts (USA). After a Fulbright scholarship he received his Master's degree in Environmental Engineering from the University of New Haven (USA). His Doctorate research was carried at the University of Architecture, Civil Engineering and Geodesy in Sofia (BG), and was obtained with the highest distinction. He investigated the effects of irrigation with treated wastewater on various soils of Cyprus. He attended professional courses on pollution management and lysimetry at the Harvard School of Public Health (Boston,USA), and at the Universitat Autonoma De Barcelona (SP), respectively. He represented Cyprus as member of the management committee of European research programs (various COST Actions), and is a member of The Lysimetry Research Group in Austria. He is a Member of the Cyprus Scientific and Technical Chamber (ETEK), and currently Member of the Management Committee of European Action 15217. He participated as partner and associate in various EU and national research projects and is a member of Editorial Boards and numerous conference scientific committees globally. He presented about 100 articles in scientific journals, as book chapters and Conference proceedings. Invited internationally as keynote speaker, UNDP consultant and invited EU (ERA) expert as research project evaluator and monitor. Since 2008, he is the Focal Point for Cyprus of the 'International Ocean Institute', with intense involvement in issues of Blue Economy and emphasis on the Blue Growth of Developing Countries (Thailand, Philippines, Malaysia, Vietnam).

DETERMINING SEVEN DIFFERENT BRAIN-COMPUTER INTERFACE COMMANDS USING FOURIER TRANSFORM AND MACHINE LEARNING METHODS FROM SSVEP

Ebru Sayilgan[1], Yilmaz Kemal Yuce[2], Yalcin Isler[3]

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Abstract. *Steady-state visually-evoked potentials (SSVEPs) is a signal that occurs in the visual cortex of the brain when the subject focuses on the visual stimuli that flicker at a certain frequency. Compared to other brain-computer interfaces (BCI) techniques based on electroencephalogram (EEG) signals, SSVEP has been preferred thanks to its higher signal-to-noise ratio and information transfer rates. However, the main challenge of the SSVEP-based BCI system is to detect the stimulus frequency from the brain signals among many fundamental frequencies where each frequency is dedicated to a specific command. Only a few studies are investigating the multiple frequencies, which are more than 3 commands, using SSVEP signals at the same time. In this study, we aimed to determine 7 different commands from the SSVEP signals in a single classifier. For this purpose, we used the AVI SSVEP Dataset that was recorded when subjects looked at a flashing box at seven different frequencies (6-10Hz). After applying the Fourier Transform, features of energy, entropy, and variance were extracted for each of the EEG subbands. These features were applied to the inputs of six basic classifiers (Decision Tree, LDA, k-NN, SVM, Naive Bayes, Ensemble Learning). The classification was analyzed by the 5-fold cross-validation model. As a result, the highest performance was 57.10% for the Ensemble Learning classifier.*

Keywords: *brain-computer interface, electroencephalogram, steady-state visually-evoked potentials, fourier transform, machine learning*

1. INTRODUCTIONS

Over the last 25 years, productive human-machine interface (HMI) research programs or applications have emerged [1, 2]. For HMI applications, only brain activities are used as input signals of the support system frequently in cases of limited use of people's eye and muscle activities or not working at all. This type of HMI systems is called the brain-computer interface (BCI) [3-6]. Communication with this technology occurs roughly as follows: biomedical signals (i.e. Electroencefalogram (EEG)) of temporal resolution produced by neuronal dynamics from the scalp are received and recorded [4, 5]. The properties of the recorded brain signals are extracted, and these properties are converted to outputs, commands, scripts, or similar applications in the real world [1-6].

Commonly used control signals in EEG-based BCIs are slow cortical potentials, sensorimotor rhythms, event-related potentials, event-related synchronization and desynchronization, and steady-state visual-evoked potentials (SSVEP). For most people, SSVEP-based BCI is more suitable than other systems. It has advantages such as high information transfer rate, simple system structure, short user training, and short time requirement [7-11]. Apart from these, the eye muscles' health is sufficient for the user to use this system.

SSVEP is a resonance phenomenon that occurs mainly in the visual cortex when an individual's visual attention focuses on a light source that flickers with a frequency equal or above 6 Hz [10, 11]. SSVEP could be recorded on the visual cortex from the scalp with maximum amplitude in the occipital region [11]. The interest in SSVEP based BCI studies is mainly owing to the robustness of the SSVEP phenomenon.

Generally, the component of an SSVEP-based BCI can be roughly divided into four stages: data acquisition, signal pre-processing, feature extraction and classification [6]. While SSVEP data is recorded as the first step, in the second step, temporal and spatial filtering is applied as pre-processing. In the third step, the most suitable features are tried to be extracted and selected among the features of the chosen paradigm. Finally, at the classifier stage, a control command based on the input signal is generated. There are many methods that can be used in each of these stages.

In this study, Fast Fourier Transform (FFT) was applied to characterize stimulus frequencies and transform them into commands. The FFT received signals were divided into EEG sub-bands and the stimulus frequency in each band was determined. In the feature extraction stage, feature vectors consisting of energy, entropy and variance values of each of the EEG subbands were extracted. Finally, in the classification stage, the classification of the signals was carried out using six different classifiers, which are widely used in the literature and have not been compared with each other before with this combination.

2. MATERIALS AND METHODS

2.1. Dataset Description

In this study, AVI SSVEP Dataset was used [12]. The data set contains data that include EEG measurements of healthy individuals looking at the repetitive flashing target to trigger responses of SSVEP signals at different frequencies. All data were recorded using three electrodes (Oz, Fpz, Fz). Using the standard international 10-20 system for electrode placement, the reference electrode is positioned in Fz with the signal electrode in Oz and Fpz in the ground electrode. The amplifier used is g.USBamp from g.tec set to a 512 Hz sampling rate. An analogue notch filter was applied to the data obtained at interference frequency (50Hz) [12].

In this experiment, individuals have seated 60 cm away from a monitor staring at a single repetitive flashing target whose colour changed rapidly from black to white. The test stimulus is a flashing box at seven different frequencies (6 - 6.5 - 7 - 7.5 - 8.2 - 9.3 - 10 Hz) presented on the monitor. The data set consists of four sessions with four different subjects. Each session in a session lasts 30 seconds and subjects take a short break between trials. Experiments were repeated at least three times for each frequency.

2.2. Feature Extraction

In the feature extraction phase, firstly, spectrum analysis was performed to determine the stimulus frequencies of the seven frequencies in the data set more clearly. This analysis is often used to obtain frequency information in evoked SSVEP responses. The basic idea

is always the same: a visual stimulus flashing at a fixed frequency (stimulus frequency) produces a response of the same frequency, or equal harmonics, in the brain [13]. At the same time, the power spectrum of EEG signals was determined by FFT using MATLAB software to calculate band power, entropy and variance in the frequency range corresponding to the frequencies [14]. For this purpose, the FFT received signal was divided into EEG subbands (delta, theta, alpha, beta, gamma) and feature vectors were created by calculating the energy, entropy and variance of each band.

2.3. Classification

In the classification stage, which is the last step of the signal processing process, the feature vectors extracted from the SSVEP signal were tested with twenty-three different methods in total due to the six basic classifiers and different sub-parameters of the classifiers. These classifiers were made with the Classifier Learner application in Matlab software [15-17]. The classifier algorithms used are: Decision Tree, Linear Discriminant Analysis (LDA), Naive Bayes, Support Vector Machines (SVM), k- Nearest Neighbor (k-NN), Ensemble Classifiers.

2.4. Evaluation of Machine Learning Algorithms

In this study, the classification was made by creating a 5-fold cross-validation model at the classification stage. In order to evaluate the performance of the algorithms, the accuracy values were calculated by extracting the confusion matrix. The confusion matrix was created by comparing the answers given by the classification algorithm to the test set with the actual values in the data set. The confusion matrix consisting of four different cases can be summarized in the following terms [18, 19]. TP (the case of correctly estimating the examined stimulation frequency), TN (the correct estimation that the estimated stimulation frequency differs from the studied stimulation frequency), FP (the case of mistakenly determining that a different stimulation frequency is the frequency being examined), FN (the case of mistakenly determining that the examined stimulation frequency is a different deciding to be a frequency). Based on these values, the accuracy value showing the classifier performance is calculated [18-20]:

$$Accuracy\ (ACC) = \frac{TP + TN}{TP + FN + FP + TN} \quad (1)$$

3. Results and Discussions

For the frequency domain characteristics used in the problem of determining seven different frequencies, firstly, spectrum analysis was performed to detect the stimulus frequencies more clearly than the signal. This analysis is often used to obtain frequency information in evoked SSVEP responses. Besides, the power spectrum of EEG signals was determined by FFT using MATLAB software to calculate its power, entropy, and variance for each band in the frequency range corresponding to the frequencies. A total of 15 feature vectors are generated. The results of evaluating the generated features with machine algorithms are presented in Table 1.

Table 1 Multiple classification results of Fourier Transform features.

Subjects	Accuracy (ACC)	Classifiers
Subject 1	29.20	Ensemble Learning (Subspace Discriminant)
Subject 2	50.00	Ensemble Learning (Subspace Discriminant)
Subject 3	57.10	Ensemble Learning (Subspace Discriminant)
Subject 4	47.60	Ensemble Learning (Subspace Discriminant)
Mean	45.98	

According to the results obtained, the highest performance was determined in Subject 3 with the Ensemble Learning (Subspace Discriminant) classifier with an accuracy value of 57.10%. In Subject 2, the highest performance was achieved with the Ensemble Learning (Subspace Discriminant) classifier again with 50.00% accuracy value, and in Subject 4, the highest performance was obtained with the same classifier with 47.60% accuracy value. Finally, in Subject 1, where the lowest result was seen, 29.20% accuracy was obtained.

4. Conclusions

In this study, it was tried to evaluate whether the frequency of the visual stimulus presented to the subjects could be detected with the same frequency in the occipital lobe

of the brain by calculating features such as energy, variance and entropy via FFT using SSVEP data. According to the multiple classification results of the seven frequencies presented in Table 1, it was determined that the best performance was in the Ensemble Learning classifier with an accuracy value of 57.10%. Another remarkable finding here is that the results of the classifier from all individuals are the same. This shows us that the Ensemble Learning classifier performs better than others. In addition, remarkable results were obtained when the results of 7-class classification were compared with the other 3- and 4-class classification results in the literature.

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INVESTIGATION OF THE EFFECT OF HISTOGRAM EQUALIZATION METHOD ON THE CLASSIFIER PERFORMANCE OF THE CONVOLUTIONAL NEURAL NETWORK FOR COVID-19 CHEST RADIOGRAPHY IMAGES

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Abstract. *The coronavirus (Covid-19) outbreak started in China and affected all over the world. The rapid spread of the outbreak among people caused governments to take very strict measures. The first of these measures was the correct detection and control of people who got the Covid-19 virus. In this study, we proposed a computer-aided detection system for automatic detection and prevention of the Covid-19 outbreak. For this, we carried out this study with 219 Covid-19(+) chest radiography images and 1341 Covid-19(-) (healthy) chest radiography images. The results were compared with both their original state and histogram equalized using the 3-fold cross-validation method. Pre-training ResNet50 deep convolutional neural network (CNN) was used as a classifier. Besides, being a classifier that we can use data directly without manual feature extraction provides ease of use. As a result, an accuracy of 99.3%, a sensitivity of 96.8%, and specificity of 99.7% were obtained without using the histogram equalization method in the classification of Covid-19(+) and Covid-19(-). Using the histogram equalization method, an accuracy of 98.8%, a sensitivity of 97.3%, and specificity of 99.1% were obtained. The application of the histogram equalization method increases the detection of patients with Covid-19(+). On the other hand, the correct detection performance of healthy people decreased, albeit slightly. According to the obtained results, we think this proposed method will provide convenience to the experts for the detection of Covid-19(+) in clinical applications.*

Keywords: *covid-19; classification; chest radiography image; resnet50*

1. INTRODUCTION

The disease, which was defined as Covid-19, which was declared as a pandemic by the world health organization(WHO), rapidly surrounded the world. This epidemic, which first broke out in Wuhan of China in December 2019, killed thousands of people, and the deaths are still increasing. [1]. The damage caused by this epidemic, which has seriously

damaged the health system of the states and disrupts economies, is considerably high [2]. For this reason, it is very important to know and identify people who have caught the Covid-19(+) cases. Thus, in addition to preventing the spread of the disease, the decrease in mortality rates and economic depreciation will be prevented. The most known method in the diagnosis of Covid-19()+ is the transcription polymerase chain reaction (RT-PCR) method [3] [4]. It is stated that the sensitivity of this method is low [5]. Applications and methods that can help and support this known method have become widespread rapidly. Artificial intelligence-based methods come first among these. With these methods, automatic diagnosis and detection applications are performed using X-ray and CT images [6] [7]. The most common of these methods is the use of deep learning models [8] [9]. Especially, these models, which do not require manual feature extraction, reach results directly from the images, increasing the popularity of these methods. For this reason, we wanted to make the following contributions in this study:

- Proposing an alternative co-diagnosis system for Covid-19(+).
- Help radiologists in this challenging epidemic process.
- The effects of the histogram equalization method to the results have been investigated in the detection of Covid-19(+) cases.

In this study, the pre-trained ResNet50 convolutional neural network model was used. The results were obtained with the 3-fold cross validation method.

In the following chapters, the data set, histogram equalization, the ResNet50 model, which is a pre-trained deep learning model, the performance criteria of the model and the final results are mentioned.

2. METHODS

2.1. Dataset

This study was carried out using Covid-19(+) and Covid-19(-) X-ray chest image data. The data taken from the Kaggle site is accessible to everyone [10]. In total, 1341 Covid-19(-) data were used with data from 219 Covid-19(+). All original images in the data set are 1024x1024 size. Images of both classes are shown in Fig. 1.

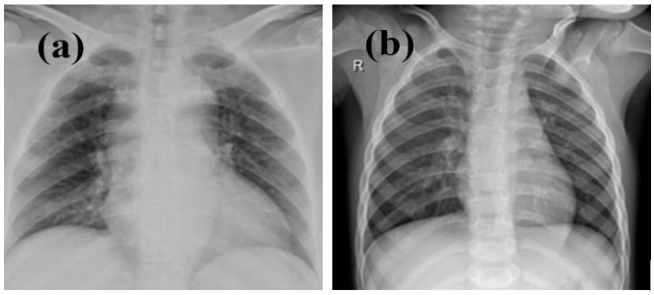

Fig. 1 a) Original Covid-19(+) image b) Original Covid-19(-) image

2.2. Histogram Equalization

A histogram is a graph that shows how many of each color value is in a digital image. Information about the brightness status or shadows of the picture can be obtained by looking at this graph. The purpose of histogram equalization is to try to create a richer image in contrast. The purpose of histogram equalization is to try to make the cumulative histogram as linear as possible, as shown in Fig. 2. To obtain a linear cumulative histogram, the histogram itself must be evenly distributed. For the purpose of achieving this equal distribution, this process is called equalization. In other words, it provides approximately the same number of pixels for each brightness level. With this method, the contrast of the image can be spread over a wide area to improve poorly taken photos and images with poor contrast.

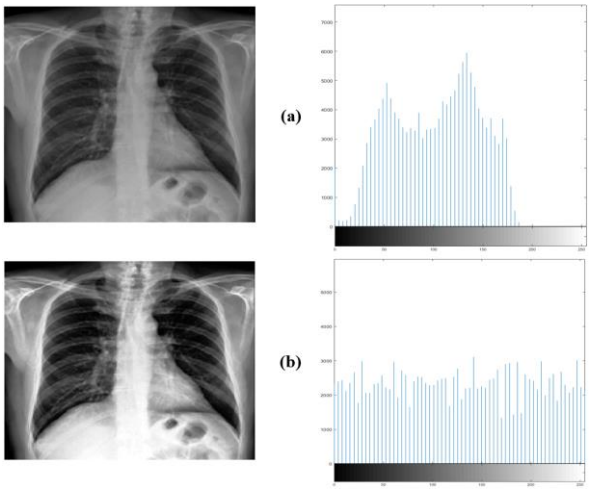

Fig 2. a) Original X-ray image and histogram graph, b) histogram equalized image and histogram graph.

2.3. Pre-Trained Deep Learnig Model

Deep learning models, which are widely used in the fields of analysis and processing of medical images, show a very high performance. Especially in studies with limited data, the use of pre-trained models both saves time and shows effective results with less data. For this reason, a pre-trained ResNet 50 convolutional neural network model, which we think is suitable for limited Covid-19 data, was used.

The name of the ResNet50 CNN model is an acronym for residual neural networks. It is an improved version of CNN with a large amount of convolutional neural networks [11]. Transitions between layers deepen the network in ResNet models. Thanks to these

transitions, the deterioration that may occur in the deepening network is prevented. In these models, blocks called bottleneck are used for fast training. ResNet-50 architecture consists of 25.6 million parameters. The pre-trained ResNet50 model is a 50-layer network trained on the ImageNet dataset. ResNet50 convolutional neural network in general; It consists of convolution layer, activation layer, pooling layer and fully-connected layer. ImageNet is an image database containing more than 14 million images belonging to more than 20 thousand categories created for image recognition competitions [16]. The pre-trained ResNet50 model used in this study is shown in Fig. 3. In this model, which consists of two parts, the first part includes the ResNet50 model trained on the ImageNet database, and the second part, the new model created with the layers we added.

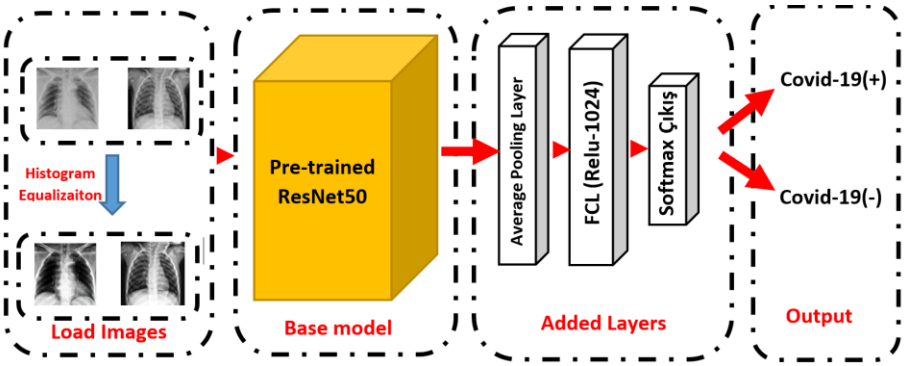

Fig 3. Representation of the Pre-Trained model realized in the study.

2.4 Performance Metrics

Three criteria were used for the performance of deep learning models [13]. These are: Overall performance value ACC = (TP + TN) / (TP + TN + FP + FN), sensitivity value SEN = TP / (TP + FN) and specificity value SPE = TN / (TN + FP). Here, TP, TN, FN, FP is expressed as true positive, true negative, false negative, and false positive, respectively. If these values are taken into consideration for our problem, the detection of a patient with Covid-19(+) as Covid-19(+) is called (TP), while the detection of a patient with Covid-19(-) as Covid-19(-) is called (TN). The detection of a patient with Covid-19(-) as Covid-19(+) is expressed as (FP) and the detection of a patient with Covid-19(+) as Covid-19(-) is expressed as (FN) [12] [13].

In this study, the k-fold cross-evaluation method was used to calculate the performance. In this method, data (k-1) divided into k parts is used for the training of the classifier and the algorithm is tested with the remaining part. This process is repeated so that all parts are used for testing, and TP, TN, FP and FN values are found as the averages of these trials [14].

3. EXPERIMENTAL RESULTS

In this study, images with histograms equalized were obtained with the help of MATLAB 2018b software. The pre-trained ResNet50 model was performed using the Python programming language in the creation of the added model and obtaining all the results. In order to avoid overfitting with this method, where data is used as direct input, 30 epochs have been trained. The learning rate is 0.00001. Optimization of the weights in the training of models was done by ADAM algorithm [15]. The accuracy and loss values of the training and test data from the obtained results are given in Fig. 4. As can be seen, the performances in the training and testing processes obtained with data with equal histograms are close to each other.

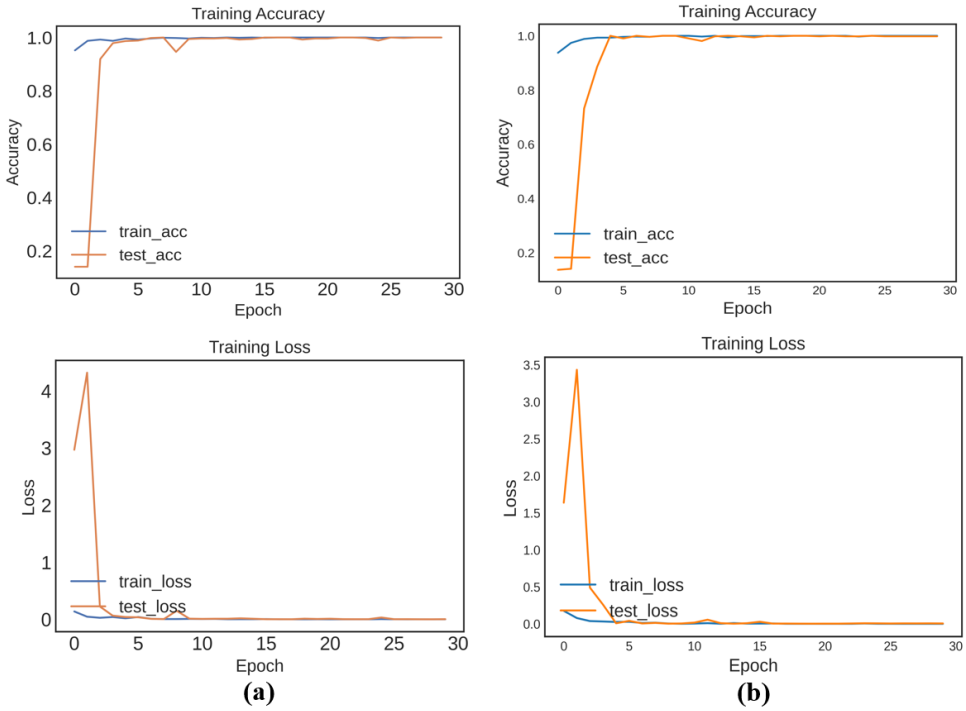

Fig 4. Representation of the Pre-Trained model realized in the study.

Accuracy, sensitivity and specificity values obtained for better analysis of test results are given in Table 1. In addition, TN, TP, FP, FN values and total values are given for each fold. Looking at the average results, it can be said that the histogram equalization method is said to detect Covid-19(+) patients higher, although it has a lower performance in detecting Covid-19(-) patients.

As a result, it is very important to correctly identify even one Covid-19(+) patient. Histogram equalized data can be used in this regard. As a result, the epidemic started from one person.

The biggest limitation of the study is the number of data. It is very important to increase the number of data and repeat not working. In future studies, we intend to increase the number of data and rework the study.

Table 1 Test data for overall performance criteria values

Model	Method	3-Fold	TP	TN	FP	FN	Acc	Sen	Spe
Resnet50	Without histogram equalization	Fold1	73	447	0	0	100	100	100
		Fold2	73	444	3	0	99.4	100	99.3
		Fold3	66	446	1	7	98.5	90.4	99.8
		Mean	212	1337	4	7	99.3	96.8	99.7
Resnet50	With histogram equalization	Fold1	72	447	1	1	99.6	98.6	99.8
		Fold2	73	436	11	0	97.9	100	97.5
		Fold3	68	447	0	5	99.0	93.2	100
		Mean	213	1330	12	6	98.8	97.3	99.1

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HIGH POWER EFFICIENCY DESIGN APPROACH OF AN LLC RESONANT CONVERTER FOR UPS BATTERY CHARGER APPLICATION AND BATTERY CHARGE-DISCHARGE REGRESSION MODEL

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Abstract - *In this study, design procedure of inductor-inductor-capacitor (LLC) resonant DC-DC converter is developed for uninterruptible power supply battery charge applications based on high power efficiency. The LLC resonant converters have many advantages such as high-power efficiency and less switching losses when compared with other converters features. It is also capable of operating in narrow switching frequency where zero voltage switching can be provided. The DC-DC converter with 400V input and 48V/3.1A output has been selected as an experimental setup. In order to reach desired design of LLC resonant converter and required output values, switching frequency might be determined as above of resonance frequency via Power Electronics Simulation package program. The obtained maximum power efficiency was measured as 95.22%. Besides, charge-discharge models of the battery were obtained from the battery data obtained via deriving regression models with machine learning algorithms where battery electrical energy consumptions, battery status, and temperature data can be analyzed. R^2 and root mean square error scores are performed for different regression models. Random forest regression is determined as the best model among regression models for the obtained data set.*

Keywords: *Energy, UPS battery charge, LLC resonant converter, machine learning, regression models*

1. INTRODUCTION

Uninterruptible power supplies (UPS) are devices that provide emergency electrical power to a connected device when the input power source fails [1]. Such devices are widely used in important sectors such as industry, healthcare, and military [2-4]. The batteries used in UPS must have satisfied the features such as smooth and quick charging, high power density, high efficiency. The charging of the batteries becomes very complicated due to the high voltages and currents involved in the system and the sophisticated charging algorithms [5]. The most commonly used battery charging architecture is shown in Fig.1. It consists of mainly two stages, namely power factor

correction PFC stage and DC-DC converter stage. The power factor correction stage is a continuous conduction mode of boost topology [6]. DC-DC converter plays an important role in battery charger by regulating the output current and voltage.

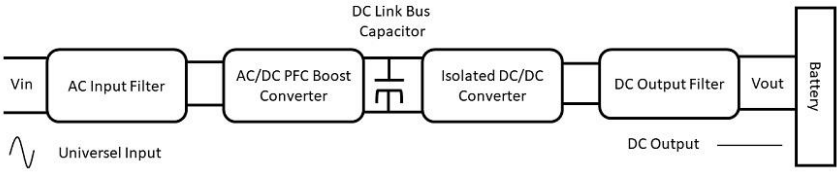

Fig. 1 Block diagram of a universal battery charger

It has been observed that LLC resonant converters are generally used in electrical vehicles battery charger applications because high power density and high efficiency battery chargers should be designed to have less volume and cost of electrical vehicles [7-9]. In this study, design procedure of LLC resonant converter for UPS battery charger applications based on high efficiency and battery charge-discharge regression model is aimed. In the design procedure, 4x12V UPS battery is taken into consideration. Thus, LLC resonant converter should be regulated the output voltage in a wide voltage range with different load conditions according to typical charging profile of battery. For the design procedure, basic operation characteristics of LLC resonant converter is defined, and operation regions are discussed in terms of high efficiency. To achieve high efficiency, all essential parasitic elements, including junction capacitances of all semiconductor devices and the leakage inductance and magnetizing inductance of the transformer should be utilized to achieve Zero Voltage Switching (ZVS). ZVS switching topology typically use resonance techniques to force the voltage or current in a semiconductor switch to zero, resulting to the elimination or reduction of the switching losses [10]. It is basically soft switching technique. The operation regions of LLC resonant converter are discussed to regulate wide output voltage range. Therefore, the purpose of the study is designing an LLC resonant converter that will have 48V/3.1A output values to charge 4 x 12V / 30Ah batteries. The circuit is simulated using Power Electronic Simulation Software (PSIM). In addition, it is presented as secondary output to find the charge-discharge models under varying conditions by deriving the regression models with machine learning algorithms where the battery electricity energy consumption, battery status and temperature data can be analyzed. Root mean square error (RMSE) and R^2 score tests were used to compare the obtained results.

The remaining sections are as follows; in the second section, circuit design procedure, simulation results and regression models are explained. In the third section, the results from the comparison of model performances with each other is done. In the last section, conclusions and recommendations of the study are presented.

2. MATERIALS AND METHOD

The half-bridge LLC resonant converter is given in Fig.2. The main parts of this converter are Square wave generator, Resonant network, and Rectifier network.

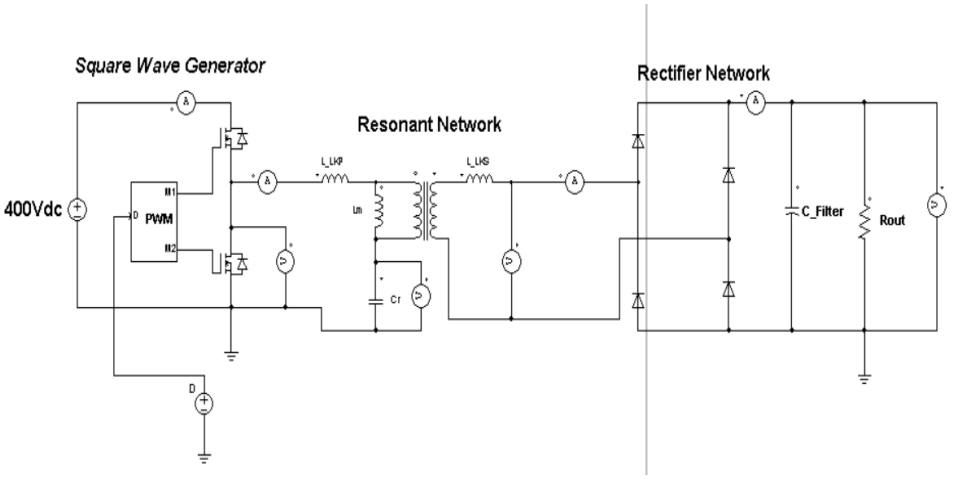

Fig. 2 The circuit schematic of LLC resonant DC-DC converter

The switching network produces a square wave voltage by alternating 50% duty cycle for each switch. The switching network can be full-bridge or half-bridge type. In this study, it is used as half-bridge type. The resonant network has a resonant capacitor, primary and secondary leakage inductances, and the magnetizing inductance of the transformer. The energy is transferred to the load with the help of transformers when the resonant converter allows the current to circulate. The resonant network filters the higher harmonic currents. Therefore, essentially only sinusoidal current is can flow from the resonance network, although square wave voltage is applied to the resonance network. The rectifier network consists of a filter capacitor and diodes. It produces DC voltage by rectifying the output of the transformer which is a sinusoidal voltage. This network can be full-wave bridge or center-tapped configuration [11].

2.1. Circuit Design Procedure

A dc/dc converter with 148.8W/48V output has been selected as a design for UPS battery charger. The design specifications are as follows; i) Input voltage: 400Vdc (output of PFC stage), ii) Output: 48V/3.1A (148.8W), iii) Holdup time requirement: 20ms (50Hz line freq.), and iv) DC link capacitor of PFC output: 220 μF. The design steps for the half-bridge LLC resonant converter are given below [12]. It is assumed that the efficiency is to be 0.88~0.92 for low voltage output and 0.92~0.96 for high voltage output, if its efficiency data are not provided, See Eq. (1).

$$P_{in} = \frac{P_o}{E_{ff}} \tag{1}$$

Mostly, LLC resonant converter operates around the resonant frequency (f_o) in normal operation to attenuate switching frequency variation. The gain at f_o is magnetizing inductance divided by primary side leakage inductance (k = L_m/L_{lkp}). Therefore, the value of k should be chosen to obtain the minimum gain. Mostly, k is chosen 5~10. See Eq. (2) and Eq. (3).

$$M^{min} = \frac{V_{RO}}{\frac{V_{in}^{max}}{2}} = \frac{L_m + L_{lkp}}{L_m} = \frac{k+1}{k} \tag{2}$$

$$M^{max} = \frac{V_{in}^{max}}{V_{in}^{min}} . M^{min} \tag{3}$$

The ratio (k) between L_m and L_{lkp} is chosen as 9.4. LLC resonant converter contains full-wave bridge rectifier for the rectifier network. The transformer turns ratio should be determined for full-wave bridge rectifier. See Eq. (4).

$$n = \frac{N_p}{N_s} = \frac{V_{in}^{Max}}{2(V_o + 2V_f)} M^{min} \tag{4}$$

Where V_f = 0.7V. Transformer turns ratio obtained from Eq. (4), the equivalent load resistance is should be obtained. See Eq. (5).

$$R_{ac} = \frac{8n^2}{\pi^2} \frac{V_o^2}{P_o} E_{ff} \tag{5}$$

The resonant network parameters should be determined to achieve soft switching. See Eq. (6), Eq. (7), and Eq. (8).

$$L_p = L_m + L_{lkp} = (k+1) L_{lkp} = \frac{(k+1)^2}{(2k+1)} L_r \tag{6}$$

$$L_r = L_{lkp} + L_m \,//\, L_{lkp} = L_{lkp}\left(1+\frac{k}{k+1}\right) = \frac{1}{\left(2\pi f_o\right)^2 C_r} \tag{7}$$

$$C_r = \frac{1}{2\pi Q \cdot f_o \cdot R_{ac}} \tag{8}$$

The calculated parameters and magnetic component values for simulation are summarized in Table 1.

Table 1. Values used for simulation

Parameters	**Values**
E *ff*	%96
P *in*	155 W
P *out*	148.8 W
N	4.375
R *ac*	251.9 ohm
L *r*	110 uH
L *lkp*	57.78 uH
L *lks*	2.879 uH
L *m*	542.2177 uH
C *r*	19.03 nF
L *p*	600 uH
M min	1.1066
M max	1.22
Np : Ns	36 : 8
Q	0.302
K	9.4

2.2. Simulation Results

LLC Resonant topology was built in PSIM software. The duty cycle is 0.5 and resonant frequency is 110 kHz. In order to reach desired design of LLC resonant converter and required output values, switching frequency was determined as above of resonance frequency, based on theoretical calculations and PSIM Simulation software. Therefore, the switching frequency is 115 kHz. Obtained efficiency is 95.22% and that zero voltage switching has been achieved as shown in Fig.3. The intersection area between voltage and current of MOSFET is very less.

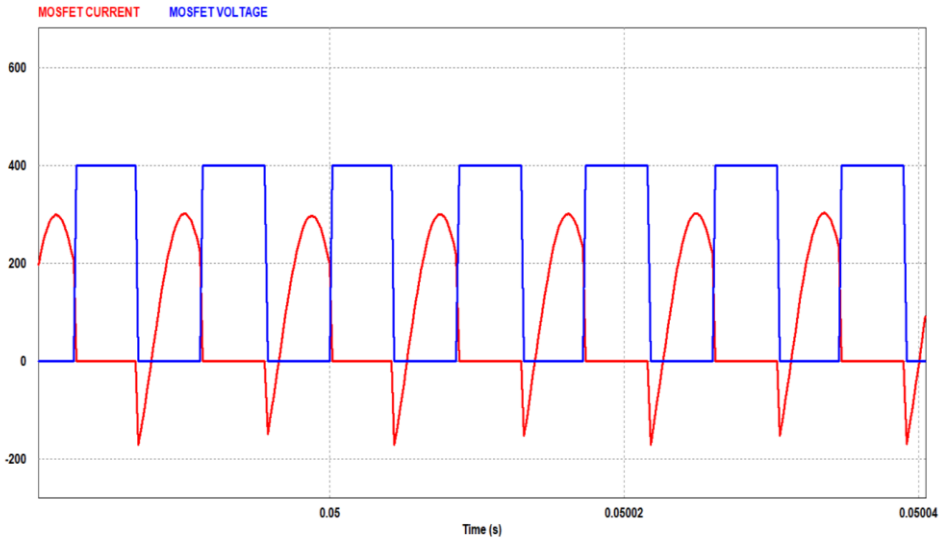

Fig. 3 MOSFET voltage (blue) and current (red) achieving soft switching

The output result of the PSIM Simulation were obtained as shown in Fig.4. The output voltage is 47.67 V and the output current is 3.07 A which are very close to required values.

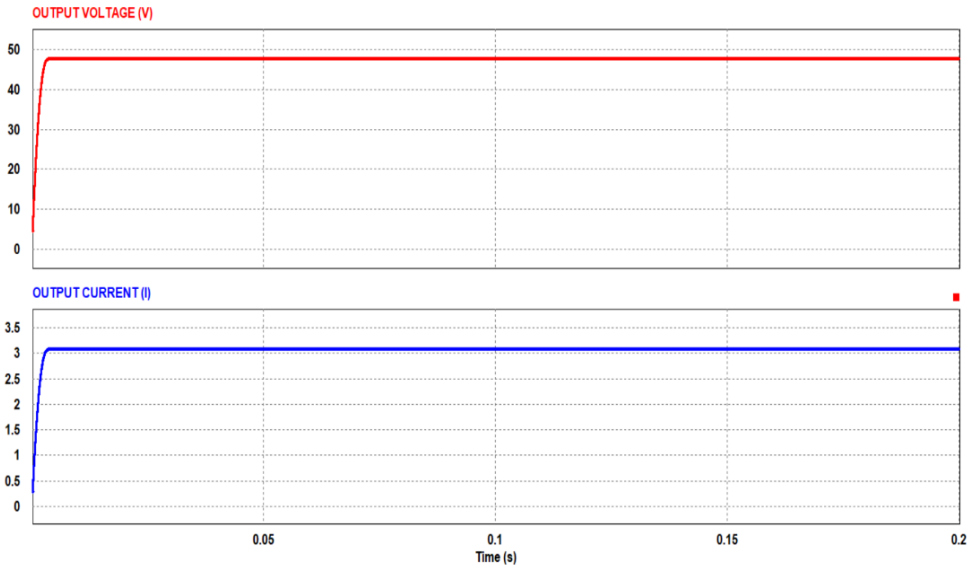

Fig. 4 Output Voltage (red) and output current (blue) of the LLC Resonant Converter

2.3. Regression Models

Regression analysis is a process of statistical methods which is used to estimate relationships between dependent and independent variables. The purpose of machine learning algorithms is learning to recognize the pattern with several different methods. For example, some of them are decision tree, linear regression, support vector machines, artificial neural networks, and k-nearest neighbor. Machine learning algorithms are divided into two groups: supervised learning and unsupervised learning. Regression models are in the group of supervised learning [13]. In this study, it is aimed to provide battery charge-discharge regression model to predict how long a battery with a known charge rate can be discharged according to the load and its medium temperature.by using machine learning algorithms.

3. RESULT AND DISCUSSION

Charge-discharge models of the battery is made by deriving regression models with machine learning algorithms. The data set is obtained from the 10kVA UPS produced by TESCOM A.Ş [14]. There are 4 different variables in the dataset which are discharge current, battery percentage, temperature, and battery usage time. The overall dataset was preprocessed and analyzed thoroughly. Different regression models were used to obtain battery charge-discharge regression models. These are linear, polynomial, light gradient boosting machine (LGBM), extreme gradient boosting (XGB), gradient boosting, random forest, decision tree, and K-neighbors regression. When applying these regression models, battery charge percentage and estimated time variables in the data set were used and to evaluate their performances RMSE and R^2 score are used. See Eq. (9) and See Eq. (10).

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{m}(y_i - \grave{y}_i)^2}{m}} \tag{9}$$

where y_i is the time variable, $\grave{y}_i$ is the value of the predicted time of the regression model.

$$R^2 = 1 - \left[\frac{\sum_{i=1}^{m}(y_i - \grave{y}_i)^2}{\sum_{i=1}^{m}(y_i - \tilde{y}_i)^2}\right] \tag{10}$$

where y_i is the time variable, $\grave{y}_i$ is the value of the predicted time of the regression model and $\tilde{y}_i$ is the is the average value of the time variable.

Finally, random forest regression model has been decided as best model among different regression models as shown in Table 2 where the lowest RMSE value and the R^2 score value is closest to 1. It is depicted in Fig.5.

Table 2. RMSE and R^2 score values of regression models

Regression Models	RMSE	R^2 Score
Linear Regression	77.2032	0.9946
Polynomial Regression	70.5056	0.9956
LGBM Regression	465.0893	0.8065
XGB Regression	93.0894	0.9922
Gradient Boosting Reg	70.8098	0.9955
Random Forest Regression	67.843	0.9959
Decision Tree Regression	128.161	0.9853
K-Neighbors Regression	104.8204	0.9901

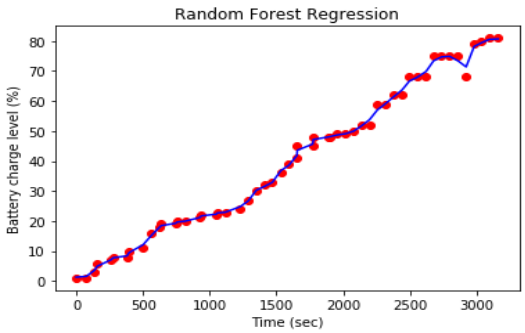

Fig. 5 Battery charge level versus time

4. CONCLUSION AND RECOMMENDATIONS

LLC resonant DC-DC converter was designed to achieve high efficiency in UPS battery charging applications. LLC resonant DC-DC converter was chosen because the LLC resonant converters have many advantages such as high-power efficiency, less switching losses, and operating in narrow switching frequency where zero voltage switching can be provided when compared with other converters features. Battery charge-discharge regression model is made by using machine learning algorithms, where battery status, battery electrical energy consumption and temperature data were analyzed. Root mean square error and R^2 score tests were performed for different regression models. The tests are generated in Python and the results of them are compared to each other. Random forest regression has been decided as the best regression among regression models for the obtained data set. Finally, it can be predicted how long a battery with a known charge rate can be discharged according to the load and its medium temperature. As a future work of this study could be the hardware implementation for the system and the data can be obtained from the real time application. In addition, more research can be done to make the system perform better.

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RADIATION FROM WELDING PROCESSES, HEALTH AND SAFETY PRECAUTIONS

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Abstract.*The most common hazards accompanying welding operations are fires, explosions, burns, fumes, electric shocks, compressed gases, hazardous substances, toxic gasses, suffocation, radiation, heat stress, dust, noise, vibration, manual handling, etc. Two types of radiation associated to the welding operations are: ionizing radiation, such as X-rays and nonionizing radiation, such as ultraviolet, visible and infrared light. Radiation is often silent and undetected, yet injury occurs. Hence, the need to understand the influence of radiation on human health is of big importance. The effects of radiation depend on the wavelength, intensity, and the time of exposure. The most common injuries occurred in radiation exposure are skin burns and eye damage. The brilliance of the high intensity visible light (wavelength 0.4 to 0.75 μm) produced by an electric arc is about 10 000 the safe glare of the eyes. This paper deals with the effects of radiation hazards of welding processes on humans and the definition of the necessary protection measures required to reduce and/or prevent their impact.*

Keywords: *Welding process, radiation, protection measures*

1. TYPES OF WELDING PROCESSES AND RELATED HAZARDS

The most common assembling methods of permanent joining are welding processes where two types of energy, heat and/or pressure are facilitating the process.

Being part in many manufacturing industries, e.g., production of equipment, home appliances, cars, in construction, petrochemical, mining, etc., welding is a common process in maintenance activities, too [1].

Regarding the mechanism used, the welding operations can be split into two main groups: fusion-welding and solid-state welding, Table 1 [2].

In Fusion-welding processes metals are melted by heat. In this type of operations, often a filler metal is used to aid the process and to strengthen the joint points. The following methods of fusion welding assembly can be designated: arc welding, resistance welding, oxyfuel gas welding, electron beam welding and laser beam welding [2].

In solid-state welding joining of parts is accomplished by the application of heat and pressure or pressure alone, avoiding the melting of the metal. Common solid-state welding includes diffusion, friction and ultrasonic operations [2].

Most of the welding processes causes adverse effects to the labour or those that are in the vicinity of the welding work stations [3, 4].

Table 1 Common Welding Processes and Their Characteristics [2]

Fusion welding Applies heat for melting the metals being assembled, and very frequently includes filler for joint strengthening		**Solid-state welding** Assembling accomplished by the pressure alone and/or application of heat avoiding metal melting, and no filler applied	
Process	**Description**	**Process**	**Description**
Arc welding	Uses electric arc to heat metals and/or application of pressure and filler.	Diffusion welding	Applies pressure at increased temperature, where joining of the parts is done by solid-state fusion.
Resistance welding	The resistance to the current flow thought the metals produces heat, and a pressure might be applied too.	Friction welding	Heat is produced by friction between the parts being assembled.
Oxyfuel gas welding	A mixture of oxygen and acetylene produce a hot flame, used in metals and filler melting.		
Electron beam welding	Heat is achieved by high-intensity beam of electrons.	Ultrasonic welding	Bonding achieved as a result of shear stresses present due to the normal and vibratory forces
Laser beam welding	Energy for welding is produced by coherent light beam.		

Hazards associated with welding operations are grouped as follows: respiratory hazards, physical hazards, fire and explosion hazards, electrical hazards and other related hazards, Table 2 [5]. Electrical power used to melt metal surfaces is a potential hazard of electrical shock. Shielding gasses used in welding, particularly when the operation is performed in confined places, replace air resulting in mild issues like dizziness or severe health problems such as asphyxiation and even death. Fumes and gasses as side-effects during welding occur depending on the welding conditions: type of the electrodes uses, base metal coatings, etc. Fumes are oxidized metal particles with micro and nano dimensions that can cause serious lung diseases. Toxic gasses formed during welding including carbon monoxide (CO), ozone (O_3), nitrogen oxides (NO_x), hydrogen chloride, hydrogen fluoride and phosgene, lead to headache, muscle weakness, asphyxiation, respiratory deceases and / or lungs, bones and kidneys problems in humans. Spatters of molten metal and sparks occurred as a result of developed high temperature in the arc welding, with a combination of combustibles and flammable materials can result in fires and explosions [5].

Table 2 Common hazards in welding [5]

Hazards	Factors to consider
Fire and explosion	Sparks, drops of molten metal, hot electrode close to the combustible and explosive materials. Critical gases mixtures, evaporation from combustible liquids, mixture of combustible dust and air, and flammable residues.
Electrical	Bad electrical connections, apparatuses used in welding, damaged electrical insulation. Electric shock as a result of unprotected electrode, faulty equipment, inappropriate electrical connections.
Physical (thermal and radiation)	Burns of the skin and eyes from the arcs, sparks and spatters. Flashes, burns of eyes and skin, skin cancer as a result of the exposure of ultraviolet, visible and infrared light. Usage of radioactive electrode.
Respiratory (Fumes and gasses)	Metal oxides and fluorides, particles of the electrodes causing respiratory diseases. Shielding gasses (argon, carbon dioxide, helium, nitrogen) used in confined spaces, toxic gasses (carbon monoxide, nitrogen oxides, ozone, phosgene) produced during welding, Harmful substances (phenol, formaldehyde, isocyanates) produced.
Other related	Trips from cables, falling from high levels, noise from welding equipment, exhaust fumes from the engine driven electric generator, musculoskeletal disorders holding heavy objects and repetitive motions.

While the most attention is paid to the other hazards associated with welding processes, the focus of our work was to underline the radiation as hazard from the welding processes, particularly from arc welding.

2. RADIATION ASSOCIATED WITH WELDING AND EFFECTS ON HUMANS

There are two types of radiation associated with welding operations, ionizing, e.g., in a form of X-rays that are produced by electron beam welding and nonionizing radiation, related to the ultraviolet, visible and infrared lights.

Welding arcs and flames emit intense visible (from around 400 to around 700 nm of the electromagnetic wave range), ultraviolet (less than 400 nm), and infrared radiation that can harm eyes and skin.

Visible light, IR radiation and part of the UV radiation can come to the retina of the eye [5].

Very high brightness of visible light produced during welding processes can restrict the ability of the iris of the eye to limit the glare to reach the retina resulting in the temporary blindness and eye fatigue [5].

Even though UV radiation is not observable by the human eyes, its physical characteristics are comparable to those of visible light. Ultraviolet radiation is further divided by the International Commission on Illumination into three wavelength groups: UV-A (wavelengths ranges from 315 to 400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).UV-C and almost all UV-B are absorbed in the cornea of the eye. UV-A passes through the cornea and is absorbed in the lens of the eye [5].

Table 3 Exposure limit values for non-coherent optical radiation [6]

Wavelength, nm	Exposure limit value	Comments
180-400 (UVA, UVB, UVC)	$H_{eff.}$= 30 J m^{-2} Daily value 8 hours	• Irradiance (E) or power density: the radiant power incident per unit area upon a surface (W m^{-2}); • Radiant exposure (H): the time integral of the irradiance (J m^{-2}); • Radiance (L): the radiant flux or power output per unit solid angle per unit area (W m^{-2} sr^{-1}); • Level: the combination of irradiance, radiant exposure and radiance to which a worker is exposed. Note 1: The range of 300 to 700 nm covers parts of UVB, all UVA and most of visible radiation; however, the associated hazard is commonly referred to as 'blue light' hazard. Blue light strictly speaking covers only the range of approximately 400 to 490 nm. ** For steady fixation of very small sources with an angular subtense < 11 mrad, L_B can be converted to E_B. This normally applies only for ophthalmic instruments or a stabilized eye during anaesthesia. The maximum 'stare time' is found by: $t_{max} = 100/E_B$ with E_B expressed in Wm^{-2}. Due to eye movements during normal visual tasks this does not exceed 100 s.
380 -1400 (Visible and IRA)	$L_R = \frac{2{,}8 \cdot 10^7}{C_\alpha}$ W m^{-2} sr^{-1} for t >10 s	
380 -1400 (Visible and IRA)	$L_R = \frac{5 \cdot 10^7}{C_\alpha \cdot t^{0.25}}$ W m^{-2} sr^{-1} t: seconds for 10 μs ≤ t ≤ 10 s	
380 -1400 (Visible and IRA)	$L_R = \frac{8{,}89 \cdot 10^8}{C_\alpha}$ W m^{-2} sr^{-1} for t < 10 μs C_α = 1,7 for α ≤ 1,7 mrad C_α= α for 1,7≤α≤100 mrad C_α = 100 for α > 100 mrad λ_1= 380 nm; λ_2= 1400 nm	
780-3000 (IRA and IRB)	$E_{IR} = 18\,000 \cdot t^{-0,75}$ W m^{-2} t:seconds for t ≤ 1000 s	
780-3000 (IRA and IRB)	E_{IR} = 100 W m^{-2} for t > 1000 s	
380-3000 (Visible, IRA and IRB)	$H_{skin} = 20\,000 \cdot t^{0,25}$ J m^{-2} t:seconds for t < 10 s	

UV radiation of arc welding can lead to the inflammation of the mucous membrane of the front of the eye, named conjunctivitis, known as "arc eye," "arc flash." or "welders' eye". The common symptoms involve tearing, sensation, the pain of the eye, high sensitivity to light [5].

During the direct exposure of UV radiation in a welding arc or radiation that is reflected from metal surfaces can burn unprotected skin and can cause skin cancer. Certain coatings reduce the quantity of the reflection of the UV radiation. Unlike UV radiation, IR radiation and visible light have an insignificant effect on the skin [5].

Often, people working in the vicinity of the arc welding performed without barrier from the radiation, are exposed to the UV radiation. Elimination or reduction of the effect of different types of radiations on humans was proposed by the European Council of the European Parliament and the Council by the introduction of the minimal exposure limits to the radiations in the Directive 2006/25 on the minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (artificial optical radiation), Table 3 [6].

Effective irradiance E_{eff}, eq. 1, is used as a measure of the degree of hazard of UV radiation that could result in severe health effects [7, 8].

$$E_{eff} = \sum_{180}^{400} E_{\lambda} \cdot S(\lambda) \cdot \Delta\lambda \tag{1}$$

Where E_{eff} [W/cm^2] is the effective irradiance, E_{λ} [W/(cm^2 nm)] is the spectral irradiance at wavelength λ, $S(\lambda)$ [nm] is the relative spectral effectiveness at wavelength λ, and λ [nm] is the wavelength bandwidth.

Based on the known effective irradiance, the maximum daily exposure time is calculated using the equation [7, 8]:

$$t_{max} = \frac{0.003\ J/cm^2}{E_{eff}} \tag{2}$$

Where, t_{max} [s] is the maximum daily exposure time.

2.1. Factors influencing the level of hazards from ultraviolet radiation

The amount of time required to cause adverse effects on welders and people in the vicinity of the welding operations depends on several factors such as the intensity of the radiation, the distance from the welding arc, the angle at which the radiation enters the eye, and types of eye protection used.

The effect of the direction of emission from the arc. It was shown [7] that for melt-run welding (a type of gas metal arc welding where only the base metal is melted and no filler rod is used) of Mg-rich mild steel, using digital inverter-type pulsed arc welding machine and pure tungsten electrode, the effective irradiance of UV radiation increases with the increase of the angle from the surface of the base metal from 20° to 40°. The irradiance drops as the angle increases from 40° to 60°. The experimental set up used was such that it mimics the normal postures of welders. The angle concerning the welding direction was fixed at 90° and the distance between the arc and the detector head was set to be 500 mm. The highest effective irradiance at 40°-50° of the angle from the surface of the base metal, was attributed to the metal vapour produced from the surface of molten metal. Thus, when the angle of the detector from the surface of the base metal is small, the actual area of the molten pool is also small. The effective area of the molten metal is bigger as the angle from the surface of the base metal increases. Thus, effective irradiance also increases. But, in a case of too large angles, the nozzle of the welding torch blocked molten pool, the radiation is hindered and effective irradiance decreases.

Reflecting these results on the human body, at the normal welding postures, the level of the hazard from ultraviolet radiation would be highest around the neck and head.

Angle concerning the welding direction. There was no significant difference shown [H NAKASHIMA et al. Industrial Health 2016, 54, 149–156] in the level of the effective irradiance in respect to the angle from the welding direction (0° - 90°).

Content of the base metal. In the case of melt-run welding, the effective irradiance was the highest in mild steel with the highest amount of magnesium. Alloys without magnesium developed the smallest value of effective irradiance [7]. Aluminium rich alloys exhibit lower irradiance and thus lower hazard of UV radiation [8]. The same findings were confirmed in a case of bead-on plate welding, a type of gas metal arc welding where base metal is melted while a filler is added. For the combination of the base metal and/or filler with the highest percentage of magnesium, the effective irradiance took the highest value. The lowest level of the hazard of UV radiation was shown for the combination base metal/filler containing pure aluminium and samples with small amounts of magnesium and silicon [8].

Effect of the welding current. In both, melt-run and bead-on plate welding, all arrangements of base metal and filler rods exhibited higher effective irradiance with higher welding currents [8]. Irrespective on the type of the shielding gases used, pulsed current showed bigger effective irradiance than the non-pulsed current [7]. As the welding current increases, the metal transfer changes from a globular to spray mode. The quantity of metal vapour in the arc for globular transfer is smaller, but the amount of radiation emitted is also decreased [7].

Metal spray transfer mode in gas metal arc welding is very hazardous for welding operators. Therefore suitable protective measures are required to be implemented [7, 8].

Effect of the type of electrode. Melt-run welding using pure tungsten electrode produced a smaller degree of the hazard of UV radiation compared to the circumstances where oxide electrodes were used [8].

Impact of the shielding gases. Combination of the shielding gases, e.g., argon and carbon dioxide promoted the production of the bigger hazard of the UV radiation compared to the mono gas (carbon dioxide). This effect was related to the type of the metal transfer, i.e., a combination of argon and carbon dioxide led to the spray transfer, while the application of carbon dioxide led to the globular metal transfer method [7].

Effect of the distance from the arc. The effective irradiance for Al alloys, measured at a distance of 0.5 m from the arc, was in the range of 0.091–0.91 mW cm^{-2} and for mild steel 0.51-12.9 mW cm^{-2}. It was assumed [8] that the effective irradiance of UV radiation decreases with the inverse square distance from the arc. For these values of the irradiance, the allowable daily exposure times for Al alloys range from 3.30 to 33.0 s and for mild steel those are 0.23-5.9 s. Consequently, for a distance of 5 m from the arc, the allowable daily exposure times will be between 23 and 590 s. Consequently, even at a distance of 5 m from the arc, exposure to UV radiation is harmful to the welders and surrounding workers [7, 8].

Effect of the local exhaust ventilation. Fumes produced during welding operations scatter and absorb the UV radiation and thus reduce its hazardous effects on humans. Local exhaust ventilation eliminates welding fumes. Because of the impact fumes have on the UV radiation, usually, such systems haven’t been used in the welding environments [7].

3. Precautionary health and safety measures

The main goal of the application of preventive health and safety measures is to reduce or eliminate the health and safety risks to levels as low as reasonably practicable.

The primary step is to accomplish a risk assessment when appropriate and acceptable safety and health measures are set, followed by their implementation and maintenance. The control the hazards at source is of primary concern while the application of personal protective means is implemented merely as complementary measures in protecting the operators against the welding hazards [5, 9].

Risk assessment embraces determination of the radiation exposure level and estimation of the level of the risk, the people that are in a risk of exposure, acceptance of the provisions to avoid or reduce the risks, giving information to the workers and providing their training, making consultation with the workers, including the participation of the workers.

Efficient protective measures for hazards control comprise:

1. Safe working system, rules and procedures of the processes performed, used to avoid or to minimize the health and safety risks.
2. Implementation of technical measures follows, like suitable design, choice and maintenance of devices, ventilation, power supply, etc.
3. Provision of appropriate and sufficient information, instruction and training to the workers and their supervisors.
4. Regular review of the efficiency of the safety measures, rules and working procedures and changes in the working environment.

Organizational measures include the establishment of a safe working system, rules and procedures for manual, provision of appropriate information, instruction and training, measures to ensure that the welding equipment is properly used and maintained, regular review of the changes in the working environment.

Suitable personal protective equipment is used in the final resort when the other protective measures can’t be implemented or don’t provide necessary control of the hazard. Appropriate means used for personal protection from UV radiation are facemasks, hats/ helmets, clothes, gloves and shoes made of flame retardant materials that protect the skin and eyes from molten metal splashing, flames, hot slag, etc.

The biggest attention is paid to the protection of those persons working in the vicinity of the welding workstations. Usually, these workers are not aware of the health and safety precautions established in the plant [5].

4. Conclusions

Welding processes are potentially hazardous activities resulting in the acute and chronic effects on operators and those working in the vicinity of the welding operations. Precautions are required to avoid electrocution, fire and explosion, burns, electric shock, vision damage, inhalation of poisonous gases and fumes, loss of hearing, and exposure to intense ultraviolet radiation.

The UV radiation released during arc welding is intensified by the reflections from the surface from base metal, the effective area of the molten metal pool and by the absorption and/or scattering by the fumes.

The effective irradiance, as a measure of the hazard of UV radiation, depends on the angle from the welding arc, type of the base material, current, type of the electrodes, shielding gas, etc.

Control measures such as the use of a safe system of work, safe working rules and procedures, as well as an application of the engineering system of control, like mechanical ventilation, suitable welding equipment and safe power supply arrangement, resulting in a safe working environment.

The use of personal protective equipment only accompanies technical and organizational measures.

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EFFECTS OF AUTOMATION ON LABOUR MARKETS IN THE EMERGING COUNTRIES

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Abstract. *Europe and the Atlantic region have been the main attraction for the economic migration flowing all over the world. This migration results in a common fear and anxiety within the Western world, due to the high possibility of losing their jobs or working for fewer wages. However, the main factor that would shake the labour markets would be automation, rather than migration. Current developments in the automation field indicate that the peak point of automation could increase the employment problems of both local people and immigrants as well. As the machines gradually replace man-power (workers), this would result in massive unemployment scenarios. This concern existed during and after the Second World War, however, it gained speed with the introduction of the Fourth Industrial Revolution at the Hannover Fair in 2011. The purpose of this paper is to examine the effects of digitization and automation to the economy and especially to labour markets, in the period when the use of the physical and mental capacity of people is minimized and in the world where machines and systems such as "artificial intelligence", "Internet of Things", "new information technologies" are interconnected and intertwined. Countries that were mostly affected by the automation are the Far East countries, mainly China, due to the cheapest production, cheap labour and tax, and other conveniences. In this paper, through panel regression of data on the growth of investments in ICT and output per employed person, we examine and prove the impact of information and communication technologies (ICTs) on labour productivity on the example of several selected emerging markets in the period from 1990-2019.*

Keywords: *automation, digitization, the Fourth Industrial Revolution, emerging markets, labour markets.*

1. INTRODUCTION

Widespread academic papers suggest that the increasing acceptance of information and communication technologies (ICT), especially technologies that support the "new industrial revolution" (artificial intelligence, Internet of Things and advanced robotics) and transformative change that ICT can bring to organizations, is a key component in

fixing lagging global productivity. ICT is a "General-Purpose Technology" that reshapes production and distribution systems, with far-reaching effects across national economies (Atkinson, 2018).

According to Brynjolfsson and McAfee (2014), finding powerful technologies is key to economic progress. Indeed, there is a broad consensus among economic thinkers that some technologies are significant enough to accelerate the normal course of economic progress. To do so, such technologies need to be spread across many, if not most; they cannot do that if they are represented in only one or a few sectors. The cotton gin was undoubtedly important in the textile sector in the early 19th century, but quite insignificant outside that sector. In contrast, steam engines and electricity quickly spread everywhere. The steam engine not only massively increased the amount of energy available to the factories but also freed them from the need to be near a stream or river to power the water wheel; it also revolutionized land travel by enabling railroads and sea travel. Electricity provided an additional boost to production by enabling machines to be individually powered. It has illuminated factories, office buildings, and warehouses and led to new innovations such as air conditioning, which has made work pleasant in the workplace.

Economists refer to these technologies as "General-Purpose Technologies" - GPTs and define them as "new ideas or techniques that have the potential to have a significant impact on many sectors of the economy". That is, in some way they have an impact on production as a result of the increase in output per employed person (productivity). Also, ICT (computer hardware, software, and telecommunications) meet all the criteria to be considered as general-purpose technologies, i.e. they are spread across many sectors of the economy, improve over time, and are a challenge for new innovations. So, it can be said that investments in ICT are starting a new "golden age" for innovation and growth.

The conference of the World Economic Forum in January 2016 announced the beginning of the new, i.e. the Fourth Industrial Revolution of global business leaders, heads of state, public intellectuals, and non-governmental organizations (Schwab, 2016). So, to speak, that year was the year of the announcement of the beginning of the new process of industrialization (Industry 4.0) as a replacement for the Third Industrial Revolution that appeared about four decades ago.

According to Um (2019), the use of the word "revolution" in combination with "industry" becomes part of our cultural heritage. Our industrial achievements are so monumental and numerous that their impact can hardly be estimated. We spend our daily lives using various appliances and instruments produced during the industrial revolutions, such as washing machines and vacuum cleaners, trains and cars, etc. The term "industrial revolution" refers to the change of technological economic and social systems in the industry.

The concept of "Industry 4.0" which was first used as a term in Germany at a fair in Hanover in 2011, in fact, describes the last phase of the industrial civilization that began to develop with the use of technologies that used water and steam, continued with electricity as the fruit of Industry 2.0 and through the digital / electronic phase in Industry 3.0. In this period of Industry 4.0 when the use of human physical and mental capacity is minimized, we experience a world where all vehicles, systems and machines are associated with the development of concepts such as, artificial intelligence, the Internet of Things - IoT . Establishing such systems that can decide on their own functioning with

their minds means establishing a production environment that is free of human weaknesses and where the most rational choices are made (Aribogan, 2019).

In the new era there are simultaneous jumps in many areas; from sequencing whole genomes, nanotechnologies, renewable energies to quantum techniques. The main difference of this revolution from the previous three will be the possibility of merging these technologies and their interaction across physical, digital, and biological fields (Schwab & Davis, 2018). Quantum computer technologies, promising huge efficiency increases in many different areas, such as logistics and drug discovery, offer incredible advances in methods for modeling and optimizing complex systems. The use of blockchain technology, as was and still is the case with bitcoin and other types of digital money, significantly reduces the cost of coordination between different parties. This technology can become a driving force for the flow of huge amounts of value through digital products and services and make all markets accessible to anyone with an Internet connection, of course if it overcomes problems with the authorities and secures digital identities using the top encryption techniques. Virtual and augmented reality offers new channels to experience the world around us, it also speeds up and enriches the process of acquiring skills and applying them anytime, anywhere. Advanced materials can revolutionize the use of civilian and military drones, the supply of electricity to poor communities, and transportation systems.

But what matters is to think about what this would mean for emerging markets and developing countries. Given that even the last stages of the industrial revolution have not yet reached a large number of citizens in these countries (who still do not have access to electricity, water, tractors, and other machinery), many aspects of the Fourth Industrial Revolution characterize transformations in advanced economies, but this does not mean that one should not consider how that process will affect both emerging markets and developing countries.

One challenging scenario for developing countries and emerging markets is if digitalization and automation as part of the Fourth Industrial Revolution process lead to a significant return to production at home "reshoring", that is, in advanced economies back, something very likely if more access to low labour costs did not boost firm competitiveness. The ability to develop strong productive sectors that serve the global economy based on cost advantages is a good path for development, enabling these countries to accumulate capital, technology, and increase revenue. If this road is closed, many countries will have to rethink their industrialization models and strategies.

Another problem is the takeover of jobs in these countries through digitalization and automation. According to Egilmez (2018), Industrialization 4.0 is expected to highly utilize computerization in the manufacturing industry and aims to equip production with the highest technology. Here are three key pointers in moving forward: (1) Minimization of the human factor in production and elimination of man-made omissions in production; (2) Achieving a high level of flexibility in production and creating conditions for designing products that will meet the specific requirements of the consumer; (3) Intensification of the production process. With this in mind, no one can predict what the labour market will look like in 2050. According to an analysis by the World Economic Forum, the Fourth Industrial Revolution is expected to cause a loss of 5.1 million jobs in 15 countries, which make up 65% of the global workforce. If the socio-economic and demographic tendencies are added to the calculation, it becomes clear that the labour market in the coming periods will experience serious changes (Aribogan, 2019).

2. PRODUCTIVITY PARADOX

Nobel laureate Paul Krugman is right when he says that "productivity is not everything, but in the long run it is almost everything". He is right because a country's ability to improve its standard of living over a long period of time depends almost entirely on its ability to increase output per employed person, that is, the number of hours of labour required to produce everything from pencils and paper, food and clothing for the military and police to tanks and submarines. Most countries do not have huge natural resources, oil reserves, or the like and therefore cannot get rich through their exports. So, the only sustainable way for countries to become richer, that is, to improve the living standards of their people is to provide more output with the same number of inputs, in other words, to produce more goods and services with the same number of people (Brynjolfsson & Hitt, 2000).

Productivity growth lays the foundation for improvements in living standards. Meanwhile, investments in information and communication technologies are considered a key driver of productivity growth. This relationship has been extensively studied for developed countries at the level of the firm, industry and national economy, with the majority of studies that show the effect of ICT on productivity as a positive and significant; but this has not been done in a sufficient manner for emerging markets, and developing countries. Perhaps this is due to the lack of high-quality micro and macro data sets for these countries.

But the problem is that in recent decades, the global world, including developed countries, has been facing a slowdown in productivity growth despite high investment in ICT. Following the introduction of technologies such as electricity, internal combustion engines and their implementation and adaptation in production systems in the mid-20th century, especially in the 1940s, 1950s, and 1960s, productivity growth was particularly rapid. However, by 1973 productivity growth had slowed.

In 1987, Robert Solow famously noted that the slowdown in productivity almost coincided with the early days of the computer revolution, arguing that "the computer age may be seen everywhere, but not in productivity statistics". Computers were still a small part of the economy, and in order for general-purpose technologies such as information technology to show their true impact on the economy, some complementary innovations had to be undertaken in organizations or institutions where those technologies are used. Recent research based on detailed data on productivity and the use of IT technologies suggests a significant and strong correlation between them. That is, firms that used IT or other general-purpose technologies and supported them with complementary innovations were more competitive than other firms that did not function that way.

So, despite the introduction and rapid development of computer technology at the time and other innovations that emerged from that computer revolution, productivity grew at a very slow pace. This is repeated today, especially in the period after the Great Recession of 2008. Brynjolfsson and McAfee (2014), have a rather interesting explanation for this phenomenon and argue that the slowdown in productivity in the 1970s and its acceleration after 20 years has an interesting precedent in the past. In the late 1890s, electricity was introduced into American factories. But the "productivity paradox" of that era was that for the next 20 years there was no increase in labour productivity. While the new technologies of the time were very different, many of the

basic dynamics were quite similar. According to research, the main reason why the global economy could not reflect investments in ICT and digitalization in productivity statistics was "complementary investments", i.e. every dollar invested in computer hardware should be invested an additional $9 for software auditing, education, and institutional process.

Most likely, it is confirmed today. Despite the rapid growth of new technologies and innovations fueled by the Fourth Industrial Revolution, this is not reflected in productivity statistics as Nobel Laureate Solow put it in 1987. The benefits of these technologies on the the overall economy and labour productivity will be reflected in the statistics after additional and complementary investments are made, and this will take time.

In this paper, through panel regression of data on the growth of investments in ICT and output per employed person, we examine and prove exactly that problem of the "productivity paradox" on the example of several selected emerging markets in the period from 1990-2019.

3. LITERATURE REVIEW

3.1. Theoretical background

From a historical point of view, in the period after 1955 we can speak of four major and influential theories of economic growth: The non-Keynesian Harrod-Domar model of economic growth; Robert Solow's neoclassical model of economic growth; The endogenous model of the economic growth of Romer and Lukas and Institutionalist theories of economic growth. According to the Harrod-Domar model, economic growth is conditioned by savings and investments, according to Robert Solow by growth, i.e. investment in capital and labour, and the so-called total factor productivity, and according to Nobel laureate Paul Romer, growth is largely determined by technology - technological innovation. It actually integrates technological innovation into long-term economic growth and shows how and why knowledge and technological innovation are the most important factors for economic growth and development (Petreski, 2000).

As Paul Romer notes, the dominant growth theory of the late 1980s - Solow's growth model, who won the Nobel Prize in Economics in 1987 - can explain many features of economic growth, but not large and persistent differences in growth rates. Solow's model predicts that poorer countries should grow faster and reach the level of the richer fairly quickly. In Solow's model, the economy can grow by accumulating physical capital, for example, machinery, and infrastructure, but capital-driven growth must stagnate in the long run; for any given technology, adding more and more capital contributes to less and less output. To allow for steady long-term growth (and growth differences) in the model, the assumption should be that over time, the workforce becomes more productive due to technological progress, albeit at a different rate for each country. Solow's model does not explain these trends, because changes in technology in its modernity simply come exogenously from a "black box" (The Royal Swedish Academy of Sciences, 2018a).

Romer's greatest achievement was that he was able to open this black box and show how ideas for new goods and services - produced by new technologies - could be created

in a market economy. He also showed how such endogenous technological changes can shape growth and what policies are necessary for this process to work well. Romer's contributions have had a major impact on the economy. His theoretical rationale laid the groundwork for the study of endogenous growth.

Romer notes three weaknesses of Solow's model: (1) Technological change is treated as an exogenous factor, because we are unable to understand the reasons that drive technological change; (2) Technology is treated as a public good - it is everywhere and anyone can use it; (3) The Law on Diminishing Returns in the Economy, i.e. if at a given level of technology you constantly invest in capital and labour, over time, the contributions of the additional invested units decrease.

Romer in his work seeks solutions to these problems. To explain this, we must first understand how technology and ideas differ from goods such as physical or human capital. Romer emphasizes two dimensions: (1) Physical and human capital are competitively good. If a particular machine is used or a trained engineer works in one factory, the same machine or engineer cannot be used at the same time in another factory. While new technologies and ideas, on the other hand, are non-competitive goods: one person or company that uses an idea or technology does not prevent other companies from using it; (2) These goods are not public goods and can be exclusive or partially exclusive if the institutions or regulations enable them to prevent someone from using them. If it is subject to private control it can be protected (for example, a patent right) and it can bring economic profit to the one who owns it. Romer's pioneering work has shown how the uncompetitiveness and exclusivity of new technologies and ideas determine economic growth and labour productivity (The Royal Swedish Academy of Sciences, 2018b).

3.2. Empirical studies

Productivity increases from a variety of factors, but the main factor is the use of more and better "tools" by manufacturers - in other words, the use of more and better machines, equipment, and software. Even in today's knowledge-based economy, the tools that are most present and most effective in increasing productivity are based on ICT. According to Thomas Niebel (2014), these digital tools are wider than just the Internet, although that in itself is driving growth. These include hardware, software, and telecommunications networks and tools that incorporate these components into them, such as IoT devices, artificial intelligence, and advanced robotics. Their impact is comprehensive as it is used in virtually every sector, from agriculture to manufacturing, from services to the functioning of governments, and so on.

Most macroeconomic and industrial studies are based on the growth accounting the framework, where it is assumed that the contribution of each input to production is proportional to the corresponding share in total input costs. The increase in output over input contributions is attributed to the growth of multi-factor productivity (MFP) or Solow total factor productivity (TFP), i.e. technological progress that is not expressed in production inputs. Jorgenson and Stiroh (2000), has applied the limit of production capacity to explain the increase in productivity growth in the United States since 1995. They found that computer hardware played a larger role as a source of economic growth and average labour productivity grew much faster between 1995 and 1999 as a result of

capital deepening as a direct consequence of falling ICT prices and rising multi-factor productivity.

Oliner and Sichel (2000), obtain similar results, based on a growth accounting model similar to Solow's methodology. They find that the contribution of ICT capital increased between 1974-1995 and 1996-1999 and that MFP growth also increased by 40% between 1996-1999.

Colecchia and Schreyer (2002), extended the approach followed by Jorgenson and Stiroh (2000), and Oliner and Sichel (2000), to nine OECD countries by 2000. They found that in the previous two decades, ICT contributed between 0,2 and 0,5 percentage points per year to economic growth, depending on the country. During the second half of the 1990s, this contribution rose to 0,3 to 0,9 percentage points per year. The contribution of ICT investment to economic growth is highest in the United States, followed by Australia, Finland, and Canada. Of the nine countries analyzed, Germany, Italy, France, and Japan had the lowest ICT contributions to economic growth.

Similar country surveys have been conducted for the United Kingdom (Oulton, 2005), but have also been conducted in a comparative context (Inklaar, Timmer, & Van Ark, 2007). A recent study by Jorgenson and Timmer (2011), confirmed growth accounting as a well-established approach, providing new analysis of patterns and structural change in developed countries. The works of Draca et al. (2007), Cardona et al. (2013), prove the relationship between ICT and labour productivity as positive and significant in the case of developed countries using different methodologies.

So, we can conclude that technology has incredible power to stimulate economic growth, improve people's lives, and create opportunities, both for individuals and for companies and countries. As we have seen, this relationship has been extensively studied in developed countries at the firm, industry, and country levels, with the majority of studies showing the effect of ICT on productivity as positive and significant. However, there is rather weak and ambiguous empirical evidence of the contribution of ICT investment to economic growth for emerging markets and developing countries. However, the World Bank (2012), is optimistic, stating that ICT is very promising and will reduce poverty, increase productivity, increase economic growth, and so on. Perhaps the weak and ambiguous empirical studies on the impact of ICT on developing countries and emerging markets are driven by the lack of high-quality micro and macro data sets for these countries.

There are also valid reasons why the impact of ICT on growth in developing countries and emerging markets is different than in developed countries. According to Niebel (2014), there are two reasons that explain this phenomenon: (1) Developing countries may not have absorption capacity such as an adequate level of human capital or other complementarity factors such as R&D costs and therefore receive less ICT investment compared to developed countries; (2) On the other hand, ICT can help emerging markets and developing countries to "skip" the traditional methods of increasing productivity mentioned by Steinmueller (2001). Additional productivity gains can be triggered by “ICT-related overflows or network effects” as ICT can reduce transaction costs and speed up the knowledge creation process. But these network effects can be more pronounced when many companies in a region or industry use similar levels or types of ICT.

Only recently Niebel (2018), based on available data from The Conference Board Total Economy database, analyzed 59 developing countries, emerging markets, and developed countries in the period 1995-2010 and showed that the percentage output

elasticity of ICT is greater than the part for compensation of the ICT factor that indicates the return of the ICT capital. The results show that developing countries and emerging markets receive no more ICT investment from developed economies.

4. Analysis of the Impact of ICT on Labour Productivity in the Case of Selected Emerging Markets

4.1. Research data and methodology

In this paper we analyze the impact of information and communication technologies have had on labour productivity per person employed in several emerging markets (Brazil, China, India, Indonesia, Mexico, Russia, South Africa and Turkey) selected based on the classification that stands for at the productivity brief for 2019 of the company "The Conference Board", in the period 1990-2019. Empirical analysis is made using the panel approach through fixed and random-effects techniques, where the dependent variable is the growth of labour productivity per person employed, and as independent variables we include the growth of investments in ICT and the growth of multi-factor productivity, using EViews econometric software. The data are provided from The Conference Board Total Economy database and are taken as annual labour productivity growth and MFP growth as annual growth rates. Only the data on the growth of investments in ICT are obtained as the first difference from the natural logarithm of the absolute values of ICT investments by years and they are presented as growth rates. In order to obtain stationary series and a more normal distribution of the residuals, we divide the time period from 1990-2019 into two subperiods, one from 1990-2006 and the other from 2007-2019; This division also helps us to compare the impact of ICT investments on labour productivity before and after the Great Recession of 2008, i.e. it allows us to determine whether after the World Economic Crisis there is a further decline in labour productivity despite the new industrial revolution and new technologies that are increasingly involved in creating added value in the economy.

Econometrically, the general model we use for estimation when using panel data can be described as (Brooks, 2014):

$$\gamma_{it} = \alpha + \beta x_{it} + u_{it}, \quad (1)$$

where γ_{it} is a dependent variable, α is the intercept term, β is a $k \times 1$ vector of the parameters of the explanatory variables to be estimated and x_{it} is a $1 \times k$ vector of observations of the explanatory variables, $t = 1, \dots, T$; $i = 1, \dots, N$.

The simplest way to analyze panel data is by estimating aggregate regression, which involves estimating one equation for all data, so that the γ database is arranged in a single column containing all cross-member observations and time series, and similarly, all observations of each explanatory variable are arranged in single columns in the matrix x. In that case, this equation is estimated in the usual way using the ordinary least squares (MLS) method.

Although this is a really simple way to proceed, and requires an assessment of as few parameters as possible, the procedure has some serious limitations. Most importantly, the aggregation of data in this way implicitly assumes that the average values of the variables

and the relationships between them are constant over time and across all the cross-members in the sample. We could, of course, estimate individual time series regressions for each member or country, but this would probably be a sub-optimal way to proceed as this approach would not take into account any common structure present in the time series. Alternatively, we could estimate individual cross-regressions for each particular time period, but again this may not be wise if there are some common variations in the series over time (Brooks, 2014).

To solve this problem, we choose between two classes of panel evaluation approaches that can be used in such research: fixed-effects models and random-effects models. The simplest types of fixed-effect models allow the intercept in the regression model to differ between the cross-members, but not overtime, while all estimated slope coefficients are fixed both cross-sectionally and temporally.

The fixed-effects model can be estimated using the following equation (Brooks, 2014):

$$\gamma_{it} = \alpha + \beta x_{it} + \mu_{it} + v_{it}, \quad (2)$$

where the error member u_{it}, decomposes into an individual specific effect, μ_i, and the "remainder disturbance", v_{it}, which varies with time and terms (including everything that remains unexplained for γ_{it}). We can count on μ_i as covering all variables which affect γ_{it} cross-over, but do not differ over time, as in our model countries belonging to a certain group of countries according to the amount of per capita income.

An alternative to the fixed effects model described above is the random-effects model. As with the fixed effects model, the random effects approach proposes different intercept terms for each member, and again these intercept terms are constant over time, assuming that the relationships between the explanatory and explained variables are the same both crosswise and temporally.

However, the difference is that according to the random-effects model, it is assumed that the intercepts for each cross-member derive from a common intercept α (which is the same for all cross members, over time), plus a random variable ϵ_i, which varies through cross members but is constant over time. ϵ_i measures the random deviation of each entity's intercept term from the "global" intercept term α. We can write the panel model with random effects as follows (Brooks, 2014):

$$\gamma_{it} = \alpha + \beta x_{it} + \omega_{it}, \ \omega_{it} = \epsilon_i + v_{it}, \quad (3)$$

where x_{it}, is still a $1 \times k$ vector of explanatory variables, but unlike fixed effects, there are no dummy variables here to capture heterogeneity (variation) in the cross-sectional dimension. Instead, it happens through members ϵ_i. It should be borne in mind that this framework assumes that the new error cross member ϵ_i has zero mean, is independent of the individual error member v_{it}, has a constant variance σ_ϵ^2, and is independent of the explanatory variables x_{it}. Finally, we run the Hausman test in order to see which of the models in our analysis is recommended and display the results.

4.2. Results of the Empirical Analysis

4.2.1. The impact of ICT on labour productivity in emerging markets in the period 1990-2006

This section provides a panel regression on the impacts of ICT investments on labour productivity per person employed in the case of emerging markets in the period 1990-2006. The results of the conducted LLC-test (Levin, Lin, and Chu) for the integrative characteristics of the examined variables in the model, we can conclude that according to the stated test, the series of productivity per person employed is not stationary at the level. Therefore, we need to consult other tests to examine the (non) stationarity of the series. The p-value of Im, Pesaran and Shin W-statistics is 0,0048, which means that the series is stationary in level, at a level of significance of 0,05; The p-value of ADF - Fisher Chi-square is 0,0083, which also means that the series is stationary in the level, at the significance level of 0,05 and the p-value of PP - Fisher Chi-square is 0,0000, which means that the series has no single root at the level even at the significance level of 0,01. Finally, according to the majority of tests, we conclude that the series of output per employed person does not have a single root in the level. The MFP data series according to the LLC test is stationary at the level of significance of 0,1; while, according to other tests, it is stationary even at a significance level of 0,05. The ICT data series, on the other hand, shows a level of stability, at a significance level of 0,05 according to the majority of tests.

Then, we evaluate the fixed effects model in order to see what information the "likelihood ratio" gives us from the "Redundant Fixed Effects Tests". The results of this test indicate that in this model it is permissible to impose fixed or random-effects on the cross-members, and not on the period. So, it is advisable to work with a model with fixed or random-effects, rather than a pooled regression where all data is considered to belong to one entity without paying attention to the different characteristics between entities / cross-member entities. Next we perform the Hausman test in order to decide which technique should be used in our model. The p-value of the Chi-square statistic is 0,6717, i.e. it has a higher value of 0,05 or 0,1; which means that we cannot reject the null hypothesis and find that in our case the random effects model is recommended.

The next step is to estimate the model, i.e. to determine the coefficients of the independent variables by imposing random effects on the cross-members in the model, and it is estimated by the following equation:

$$output\_per\_employed\_person\_growth_{1990-2006} = \alpha + \beta_1 \Delta \ln(ict)_{1990-2006} + \beta_2 mfp\_growth_{1990-2006} + (\mu + \epsilon_{1990-2006}). \quad (4)$$

The table below shows the results of the estimated model based on Equation 4. The coefficient of determination R^2 has a value of 88,52% which indicates that most of the variations in the model are explained by the included variables. The p-value of the F-statistics of the estimated model is 0%, i.e. lower than 5%, which means that we accept the hypothesis that the explanatory variables together have a significant influence on the movement of the dependent variable. In order to examine the multicollinearity, we present the growth in MFP as a function of the growth of investments in ICT. The VIF result obtained from that model is about 1; and it is generally accepted that

multicollinearity should be treated as a problem in case the VIF is greater than 5. Also, many consider the absolute value of the simple correlation coefficients (r) higher than 0,80; is already a sign of strong multicollinearity. In our case, we can say that multicollinearity according to both criteria should not be treated as a problem. In order to examine whether the residuals follow a normal distribution, the Jarque-Bera test was performed. In our model, the p-value of the test statistics is 12,68%, i.e. it has a higher value of 5%; in that case we cannot reject the null hypothesis that residuals follow a normal distribution.

Table 1. Results for the estimated coefficients based on the model with random effects in the model for the emerging markets in the period 1990-2006

Explanatory variables	Coefficient	t-statistics	p-value
Δln(ict)	0,054021	4,425895	0,0000
mfp_gowth	0,987210	29,44819	0,0000
α	0,895867	1,333721	0,1846
R^2	0,885195		
F-statistics	512,7415		
p-value (F-stat)	0,000000		

Specification of effects		
	S.D.	Rho
Cross-members random	1,694057	0,5769
Characteristic-random	1,450653	0,4231

Source: Authors' own calculations using EViews.

After these diagnostic tests, we can proceed to the interpretation of the estimated coefficients of the explanatory variables. From the obtained results in table 1, it follows that the growth of ICT investments in selected emerging markets in the period 1990-2006 had a positive and significant impact on the output growth per employee (p-value of t-statistics is 0%). The growth of investments in ICT by 1% slightly increases the productivity per person employed by 0,05%. Also, the growth of MFP in emerging markets in the same period had a positive and significant effect on productivity per person employed, but with greater intensity, increasing productivity per person employed almost unit, i.e. 0,99% (p-value of t-statistics is 0 %).

4.2.2. The impact of ICT on labour productivity in emerging markets in the period 2007-2019

In this section, we analyze the impacts of ICT on labour productivity in the case of emerging markets, but in the period 2007-2019. From the results for the integrative characteristics of the used variables from the conducted LLC-test in the model on the emerging markets in the period 2007-2019, it is obvious that all data sets of the used variables are stationary in the level I (0), i.e. the p-values of their LLC-statistics for all three variables are below 5%.

The results of the Redundant Fixed Effects Tests, suggest that we can impose fixed or random-effects only on the cross-sections, and not on the periods. Then, we perform the

Hausman test in order to decide which technique should be used in our model. The p-value of the Chi-square statistic is 0,0029, i.e. it has a lower value of 0,05 or 0,01; which means that we can reject the null hypothesis and find that in our case the fixed-effects model is recommended.

The next step is to estimate the model, i.e. to determine the coefficients of the independent variables by imposing fixed-effects on the cross-section in the model, which, as with the random-effects model, proposes different intercepts for all cross-sections, and it is estimated by the following equation:

$$output\_per\_employed\_person\_growth_{2007-2019} = \alpha + \beta_1 \Delta \ln(ict)_{2007-2019} + \beta_2 mfp\_growth_{2007-2019} + \mu + v_{2007-2019}. \quad (5)$$

The table below shows the results of the estimated model based on Equation 5.

Table 2. Results for the estimated coefficients based on the model with random effects in the model for the emerging markets in the period 2007-2019

Explanatory variables	Coefficient	t-statistics	p-value
Δln(ict)	0,029181	2,570757	0,0117
mfp_growth	0,861042	29,22879	0,0000
α	2,050874	10,20794	0,0000
R^2	0,987715		
F-statistics	839,7624		
p-value (F-stat)	0,000000		

Source: Authors' own calculations using EViews.

The coefficient of determination R^2 has a value of 98,77% which indicates that most of the variations in productivity per person employed came from variations in investments in new technologies. The p-value of the F-statistics of the estimated model is 0%, i.e. lower than 5%, which means that we accept the hypothesis that the explanatory variables together have a significant influence on the movement of the dependent variable. To examine multicollinearity, we present the growth in MFP as a function of the growth in investments in ICT. The VIF result obtained from that model is about 1,05; and it is generally accepted that multicollinearity should be treated as a problem if the VIF is greater than 5. Also, many consider the absolute value of the simple correlation coefficients (r) to be higher than 0,80; is already a sign of strong multicollinearity. In our case, we can say that multicollinearity according to both criteria should not be treated as a problem. To examine whether the residuals follow a normal distribution, the Jarque-Bera test was performed. In our model, the p-value of the test statistics is 14,04%, i.e. it has a higher value of 5%; in that case, we cannot reject the null hypothesis that residuals follow a normal distribution.

After these diagnostic tests, we can proceed to the interpretation of the estimated coefficients of the explanatory variables. From the obtained results in table 2, it follows that the growth of ICT investments in the selected emerging markets in the period 2007-2019 had a positive and significant effect on the output per employed person growth (p-value of t-statistics is 1,17%). 1% increase in investments in ICT increases the output per employed person by a minor 0,03%. While the growth of MFP in developed countries in

the same period has a positive and significant effect on productivity per person employed (p-value of t-statistic is 0%). 1% growth in MFP leads to 0,86% growth in output per employed person in the emerging markets in the analyzed period.

5. CONCLUSION

In the previous sections we examined in detail the impact of ICT investments on labour productivity in the example of 8 emerging markets (Brazil, China, India, Indonesia, Mexico, Russia, South Africa and Turkey) using the panel regression method and the techniques of fixed or random effects. The analysis covered the period from 1990-2019, but in order to get better results for the stability of the series and the normality of the residuals, and to better see the impact of the Great Recession, we divided that period into two sub-periods, one from 1990-2006 and the other from 2007-2019.

The basic question is whether the benefits of ICT are different between developed countries and emerging markets and whether there is a difference in the impact of ICT investments in the two periods. As we can conclude we see that the impact of ICT investments on labour productivity in the period before the Great Recession and in the post-crisis period remain minor and contribute to a very small part of labour productivity growth, and this is in favor of the "productivity paradox" by Solow that "the age of computers may be seen everywhere, but not in productivity statistics". But, as we said before, the slowdown in productivity in the 1970s and its acceleration after 20 years had an interesting precedent in the past. In the late 1890s, electricity was introduced into American factories. But the "productivity paradox" of that era was that for the next 20 years there was no increase in labour productivity. While the new technologies of the time were very different, many of the basic dynamics were quite similar. We had an interesting conclusion, and we will use it now, that in order for these "general-purpose technologies" and other ICT investments of the Fourth Industrial Revolution to be reflected in productivity statistics, they will need additional complementary innovations, and that will take time. Therefore, in 2016, developed countries opened the topic of the Fourth Industrial Revolution in order to quickly reconcile the circumstances of that revolution, and perhaps for the next so that they can reflect the benefits of them in statistics.

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BIM-BASED INFORMATION MANAGEMENT FOR SUSTAINABILITY ASSESSMENT OF BUILDINGS

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Abstract : *The construction industry is one of the largest consumers of natural resources but with the growing concerns about climate change, construction companies aim at reducing their projects' environmental impact.*
Companies normally achieve that by implementing sustainability certification schemes like BREEAM, DGNB, etc. However, the implementation of such schemes requires the allocation of more time, money, people etc. One of the biggest challenges is how to reduce the higher costs when using such schemes. Higher costs arise due to the usage of more eco-friendly and expensive construction materials, but also, time delays due to the bad management of information.
Information management is crucial for the sustainable assessment of buildings and takes central part of Building Information Modelling (BIM). Building sustainability assessments require the collection of data from dozens of processes, construction products, etc., collected from many different actors.
The report will have a look at some of the most used certification schemes in Europe and will point out some of the major issues related to the management of sustainability assessment and certification processes. The authors will put this in the context of the recommended framework from EN ISO 19650 and will propose a method for structuring information required in such processes.

Keywords: *sustainability certification, BIM, EN ISO 19650, information management*

TOWARDS CONSTRUCTION, THAT "DOESN'T COST THE EARTH

The construction industry is one of the largest industries and it accounts for 13% of the world's GDP. [1] [2] The industry has its big share economically, but it has a bigger one in our lives in general. The "built environment", which is a new term recently growing in use, includes everything that is built by humans – buildings, infrastructure, parks, utilities, etc., as we spend about 90% of our time in buildings living, learning, and working in there. [3] In addition to that, the world's population is expected to increase by 2 billion persons in the next 30 years, from 7.7 billion, currently, to 9.7 billion in 2050, according to the new United Nations report from June 2019. [4] Although it is expected that this

growth will come to an end in about 2100, we still need to secure the "built environment" for the ones to stay and come. [5]

Buildings and cities' life span are much prolonged than human lives and their impact stretches into future generations. This leads to the need of good resource planning because of the unknown future consumption, population or climatic conditions.

The construction industry is one of the biggest consumers of natural resources and it has a huge negative environmental impact with about 40% of the energy consumed. It generates about 50% of the waste disposed in landfills and it accounts in about 35% of all carbon dioxide emissions. In addition, around half of the non-renewable natural resources are consumed by the construction industry, which makes it one of the least sustainable industries in the world. [6]

All the above makes the world and governments pay more attention to the industry's environmental impact and to set goals, which will lead to improvement. One of the latest actions in this area is the European Green Deal, which aims at tackling climate change and environmental challenges. Exact measures are not proposed yet but some of the overall goals for the construction industry are:

- Energy efficiency in the built environment
- Building design more in line with circular economy
- Greenhouse gas and environmental footprint accounting
- Increased digitalization [7] [8]

As a result, "green" building projects attract more and more interest, and sustainability certification schemes are at the middle of this. Today, there are many sustainability certification schemes around the world like BREEAM developed in the UK, LEED developed in the US, DGNB developed in Germany, etc. Just for example, BREEAM is used all over the world with more than 590 000 certificates in more than 80 countries (Figure 1).

Fig. 1 BREEAM certified projects around the world

SUSTAINABILITY CERTIFICATION SCHEMES – OVERVIEW

Certified sustainable buildings ensure the outperformance compared to other conventional buildings. Therefore, sustainability certification schemes are widely used in the sector to ensure a high level of quality while strengthening sustainable agendas. Normally, these schemes require checking buildings against lists of criteria by measuring the compliance against specific requirements set in the criteria. However, the requirements might differ in the different schemes and this makes it difficult to compare them. The lack of standardization makes it difficult to navigate through the different schemes and it makes it difficult to choose the best, which will suit the building and company's sustainability goals. Let us look at some of the most used ones.

BREEAM

BREEAM is developed in the UK and is administered by the Building Research Establishment. This is the first sustainability certification scheme and is one of the most used ones all around the world. BREEAM has served as a template for other schemes that have been developed afterwards.

BREEAM describes a methodology on measuring the buildings and infrastructure's environmental, social and economic impact. The environmental aspect measures requirements related to water, energy, materials, waste, land use and others. The social aspect is mostly concentrated on the health and well-being of occupants and the economic aspect is mainly covered by life cycle costing.

BREEAM can be applied to many different types of projects and it has a specific guidance to each, e.g. New Construction, In-Use, Infrastructure, Communities etc. The overall process of certification goes as following:

1) An accredited BREEAM assessor is hired.
2) The assessor registers the project and collects all the needed project information and documents proving compliance against the scheme's requirements.
3) The assessor submits everything to the certification body and if the project meets the requirements, it is awarded one of the six certification levels – acceptable (In-Use only), pass, good, very good, excellent and outstanding.

There are two types of BREEAM certificates – intermediate that is awarded at the end of the design stage and final that is awarded at the end of the construction stage, as the intermediate one is optional. [9]

LEED

Leadership in Energy and Environmental Design (LEED) is developed in the US by the Green Building Council and is another one used all around the world. The core of the scheme is the environmental aspect rather than the social and economic one. The focus is in categories like water efficiency, materials and resources, energy, atmosphere etc. There is a small focus in the economic aspect expressed in life cycle costing, and on the social aspect, the focus is in indoor health environment.

LEED can be also applied to different types of projects like new buildings, existing buildings, retails, cities and communities etc. The overall process of certification for this scheme goes as following:

1) The owner, or an agent hired by the owner, registers the project.

2) The project administrator manages the team who collects the required information, performs analysis and calculations, and at the end prepares the documentation for the selected credits.

3) GBCI performs a review and certifies at one of the possible levels – certified, silver, gold and platinum.

LEED allows a precertification to demonstrate a commitment to a specific level of LEED Certification. Precertification does not guarantee the level of eventual certification, nor does it commit the project team to a certain level of certification, however it is important that the level of precertification sought is in line with the eventual project certification goals. Then at the end of the construction stage, a final certificate is awarded. [10]

DGNB

Deutsche Gesellshaft fur Nachhaltiges Bauen (DGNB) is developed in Germany but is also used internationally as the two previous systems. The system measures all three main aspects of sustainability – environment, economics and sociality. The main criteria that are assessed and measured are:

- Environmental quality – life cycle assessment (LCA) is crucial, avoidance of harmful materials to the immediate environment, purchase of wood from local companies etc.
- Economic quality – life cycle costs (LCC), space efficiency, flexibility and adaptability etc.
- Socio-cultural and functional quality – indoor air quality, accessibility for disabled persons, facilities for bicycles etc.
- Technical quality – smaller fire/smoke sections than required by building regulations, more evacuation routes, sound insulation etc.
- Process quality – interdisciplinary teams, site organization, design processes etc.
- Site quality – influence on the district, transport access etc.

DGNB is available in different variants for buildings, districts and interiors. The overall process of certification for this scheme goes as following:

1) An accredited DGNB auditor is hired.

2) The auditor supports the registration process for the project and the collection of all the needed project information and documents proving compliance against the scheme's requirements.

3) The DGNB auditor submits the project to the certification body and if the project meets the requirements, it is awarded one of the four certification levels – bronze (only for existing buildings), silver, gold and platinum.

These are the three most used and popular construction sustainability certification schemes in the world. They all require the collection and analysis of tons of information that should be collected from the whole project supply chain and this is a heavy and time-consuming process, which is even more complicated because of the differences in these schemes.

Even though all three of them are measuring the level of sustainability of buildings and infrastructure, they differ a lot between each other – in terms of requirements, structure, certification processes etc. This only leads to a confusion, misunderstandings and issues that create unnecessary additional project costs and bad quality documentation that ends up in low certification levels. The following chapter explains some of the major issues, again, in the context of the three described certification schemes.

ISSUES AFFECTING COST AND QUALITY PERFORMANCE OF "GREEN" PROJECTS

Lack of clear definition of green building materials

One of the major techniques to make a building or infrastructure "green" is the use of green building materials. But what do green building materials mean? How do you define it? Green building materials is a broad term and it includes many different aspects in its meaning. If we are to summarize, these are materials which have a low environmental impact during their life cycle (extraction, production, installation, operation and maintenance, deconstruction etc.), they are locally resourced, durable, recyclable, reusable, have reduced maintenance/replacement cost etc. [11]

All the three certification schemes set requirements on materials and their sustainability aspect, however, they differ. For instance, BREEAM awards credits if materials have a third-party verified environmental product declaration (EPD), certification for responsible sourcing of materials (e.g. FSC, PEFC etc.), have been tested for durability according to different European and International standards and guides, etc. LEED, on the other side, awards credits if the project has used a certain percentage of materials with post-consumer and pre-consumer recycled content, locally resourced, responsible sourcing certified etc. And DGNB sets criteria on reporting materials emissions, the amount of sustainably produced raw materials that were installed etc. All these differences just lead to the uncertainty of project actors what green building materials are and to unsuitable designs, negligence, and limited creativity. In addition, the differences between schemes make it difficult for companies to choose a certification scheme that best fits their sustainability goals and strategy, and hinder transparency and market comparisons.

Long approval processes of green materials

In addition to the confusion of what green building materials are, the way requirements are set in the different certification schemes lead to long approval processes. The information which is needed to answer the requirements can be normally found in many different documents like environmental product declarations (EPDs), certificates, declaration of performance (DoPs), and in order to ensure credits, these documents should not just be collected but also checked in their content. These collection, checks and validations require a huge effort, and are often prompt to mistakes and additional costs.

Working with tons of documents that are provided in an unstructured formats like PDFs, word etc. leads to undelivered and/or inaccurate information, delay in certification processes due to untimely collection of information etc.

Insufficient use of already existing information

Most of the requirements in sustainability certification schemes are cross-referenced with other already existing information requirements in building regulations, design codes, product standards etc. However, the fact that all these sources of the same requirements are unstructured and kept separately makes it almost impossible to sufficiently use of information.

One good example is the requirement set in BREEAM Hea 02 Indoor Air Quality – "At least four of the five product types listed in Table 17 meet the emission limits, testing requirements and any additional requirements listed in Table 17.". Whereas, Table 17 refers to European test standards like EN 16402 for testing emissions of paints, EN 717-1 for testing formaldehyde emissions of wood-based products, etc.

Such referencing only means that whoever is checking the construction products and materials against these requirements will lose a lot of time to jump from one document to another, understanding what is written in them, and will perform the work with a lot of mistakes.

Major changes in the project due to poor communication and coordination between the teams

All the requirements set in these certification schemes refer to information that should be brought to the knowledge of all project actors. From designers who will need to design the building and set requirements on materials in order to achieve credits to contractors who will have to comply with the designers' requirements and find conformant products. However, this is done in a very manual way and often leads to miscommunication, or even no communication between the interested parties. [12]

All the above described issues have one thing in common – information. Information has a key role when it comes to managing "green" projects and certification processes. Therefore, information management is crucial for the sustainable assessment of buildings and it also takes a central part in Building Information Modelling (BIM).

The state of digitization of the construction industry

Compared to other industries, the construction industry is the least digitized. There are a lot of articles, studies, reports and others that investigate this issue, and most of them emphasize on prerequisites like the uniqueness of projects, the number of stakeholders involved, the iterative nature of design processes etc. But thinking about all of these, don't other industries also have these? Based on the sources researched, the authors conclude that there are two significant drawbacks: reluctance to go digital and skilled labor shortages. [13]

The reluctance is not just a whimsey, but it has its good reasons. The construction industry took the hardest hit of the global economic crisis in 2007 - 2008 and most of the investments in research and innovations either decreased or stopped, and such investments play a major role in digitalization.

The problem with skilled labor shortages have a few dimensions. One is the nature and the fame, which the construction industry and construction jobs have - hard work, poor payment, safety issues leading to many injuries some of which fatal and so on. Another

dimension is the transition from “Baby Boomers” to “Millennials” - from the ones who have strong work ethics, and they have mostly joined organizations to pursue their careers, to the ones who have short attention spans and lack of interest in joining organizations. [14]

And yet, the low level of productivity in the construction industry is a fact that cannot be ignored. The McKinsey Global Institute (MGI’s) Reinventing construction: A route to higher productivity report, released on February 2017, found that global labor-productivity growth in construction has averaged only 1 per cent a year over the past two decades, compared with growth of 2.8 per cent for the total world economy and 3.6 per cent in manufacturing. [15]

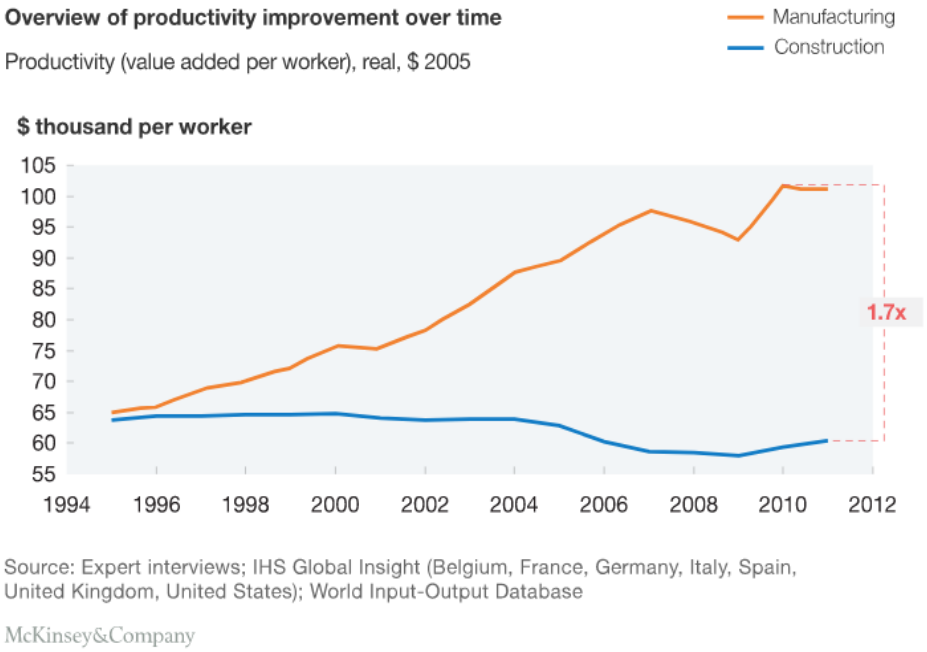

Fig. 2 Construction industry productivity over time

The digitalization of the construction sector is increasingly recognized as a potential game-changer for the sector, which could contribute significantly to sustainable development and the EU 2020 Strategy. [16]

BUILDING INFORMATION MODELLING (BIM)

When speaking about digitalization in the construction industry, a certain abbreviature comes to mind - BIM or Building Information Modelling. This is a concept, which has existed for many years now, and there are many definitions of what BIM is. The two most recognizable definitions are by EU BIM Task Group’s BIM handbook and JRC report on

Building Information Modelling (BIM) standardization. The first one states “BIM is a digital form of construction and asset operations. It brings together technology, process improvements and digital information to radically improve client and project outcomes and asset operations.”, as the handbook also says “BIM can be thought of as ‘digital construction’.” [17]

The second one states “BIM is a digital tool disrupting the construction industry as a platform for central integrated design, modelling, asset planning running and cooperation. It provides all stakeholders with a digital representation of a building's characteristics in its whole life-cycle and thereby holds out the promise of large efficiency gains.” [18]

Both use the word ‘digital’ a lot, and this just strengthens the position which the authors have, that BIM and digitalisation of the construction industry can be used interchangeably. As a summary, BIM is a digital transformation approach. In its essence, BIM is a 3D model with integrated data that can be shared among the different actors during the whole life cycle of the project.

With the growing number of initiatives and strategies for the implementation of BIM in different European countries, a number of international and European standards have emerged.

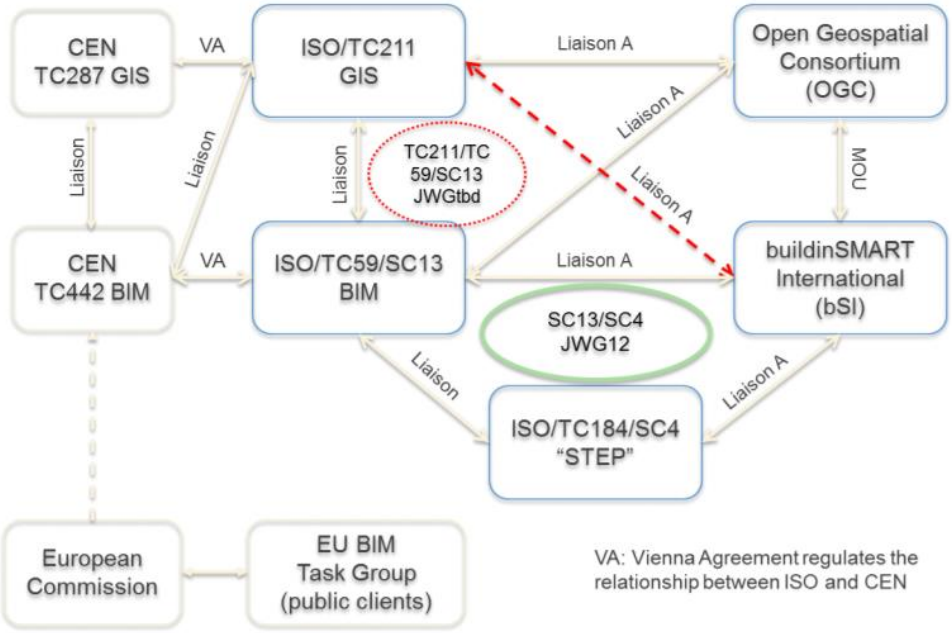

Fig. 3 International BIM standardization

One of the core standards, along with a few others, is ISO 19650 as part of the work in ISO/TC 59/SC 13 - Organization and digitisation of information about buildings and civil engineering works, including building information modelling (BIM). The standard sets out the principles on how to manage projects and digital exchange of information between contract parties. It sets out the different roles involved and their responsibilities, as it emphasises on the importance of the whole supply chain being involved in order to

achieve good results. [19] It is applicable to any business process and its principles can dramatically improve the information management in sustainability certification processes.

The processes and roles described in the standard rely on information, which has to be collected, processed and delivered using certain methodologies and tools. The information, which has to be digitised or turned on what is called 'digital data'.

DIGITAL DATA AND STANDARDS FOR DIGITAL DATA

First, let us look at what types of data exist. Data in the world of data science is structured and unstructured. Structured data is highly organised data, which can be used in relational databases. Such data can be easily understood by machine languages and can be searched, retrieved, analysed and manipulated. Unstructured data on the other side is precisely the opposite. This is data, which cannot be processed and analysed using conventional tools and methods. This are, for example, emails, word documents, PDFs, multimedia, spreadsheets etc. [20]

The data, which is needed to perform sustainability assessments in accordance with the above-mentioned schemes, is unstructured and is used inefficiently. The purpose of digitising the construction industry is to make it efficient and effective and to do that the information shall become structured so it can be quickly retrieved, manipulated and analysed. [21] Since the industry has realised the need to make data structured, machine-readable and interoperable, CEN/TC 442 was established to take charge of the standardisation work regarding all information in the built environment. The committee adopted the three international standards, which are the pillars of BIM – ISO 16739, ISO 12006-3 and ISO 29481. [22]

EN ISO 16739, or Industry Foundation Classes (IFC), is a standard used to describe, share and exchange information. IFC is a neutral and non - proprietary format, which is used by different software vendors like Autodesk, Graphisoft, etc., and it ensures interoperability between the different tools. This basically means that no matter what software tools the architects use or the engineers, they will be able to collaborate and exchange data seamlessly. Interoperability is important as it leads to efficiency - less time to convert or transfer data, minimal loss of information etc. [23]

EN ISO 12006-3, IFD, "specifies a language-independent information model that can be used for the development of dictionaries used to store or provide information related to construction works". [24] EN ISO 29481, Information Delivery Manual (IDM), is split into two parts – EN ISO 29481-1 sets out the methodology and format, and EN ISO 29481-2 describes the interaction framework. In short, IDM describe processes, which help users to get the full benefit of BIM. The standard sets out rules for processes related to the interaction between different roles, information transactions between parties and exchange requirements. [25]

All three standards described above are seen as the three pillars of BIM. Their main purpose is to ensure a neutral and interoperable way of transferring information between different tools, and also, set out some common rules for processes. And yet, CEN/TC 442 realized that there is something missing - a standard way of making information digital.

The two standards, which were in addition developed, are EN ISO 23386 (published) and prEN ISO 23387 (soon to be published). The aim of these two is to set out some rules

on how experts create digital data within data dictionaries (based on ISO 12006-3) and how they ensure that strict processes are followed in order to have good quality data.

EN ISO 23386 and prEN 23387 describes a methodology for experts in different domains in the construction industry to describe construction products and materials properties (characteristics) for digital use. What is meant by describing properties is for experts to identify characteristics of products that express their technical, environmental and other performance like, for example, thermal transmittance, fire resistance, global warming potential, formaldehyde emissions etc. Such characteristics can be found in product standards, building regulations etc. and are the basis for any decision related to energy efficiency, indoor air quality, reduction of carbon emissions etc. [26]

Simply said, all these standards aim at standardising a common digital language for construction products and materials information. Such an approach might allow for more precise predictions in the design phase, unambiguous communication between actors and an automatic purchasing of products using 3D models and integrated digital data based on certain requirement. All this perfectly fit to the need for better information management for sustainability assessment and certification processes.

OPTIMISING SUSTAINABILITY ASSESSMENT PROCESSES THROUGHOUT THE USE OF DIGITAL DATA

The information required for a large set of sustainability certification schemes' criteria is products' technical and environmental information. A lot of analysis and simulations are performed based on such information like energy analysis, life cycle assessment, indoor air quality analysis, daylight simulations, etc. In the context of BREEAM, for instance, all these analysis and simulations can be referred to criteria like Ene 01 Reduction of energy use and carbon emissions, Hea 02 Indoor air quality, Mat 01 Life cycle impacts, etc.

Such information about products can be normally found in documents like technical data sheets, declarations of performance, environmental product declarations, safety data sheets, etc., which all rely on different standards and regulations. For example, the information that can be found in an environmental product declaration (EPD) is based on ISO 21930 and/or EN 15804 – core product category rules for EPDs. Another example is the information found in a declaration of performance based on EN 771-1 – a harmonised European standard for the performance of bricks.

Therefore, the authors propose digitizing this information following the previously described standards for digital data facilitated by CEN/TC 442 which will promote a data-driven process for sustainability assessment and certification. This proposal aims at providing actors with a way to easily extract from or input data directly in BIM models in order to forecast the sustainability rating in accordance to different schemes in every stage of a project. This can be only achieved by the use of digital data (EN ISO 23386 and prEN ISO 23387) stored in data dictionaries (EN ISO 12006-3) and exchanged through a neutral format – IFC (EN ISO 16739).

Specifically, for the exchange of data through IFC, there is a need for the definition of standardised MVDs (Model View Definitions). A MVD is a subset of the IFC schema and provides a "snapshot" of the required information for a specific purpose. [27] The different actors in a project have different roles, responsibilities and needs in terms of

information. They all have to collaborate with each other, exchanging information, in order to do their tasks, therefore, they need a way to define such subsets of information, or MVDs. A good example for an MVD is when an architect provides a BREEAM assessor with an information about products and materials being used in the project and their technical and environmental performance project requirements. Based on these requirements, the BREEAM assessor should advise on the best alternative that would ensure the project earning credits for the goal rating level. [28]

The general workflow to achieve such an optimisation of sustainability assessment and certification processes by the use of digital data is as follows:

1) Identify all input and output data as required in the different certification schemes and their criteria
2) Model input and output data in accordance with EN 23386, prEN ISO 23387 and EN ISO 12006-3
3) Connect the modelled data with IFC schema and definitions
4) Create Model View Definitions

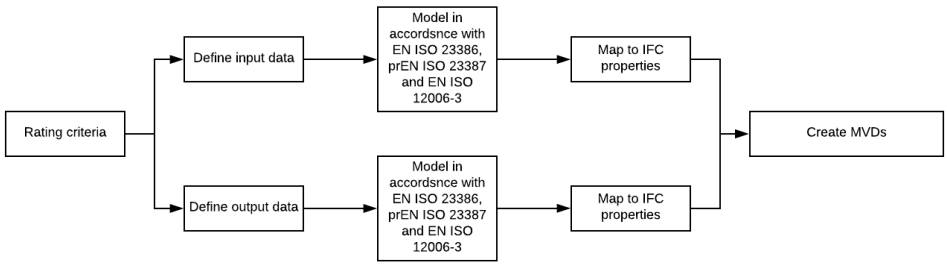

Fig. 4 Proposed overall workflow

Once the MVDs are created, any actor can start using them in BIM models. The aim is to provide all actors with a standardised data set which will be used to exchange information needed for achieving sustainability rating credits. The role of manufacturers and them providing products information is crucial, i.e. they should be also using these MVDs to provide digital data about their products and such products information will be used for the different analysis and simulations which will secure certain credits, as explained earlier. The use of manufacturers' data will ensure more accurate predictions which will secure the desired result in credits. The use of such data will also, for example, reduce the risk of discrepancies between interim and final BREEAM certificates.

Examples with the criteria set in BREEAM Ene 01

The authors chose this category as it has some of the largest weightings in BREEAM, respectively 17%.

1) The first step is to identify the input parameters. In this case these are the technical and environmental characteristics of construction products and materials. The credible sources for defining such are different European and International standards, directives, regulations etc. which describe the characteristics of products and their test

methods. For example, the characteristics relevant for windows can be found in the European harmonized standard EN 14351-1. This standard clearly defines what "thermal transmittance" means and how such is tested for windows. To illustrate the workflow better, the authors have chosen a few technical and environmental characteristics for a brick. All these characteristics are also referenced to corresponding analysis and simulations which should be performed in order to predict certain project performance and achieve rating credits (Table 1).

Table 1 Input parameters

Brick's characteristics	Examples of manufacturers' data	Analysis/simulations	Source document
Density	600 kg/m³	Energy analysis	EN 771-1
Thermal conductivity	0,108 W/mK	Energy analysis	EN 771-1
Weight	14.5 kg	Energy analysis	EN 771-1
Global warming potential	5.37E+1 kg CO_2 equiv.	Life cycle assessment	EN 15804
Ozone depletion potential	3.07E-9 kg CFC11 equiv.	Life cycle assessment	EN 15804

As a next step, the output parameters shall be identified in the same way (Table 2).

Table 2 Output paramaters

Output parameters	Unit	BREEAM category
Energy performance ratio	-	BREEAM Ene 01
Heating and cooling energy demand	MJ/m²	BREEAM Ene 01
Primary energy consumption	kWh/m²	BREEAM Ene 01
Total resulting CO_2 emissions	kg CO_2 /m²	BREEAM Ene 01

2) Once the input and output parameters have been identified, they should be modelled following the principles of EN ISO 23386, prEN ISO 23387 and EN ISO 12006-3. In order to do this, users shall have access to a tool that creates standardised information in data dictionaries, e.g. Cobuilder Define. [29] What such tools require users to do is to define the names of the parameters, their definition, source document and some other metadata attributes as recommended in EN ISO 23386. Some of the attributes are automatically generated from the tool, e.g. unique identifiers (GUID), date of creation etc. For more information, please see the video - https://www.youtube.com/watch?v=APkPHTZ5h4M.

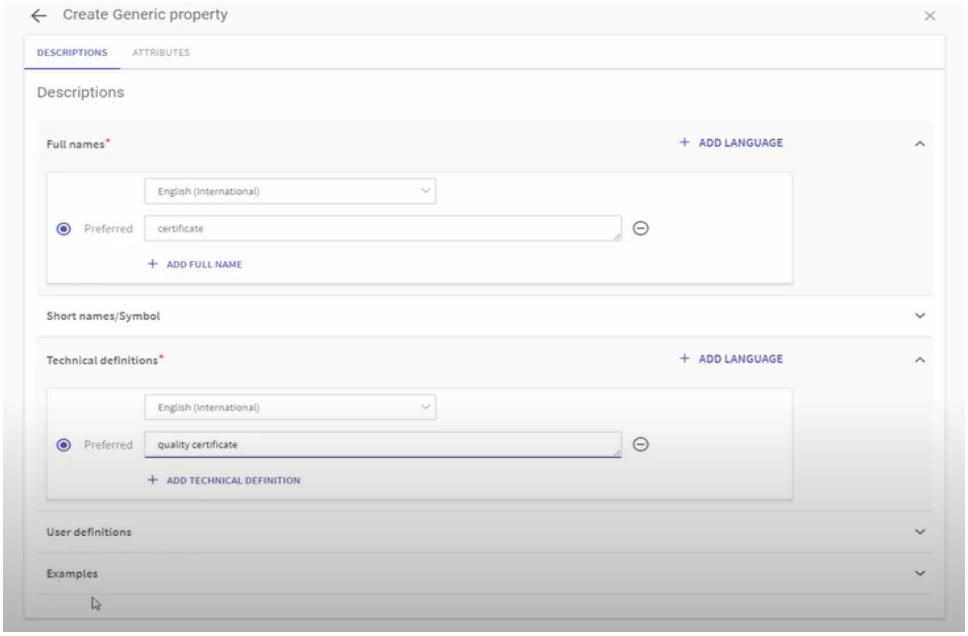

Fig. 5 Modelling digital data in a data dictionary

3) As a third step, all parameters should be either mapped to existing IFC parameters or shall be created if they do not exist in the standard IFC schema. The IFC parameters that already exist are called "predefined parameters" and they are automatically generated and used by authoring tools like Revit, ArchiCAD etc. In addition to these predefined ones, user can also create their own custom parameters. Such are needed also for the purpose of the examples described in this paper. The authors propose two different ways for creating such custom properties – 1) use an authoring tool that allows for the creation of custom IFC parameters, e.g. ArchiCAD and 2) use IfcDoc tool. [30]

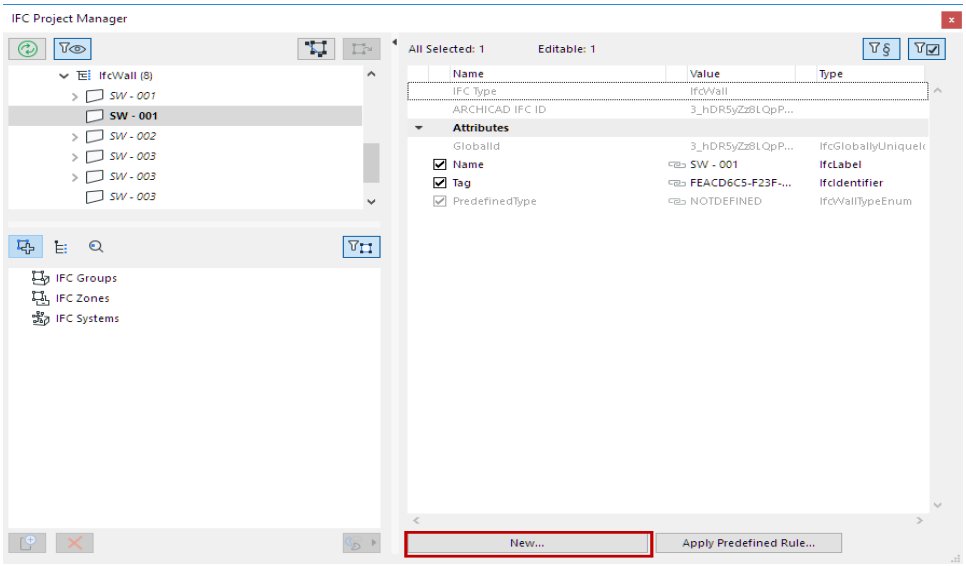

Fig. 6 Creating new IFC parameters in ArchiCAD

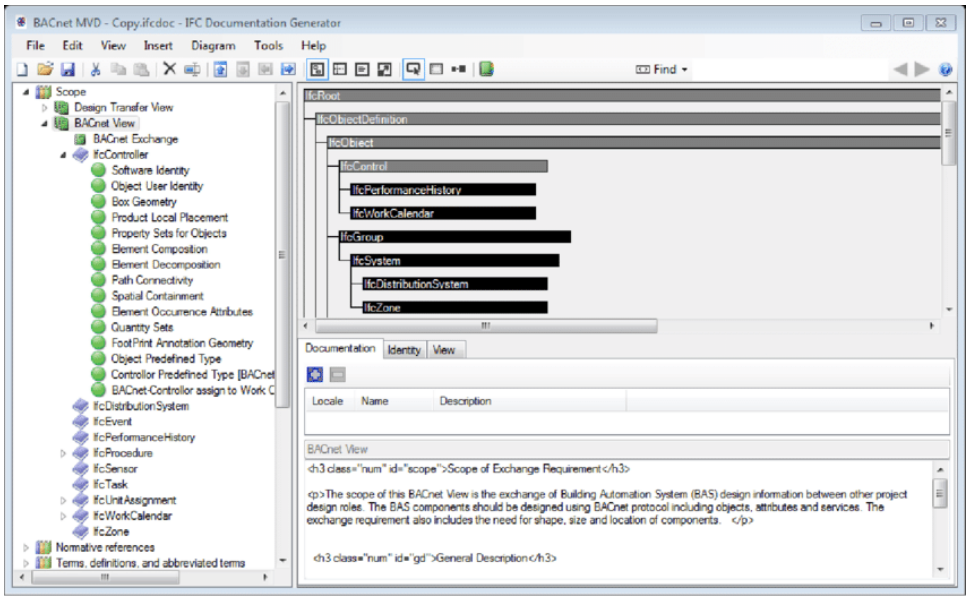

Fig. 7 Creating new IFC parameters in IfcDoc tool

Table 3 Mapping to existing IFC parameters

Parameters	IFC parameters mapping	IFC property set source	IFC object
Density	Mass density	Pset_MaterialCommon	IfcMaterial
Thermal conductivity	Thermal conductivity	Pset_MaterialThermal	IfcMaterial
Weight	Density	Pset_MaterialCommon	IfcMaterial
Global warming potential	Climate Change Per Unit	Pset_EnvironmentalImpactIndicators	IfcMaterial
Ozone depletion potential	Stratospheric Ozone Layer Destruction Per Unit	Pset_EnvironmentalImpactIndicators	IfcMaterial

4) And at last, as a fourth step, MVDs shall be created. There are already existing MVDs which can be found on buildingSMART website, but for the purposes of this example new ones shall be created, again, using an authoring tool or IfcDoc tool.

IFC SCHEMA	MVD	PUBLICATION STATUS
IFC 2X3	Coordination View	published
IFC 2X3	Space Boundary Addon View	published
IFC 2X3	Structural Analysis View	published
IFC 4	Reference View	published
IFC 4	Design Transfer View	published
IFC 4	Quantity Takeoff View	NOT published
IFC 4	Energy Analysis View	NOT published
IFC 4	Product Library View	NOT published
IFC 4	Construction Operations Building Information Exchange	NOT published

Fig. 8 Existing MVDs

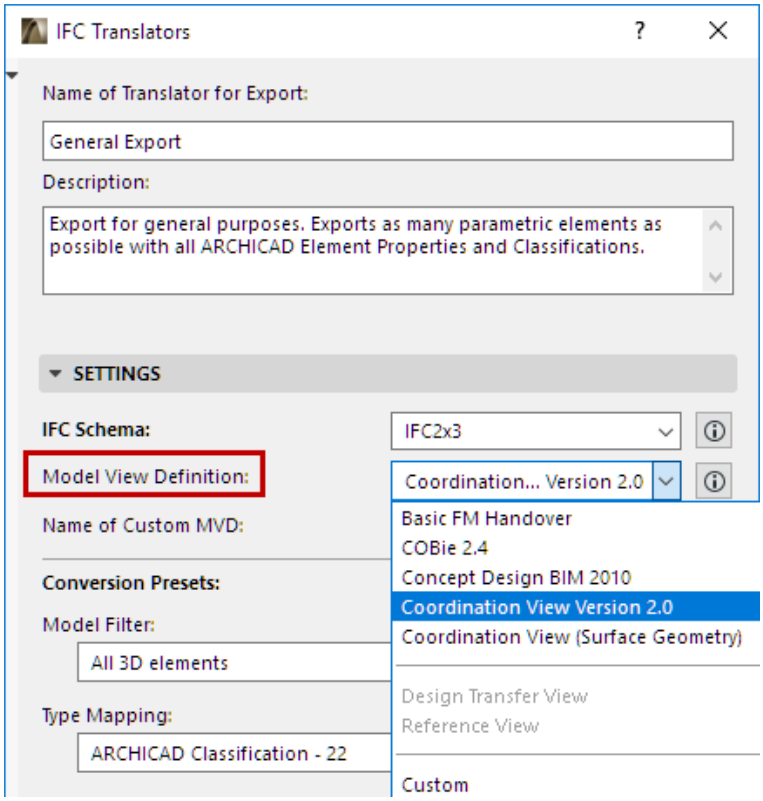

Fig. 9 Creating a new MVD

CONCLUSION

The digitization of such parameters enables the creation of rules that would allow for automatic validation against sustainability certification criteria. The propose approach will lead to the more sufficient use of information in the processes of sustainability assessment and certification by standardizing the required information and enabling a further development for automatic validation against schemes' criteria.

In addition, by standardizing information requirements following standards for enabling digital data in data dictionaries using already existing knowledge in European and International standards, directives, regulations, etc., ensures the involvement of manufacturers. Manufacturers providing information about their products will ensure more accurate predictions, better communication, less misunderstandings and will reduce risks associated with these.

However, the proposed approach in this paper needs further research and tests of the different tools given as examples in this paper. The practical application of this approach will require the involvement of highly educated BIM people which means that a research in the area of how to bring that knowledge to project actors will be needed.

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EVALUATING PRISHTINA'S URBAN DEVELOPMENT PLAN IN TERMS OF SMART CITY CHARACTERISTICS

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Abstract – *Smart city is a fairly new city concept that has been used extensively in scientific literature and international policies in the past two decades. Reflecting contemporary city developments, smart city has entered various professional discourses, and has brought enthusiasm in regards to the advanced ways of addressing present urban challenges in developed and developing world. On the other hand, it has raised skepticism as it is still considered a vague concept, with possible unknown consequences. The aim of this paper is to provide an extensive literature review of the smart city definitions and models, to be followed with an evaluation of current Prishtina's Urban Development Plan (PUDP), through six dimensions of the smart city model: smart environment, smart mobility, smart living, smart governance, smart economy and smart people. The results show that city of Prishtina rates moderately (66 %) in terms of smart city characteristics integrated in the planning documents. Considering that the current city plans will expire in 2022, the recommendations from this article can be used as a contribution for future smart(er) planning of Prishtina.*

Keywords: *smart city, smart planning, smart city model, Prishtina urban development plan.*

1. Introduction

For the first time in human history, the urban population has surpassed the rural population worldwide, as the city appears to be an ultimate choice for a place to live. Urban areas are chosen for settlements over rural areas. As of 2007, more than 50% of the global population was living in cities, and this number is expected to rise to 75% by 2050. Continent of Europe is even more urbanized, as 74% of its population now is living in the cities. Looking further to western Balkans countries, the urbanization trend is high as well; Montenegro is leading in urbanization trends where 66.48% is urban population; Albania follows with 59.8% of urban population, Northern Macedonia 57.75% of urban population, Serbia 55.94% of urban population, Bosnia 47.88% of urban population, and

there appear to be no data for Kosovo [1]. There is no information in regards to Kosovo's population UN world urbanization prospect. However, according to Agency of Statistics of Kosovo, 38% of the country's population lives in urban area [2]. We expect this percentage to be higher, as not all the municipalities had their information available, some for political reasons.

Even-though cities occupy only 2% of the world's land, they are responsible for 75% of the consumption of world's natural resources and waste production [3]. People move from rural areas to urban areas with the hope of finding better job opportunities as well as a better standard of living. City is an important node, as a focal point of culture, education, politics, finance, industry, and communications. Although cities are productive, innovative and creative nodes, they have also become centers of poverty, violence, pollution, and congestion. Despite being engines of growth, complex problems come with them. These complex problems directly threaten livability, wellbeing, and prosperity, which are also in direct conflict with the principles of sustainability [4].

Rapid urbanization adds continues pressure to the resource base and increases demands for energy and water resources, sanitation and public services, education, and healthcare services. Climate change further increases cities' vulnerabilities and puts further stress on the adaptive capacities of the poor cities in particular [5]. To resolve these present complex urban challenges, cities need new and innovative solutions. As "one size fits all" approach toward better city development is not possible, urban planners face challenges on developing strategies and policies on setting a balance between protecting environment, and promoting economic and social development. Reflecting contemporary city developments, many new categories of cities have entered various professional discourses. A comprehensive bibliometric analysis investigated how the 12 most frequent city categories are conceptualized individually and in relation to one another in the academic literature. The 12 city categories include sustainable, smart, resilient, green, digital, intelligent, information, knowledge, eco, low-carbon, livable, and ubiquitous cities. Regardless of some degree of overlap, of the 12 city categories, six were found distinctive enough to be seen as supported by a specific body of theories: the sustainable city, smart city, eco city, resilient city, knowledge city, and low carbon city [6].

Smart city category is a fairly new concept introduced in 1990s that has been used extensively in scientific literature and international policies [7]. Smart city has entered various professional discourses, and has brought enthusiasm in regards to the advanced ways of addressing present urban challenges. Although the smart city notion is often used from academicians and policy makers, this term is still fuzzy and there is no consistent definition of its meaning [8, 9, 10]. Unfortunately, there is no set definition or template for defining a smart city framework that could be used for any cities. As the term is still vague, is it often used interchangeably with term of intelligent city, information city, digital city, hybrid city, ubiquitous city and wired city, even though these terms are not identical in their meanings.

As the first part of this research aims to clarify the meaning of the smart city concept, the second part of the research challenges the existing Prishtina's urban development plan through the identified significant indicators.

Prishtina is the capital city of Kosovo, with an area of 572 km². It is located in northeast Kosovo, an eastern city that developed in the Balkan Peninsula over a long time, with remarkable steady growth during the twentieth century. However, the beginning of the twenty-first century brought in a new development era for Prishtina. It has faced massive population migration, urban destruction, and urban sprawl. In the past twenty years, its population almost doubled, and the city government failed to orient growth toward sustainable urban development. Similar to other congested cities, Prishtina now faces the challenge of pollution migration, cultural heritage degradation, financial and social differences, and environmental degradation. Due to its developing patterns, Prishtina currently does not offer wellbeing, and it lacks sufficient public transportation for the new developed parts of the city, public spaces, pedestrian-friendly sidewalks, affordable housing and social inclusion, water supply and treatment, and energy and heat supply. Prishtina is the center of cultural, economic, and political developments in country [11].

The results of this study will help the authorities to make information-based, future strategic planning decisions in regards to smart city development.

2. Methodology and Data

This paper is based on two methodological steps. The first step is the investigation of the "smart city" concept through an in-depth literature review by reviewing various smart city definitions, the pros and cons of this new concept and identifying important characteristics through which we can evaluate the selected urban plans. Despite the fact that the term is still new and the definitions are somewhat fuzzy, the theoretical investigation wraps up with the defined smart city characteristics. The second step consists of evaluation of the Prishtina's urban development plan [12] in terms of smart city characteristics. These six 'smart' characteristics - economy, people, governance, mobility, environment and living – which have been used as assessment tool for the current local urban plan have been broken down into 31 relevant factors, reflecting the most important aspects of every smart characteristic [13].

3. Theoritical Background

Rapid urbanization in combination with climate changes and other vulnerabilities have put pressure on urban planners, policy makers and scientists to come up with innovative solutions for city planning [14]. While smart city is being considered as a promising concept, the research initiatives, publications and forums regarding this concept enlightenment are increasing significantly for the past two decades. We now witness that new information and communication technologies (ICT) are changing the way we live,

work, travel, shop and play in daily bases. Our societies worldwide are experiencing an era of tremendous change and transformation.

As the challenging patterns of the city developments keeps rising, city's performance and success is measured by how wisely cities use and manage renewable and non-renewable resources such as energy, water and other resources, while keeping a high quality of life for its citizens. Cities need to alter their developing patterns, in order to become smarter in regards to existing resources use and capacities [15].

Smart city concept was first used in early 1990's and couple publications show various evidence on where was the term used for the first time. Smart city concept appeared in early 1990's, within the book entitled "Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks." This book elaborates the global vision of technology driven urban developments that are concentrated in the world cities such as Hong Kong, Singapore and London [16]. In the beginning, the focus of the smart city concept seemed to be on the significance of new (ICTs) in regards to recent infrastructures within urban areas. Other sources state that, the concept of "Smart Community" was first used in 1993 in Silicon Valley, California, as a response to this region's severe recession. [17]

Smart city, as a relatively new notion in scholarly literature and international policies, has been perceived as a progressive successor to the previous city concepts as information city, digital city, and intelligent city [6], although recent academic literature highlights that the smart city concept goes beyond the previous concepts and is contextualized in broader social and physical systems. The term smart city is not used in one general way describing a city with certain characteristics. It is rather used for various features that range from the smart city as an information technology (IT) district to a smart city in regards to education of its inhabitants. Cities are not static; there is no absolute definition of a smart city that would fit all; it has been elaborated as a process, by which cities become more livable and resilient, and able to respond more efficiently to un/expected future challenges [10].

Smart city concept is thought-out to be an effective response to today's dynamic needs, representing an important step in the social and cultural change required for the future development. Cities must be re-thought, starting from its basic premises and traditional organizational structures, as it is evident that the dulcification of urban development trends of the past will not sufficient. Thus, smart and efficient urban systems are an absolute necessity for future urban development. Development of more integrated and inclusive urban models, strategic management of natural resources, new models of mobility, better quality of life for all, are the emerging needs [18].

Smart city concept goes beyond the integration of modern ICT into the infrastructure of our cities. A city is considered smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life. A wise management of natural resources, through participatory governance is a requirement [19]. Furthermore, a smart city is a well

performing city built on the smart combination of endowments and activities of independent and partaking citizens [20].

According to recent research, there is not as much focus on technological innovations in smart city initiatives as it might seem from the theoretical conceptualizations. The integration of technology, human resources and interactive governance is key to contemporary urban development, while governance leadership is considered key for ensuring holistic sustainability [21].

Considering that the smart city concept is relatively new, its application is still limited and its consequences are considered to remain unforeseen . Furthermore, it is argued that there are disadvantages of this new concept. Extreme dependency on technology and on corporations dominating technology and related services, besides the still-unknown other social and economic implications of introducing smart technologies into city buildings are considered some of the dark sides of this concept [10].

For world corporations such as IBM, Cisco Systems, and Siemens AG, the technological component is the key component to their conceptions of smart cities. Their approach has recently been critiqued for the corporate-designed cities such as Songdo (Korea), Masdar City (UAE), or PlanIT Valley (Portugal). The planning of these new cities void the actual knowledge about how cities function and represent "empty" spaces that disregard the rich values of complexity and the mixed uses of urban spaces [22].

Furthermore, connecting social sciences with the new technologies remains challenging, as a vast portion of society still doubts that the technological evolution is able to improve life quality of citizens [23].

A city that acts future-oriented in six characteristics: smart people and smart living, a smart economy and smart mobility, a smart environment and smart governance, can be considered as a smart city. Moreover, a smart city is based on the smart combination of equipment and activities of self-determined and conscientious citizens [13, 20]. Giffinger and Gudrun consider that this city concept includes couple dimensions of smart economy (innovation spirit, entrepreneurship, economic image & trademarks, productivity, flexibility of labor market, international embeddness and ability to transform); smart people (the level of education, Affinity to lifelong learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism/open-mindedness, participation in public life); smart governance (participation in decision-making, public and social services, transparent governance and political strategies & perspectives); smart mobility (local accessibility,(inter-)national accessibility, availability of information and communication technologies infrastructure, sustainable, innovative and safe transport systems); smart environment (lack of pollution of natural conditions, pollution, environmental protection, sustainable resource management); and smart living (cultural facilities, health conditions, individual safety, housing quality, education facilities, touristic, social cohesion) [13].

In addition to the theoretical debate in the scientific field, there is evidence that smart city concept has been evolving in the practice, being recognized in European strategic

documents. European Union's ten year strategy - Europe 2020 – was launched in 2010, which aimed to prioritize smart growth (developing an economy based on knowledge and innovation), sustainable growth (promoting a more resource efficient, greener and more competitive economy) and inclusive growth (fostering a high-employment economy delivering social and territorial cohesion), and smart specialization strategy [24]. Smart specialization strategy (3S) is an innovative approach that aims to improve growth and jobs in Europe, by enabling each region to identify and develop its own competitive advantages, combining industrial, educational and innovation policies to help cities in recognizing priority areas for knowledge-based investments [19].

As there is not enough evidence in scientific literature on the implementation of the smart city concept in the" new" EU member countries [25], there is no evidence on the non EU member countries of Europe, Kosovo being one of them.

4. Analysis

A two step analysis is conducted to evaluate Prishtina Urban Development Plan (PUBD) in term of "smart city" planning. The first part of the analysis evaluates whether the term smart city is integrated in the current urban plan. The second part of this analysis is based on the previousy mentoned six 'smart' characteristics - economy, people, governance, mobility, environment and living - that are further broken down in 31 factors, used as criteria to be checked in Prishtina Urban Development Plan (PUDP 2012-2022). The goal is to understand if and how these characteristics are integrated in the structure and content of the current urban development plan of Prishtina.

The results show that the „smart city" term is integrated „lightly" in the structure and content of the plan, more precisely, the term „smart city" it is motioned seven times in the text part of the plans. „Smart development"and „smart strategies"are also integral terms in the plans.

However, it is interesting that the second part of the analysis is different from what was expected, considering the first part of the analysis. The assessments show that factors of smart city characteristics are actually integrated in the urban planning content. As the Table 1 shows, there are 33 relevant factors that reflect the most important aspects of the smart characteristics. Regarding the assessment of PUDP, the factors that are integral part of the current plans are rated with 1; in contrast, they are rated with 0 if considered to be poorly integrated or not integrated at all in the plans.

Overall, it seems that the smart city characteristics are moderately integrated in the plans, 22 out of 33 in total (66%); leading with the smart mobility that is rated maximum 4 out 4; followed by smart governance and smart environment, each rated with 3 out of 4 possible factors. Smart living follows with 5 out of 7 possible factors. Finally smart people and smart economy are rated with low scores as 4 out of 7 and 3 out of 7 respectively.

Characteristics of smart city	Possible factors	Prishtina Evaluated factors	Total Factors for PUDP
01. SMART ECONOMY	7	3	22 out of 33
02. SMART PEOPLE	7	4	
03. SMART GOVERNANCE	4	3	
04. SMART MOBILITY	4	4	
05. SMART ENVIRONMENT	4	3	
06. SMART LIVING	7	5	

Table 1. Assessment of Prishtina Urban Development Plan (PUDP 2012-2022) in terms of smart city characteristics

5. Conclusion

Based on the findings of this research, several recommadations are laid out in order for the smart city characteristics to be better integrated in local planning, as: a further definment of these characteristics in local context; a better integration of the low rated characterisics, in particular the smart economy and smart people; and finally, further future studies to be need to be carried out, showing the actual implementation of smart city characteristics, identifying the challanages of their implementation which can be used as a feedback for the future local smart planning

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APPENDIX

Table 2. A detailed assessment of PUDP		
01. SMART ECONOMY		
Innovative spirit	1	- Establishing business parks and industrial zones
Entrepreneurship	1	- Favor conditions for starting up new businesses incubators
Economic image & trademarks	0	\
Productivity	0	\
Flexibility of labor market	0	\
International embeddedness	1	- Attract capital/foreign investment
Ability to transform	0	\
3 out of 7		

02. SMART PEOPLE		.
Level of qualification	1	-Valorize the public/private institutions of higher education and research
Affinity to lifelong learning	0	\
Social and ethnic plurality	1	-Providing qualitative and all-inclusive education
Flexibility	0	\
Creativity	1	-Young and creative youth that are protagonists of the evolution of the social and economic activities
Cosmopolitanism	0	\
Participation in public life	1	-Improving involvement, participation and awareness
4 out of 7		

03. SMART GOVERNANCE		
Participation in decision-making	0	\
Public and social services	1	- sustainable, energy-efficient and affordable public transport systems; education
Transparent governance	1	-transparent roles of all stakeholders
Political strategies	1	-spatial development concepts: 7 strategies
3 out of 4		

04. SMART MOBILITY		
Local accessibility	1	- Reliable public transport lines and modernizing of the public transport vehicles; * Retain and potentiate rail links (or tram ways) with different urban polarities (airport, bus terminal, city centre)
(Inter-)national accessibility	1	-Increasing the accessibility to the international transport networks (connection with European corridors)
Availability of ICT-infrastructure	1	- Prishtina towards "smart city", creation of free zones internet zones
Sustainable, innovative and safe transport systems	1	- Creation of a complete and efficient traffic system
4 out of 4		

05. SMART ENVIRONMENT		
Attractively of natural condition	1	
Pollution	1	- Provide a wastewater treatment system for the city, waste collection, improving the delivery of electricity, improving, develop energy efficiency strategies
Environmental protection	1	- Preserve biodiversity, protect the forests, avoid urban sprawl
Sustainable resource management	0	\
3 out of 4		

06. SMART LIVING		
Cultural facilities	1	- Participate to knowledge sharing networks - Valorize historical heritage
Health conditions	1	-Providing qualitative health and social welfare amenities
Individual safety	0	\
Housing quality	0	\
Education facilities	1	-Create network of schools, adequate facilities, labs, sports hall, computer network and internet - Expansion of the network of preschool institutions and schools in rural areas
Touristic attractivity	1	-Promote archaeological tourism, eco-tourism or green tourism by exploiting nature and landscape beauties; cultural tourism, rural tourism - Objective III. Enhance cultural and tourist attractions (qualify museums, etc.);
Social cohesion	1	-Promotion of culture and sports for youth and other
5 out of 7		

Source: Author's analysis/assessments.

INFLUENCE OF THE CROSS SECTION WIDTH ON FIRE RESISTANCE OF RC BEAMS ACCORDING TO EUROCODE 2

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Abstract
A parametric analysis of two span continuous reinforced concrete beam exposed to standard ISO 834 fire curve is presented in this paper. The influence of the width of the cross section on the fire resistance of the beam exposed to fire only from three sides is analyzed.
The analysis of the reinforced concrete beam is conducted by using the Reduced Cross Section method, given in Eurocode 2-1-2. Temperature dependent mechanical and thermal properties of the constructive materials (concrete and steel) are adopted according to the recommendations given in Eurocode 2-1-2.
The analysis has shown that the width of the cross section has positive effect on the fire resistance of the analyzed RC beam. Due to the wider cross section the temperature penetration is slower. The concrete temperature in the middle of the section and the reinforcment temperature are slightly lower, consequently a higher fire resistance is achived.
Based on the results of the conducted analysis the behavior of the reinforced concrete beam exposed to fire has been defined and recommendations for increasing the fire resistance are given..

Keywords: *Continuous RC beam; Standard fire curve; Thermal analysis; Fire resistance*

1

. INTRODUCTION

The subject of this paper is the analysis of the impact of fire on continuous reinforced concrete beams as structural elements of buildings. The influence of the cross-section width of continuous reinforced concrete beams on their fire resistance is analyzed. The analysis is carried out on continuous reinforced concrete beams loaded with constant distributed loads, exposed to the fire from three sides during the time: R60, R90, R180 and R240.

The main objective of this paper is to define data on impact of analyzed parameters on the fire resistance of continuous reinforced concrete beams. When designing constructions for ambient temperature, these data should be taken as appropriate measures for ensuring greater fire resistance and better fire safety of buildings. The parametric analysis of continuous reinforced concrete beams was performed using the Method of Reduced Cross Section, according to Eurocode 2-1-2 [5]. The analyses were performed for continuous reinforced concrete beams with dimensions 30x40 cm, as well as for continuous reinforced concrete beams with dimensions 40x40 cm. The rise of temperature in the fire sector over time is defined by the standard fire ISO 834.

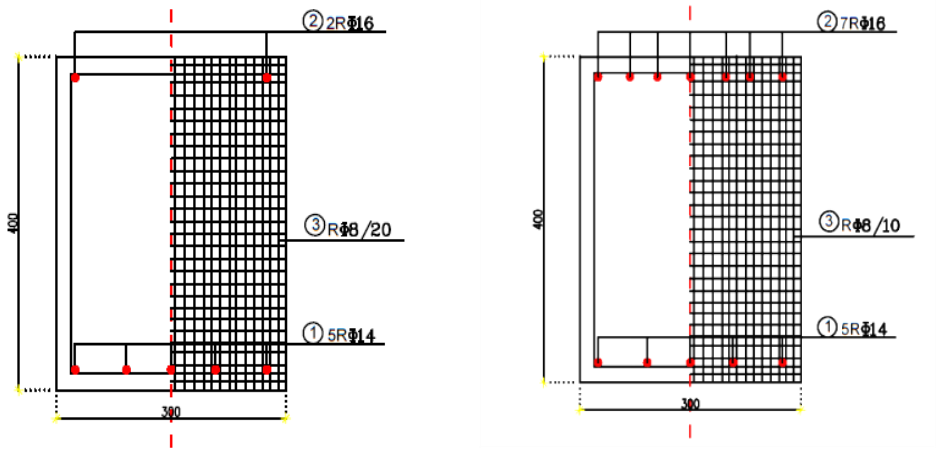
Temperature dependent mechanical and thermal properies of constructive materials (concrete and steel) have been adopted in accordance with the recommendations given in Eurocode 2-1-2, which also provides the design procedures for the approximate calculation on fire resistance of structural elements.

2. COMPARATIVE ANALYSIS ON FIRE RESISTANCE OF RC BEAMS ACCORDING TO EUROCODE 2

The influence of the cross section height on the fire resistance of continuous reinforced concrete beam with spans 2 x 5 = 10 m is analyzed. The first case is when the cross-section is 30/40 cm, while the second case is when the cross-section is 30/45 cm. In both cases, the beam is exposed to a permanent load of 23 kN / m ' and a variable load of 10 kN / m'.

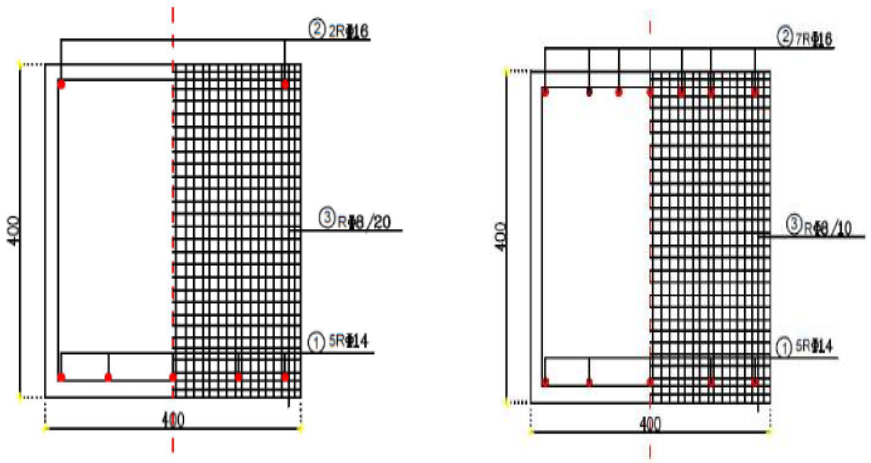
According to the calculations carried out for a 30/40 cm cross section, 5ϕ14 were adopted as the main positive reinforcement in the bottom part of the cross section, and 2ϕ16 were adopted in the top zone along the whole span, while 5ϕ6 bars were added as negative reinforcement above the internal support (Figure 2.1). According to the recommendations for providing greater fire resistance, 20%t of the main reinforcement over the supports should be extended along the span, and for this reason the longitudinal reinforcement in the top zone have been adopted to be 2ϕ16.

According to the calculations for the cross section 40/40 cm, the same number of reinforcing bars were adopted: 5ϕ14 were adopted as main reinforcement in the bottom zone, and 2ϕ16 were adopted as longitudinal reinforcement in the top zone, while 5ϕ6 were added above the support as negative reinforcement (Figure 2.2).



a) cross section along the span b) cross section above the support

Fig. 2.1: Cross section of continuous reinforced concrete beam in the middle of the span and above the support, for cross section with dimensions 30/40 cm



a) cross section in the field b) cross section above the support

Fig. 2.2: Cross section of continuous reinforced concrete beam along the span and above the support, for cross section dimensions 40/40 cm

According to the calculations carried out by using the Reduced Cross Section Method given in Eurocode 2, Part 1-2 [5], for the cross section 30x40 cm, the beam failure is reached after **128 min.**, while for the cross section 40x40 cm it is achieved after **144 min.**. It means that the fire resistance of the first beam is 128 min. and of the second one is 144 min. According to Eurocodes, both beams have fire resistance R120. For the both cross-sections, the steel temperature for the bottom reinforcement is taken from the isotherms given in [2], which refer to a certain time of fire exposure.

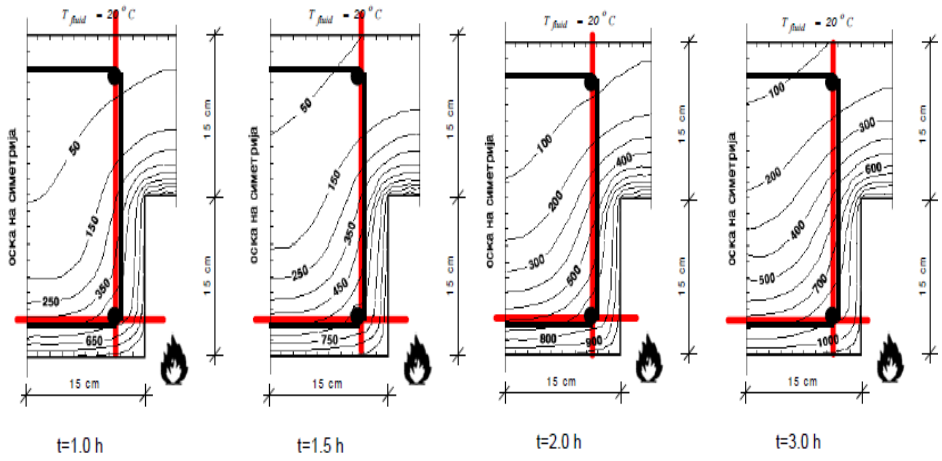


Fig. 2.3: Time development of isotherms in the cross section of RC beam with dimensions 30/40 cm, exposed to ISO834 fire curve from the bottom side

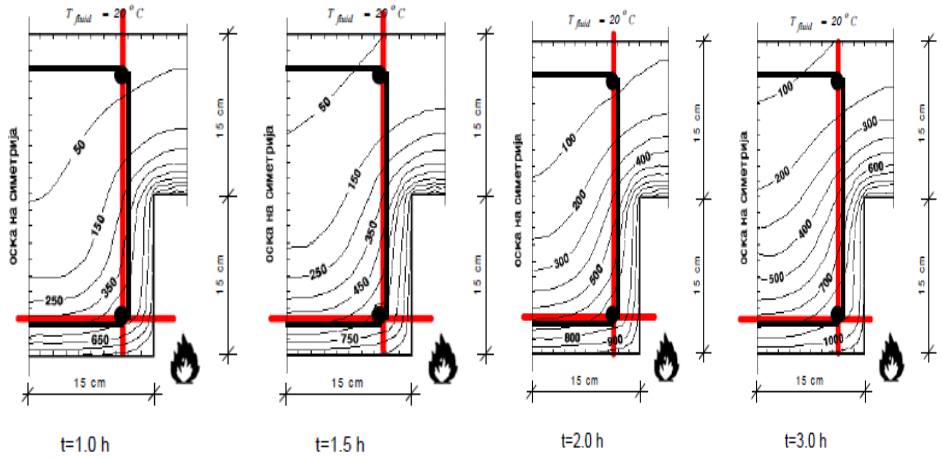


Fig. 2.4: Time development of isotherms in the cross section of RC beam with dimensions 40/40 cm, exposed to ISO 834 fire curve from the bottom side

The temperature values for the steel elements 1, 2 and 3, defined according to the isotherms for a particular time, are shown in Table 1.1. The results show that the temperature in the steel elements differ due to the greater width of the cross section 40/40 cm.

Accoding to the Reduced Cross Section Method, for given fire resistance: R60, R90, R120 and R180, the load bearing capacity for positive and negative moments is defined and compared with the bending moments coused by the permanent and variable loads for fire situation. For the beams with cross sections 30x40 cm and 40x40 cm, the time dependent bending moments at the mid span and over the internal support are defined and presented in Figure 2.5 and Figure 2.6, respectively. According to the presented results it is obvious that, as a result of high temperatures, the load bearing capacity of the RC beams is reduced in time. At the moment when the bending moment at the support, or at the mid span, will be equal to the bearing capacity of the cross section, the failure occurs.

Table 1.1: Temperature of steel elements according to isotherms given in Eurocode 2, for cross sections 30x40 cm and 40x40 cm

Eurocode 2, cross section 30/40 cm			Eurocode 2, cross section 40/40 cm		
Time (min)	Element	Temperature (°C)	Time (min)	Element	Temperature (°C)
60	1	450	60	1	350
	2	450		2	350
	3	550		3	550
90	1	550	90	1	550
	2	550		2	550
	3	700		3	650
120	1	600	120	1	550
	2	600		2	550
	3	750		3	750

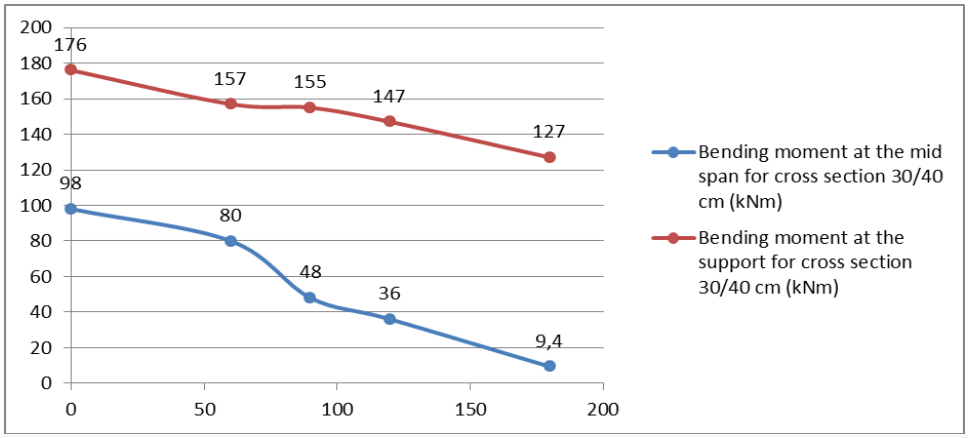


Fig. 2.5: Load bearing capacity of the RC beams with cross section 30x40 cm, for time 60, 90, 120 and 180 min

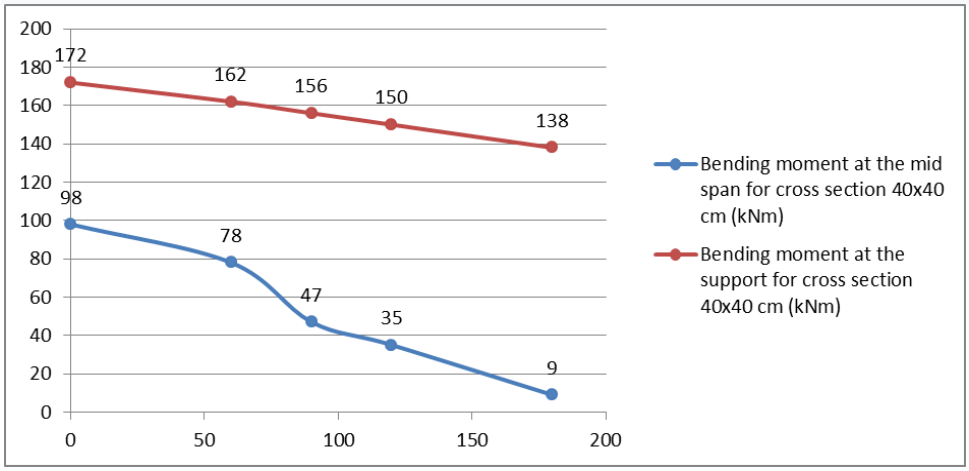


Fig. 2.6: Load bearing capacity of the RC beams with cross section 40x40 cm, for time 60, 90, 120 and 180 min**.**

The diagrams show a small difference in the results for the bearing capacity of both beams at mid span and at the support. For cross section 30/40 cm, at time t = 120 min, the bearing capacity for sagging moment in the mid span is $\mathbf{M^+ = 36\ kNm}$, and bearing capacity for hogging moment at the support is $\mathbf{M^- = 147\ kNm}$, while for the cross section 40/40 cm, the bearing capacity for sagging moment in the mid span and bearing capacity for hogging moment at the support are: $\mathbf{M^+ = 46\ kNm}$, and $\mathbf{M^- = 150\ kNm}$, respectively. The small difference in the obtained results is due to the greater width of the cross section 40/40 cm.

Table 1.2 presents the values for the load bearing capacity at the mid span and at the support for different times of fire action, for the two different cross sections.

Table 1.2: Load bearing capacity at the mid span and at the support, according to Reduced Cross Section Method given in Eurocode 2, for cross sections 30/40 cm and 40/40 cm

Eurocode 2, cross section 30/40 cm			Eurocode 2, cross section 40/40 cm		
Time (min)	Bending moment at mid span (kNm)	Bending moment at the internal support (kNm)	Time (min)	Bending moment at mid span (kNm)	Bending moment at the internal support (kNm)
60	80	157	60	87	162
90	48	155	90	53	156
120	36	147	120	46	150

The sagging moment at mid span exceeds the cross section bearing capacity after 90 minutes of fire exposure and this effect causes redistribution of the bending moment diagram and the negative momentum above the support is increased. The values for the redistributed bending moments at the support, for the beams with cross sections 30x40 cm and 40x40 cm, are shown in Figure 2.7 and Figure 2.8, respectively.

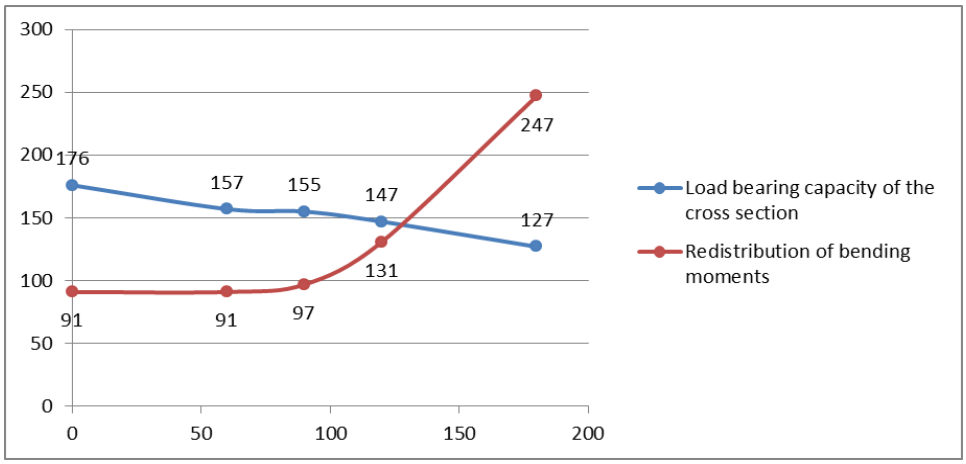


Fig. 2.7: Load bearing capacity and redistribution of the bending moments at the support for the beams with cross section 30x40 cm

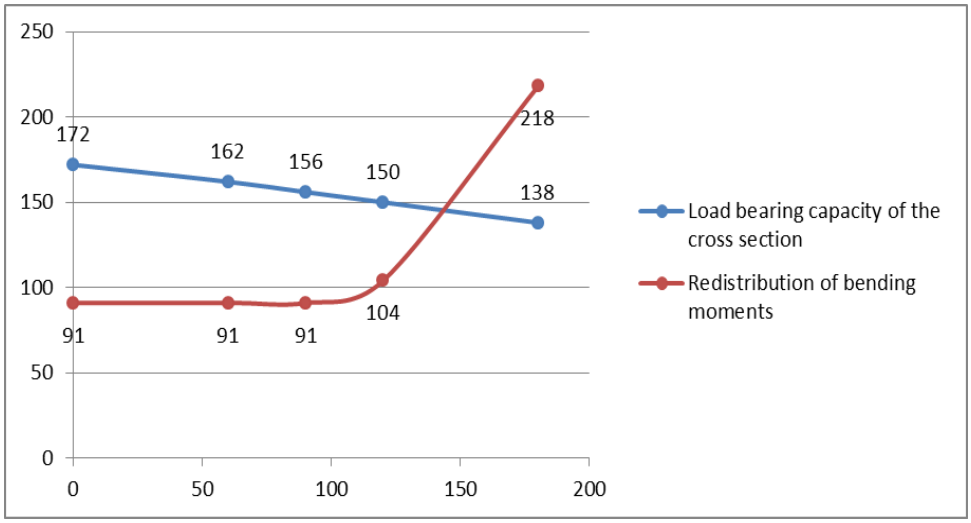


Fig. 2.8: Load bearing capacity and redistribution of the bending moments at the support for the beams with cross section 40x40 cm

According to the analyses for the beam with cross section 30/40 cm, the plastic hinge in the middle of the span occurs after 90 minutes of standard fire action, and from that moment the redistribution of bending moments starts. From the presented diagrams it can be seen that at the moment **t=120 min.** the negative moment at the support is **M^- = 131 kNm**, but after **8 min** (t = 128 min) the cross section does not accept the redistributed moment, resulting in a plastic hinge at the support and the beam failure occurs. According to Eurocode 2-1-2, the fire resistance of the beam is **R120**.
According to the analyses for the beam with cross section 40/40 cm, the plastic hinge in the middle of the span occurs after 120 minutes of standard fire action, and from that moment the redistribution of bending moments starts.The negative moment at the support after 120 min. of fire action is **M^- = 104 kNm**. A plastic hinge is formed **24 minutes** later (t = 144 min), and beam failure occurs. Although the failure of the second beam occurs later than for the first beam, according to Eurocode 2-1-2, the fire resistance of the beam is **R120**, too.

Table 1.3 shows the values of the redistributed bending moments at the support, for the two cross sections, for different time of fire exposure.

Table 1.3: Redistribution of bending moments at the support, for cross section 30x40 cm and cross section 40x40 cm

Cross section 30/40 cm		Cross section 40/40 cm	
Time (min)	Redistributed moment at the support (kNm)	Time (min)	Redistributed moment at the support (kNm)
0	91	0	91
60	91	60	91
90	97	90	91
120	131	120	104

CONCLUSIONS AND RECOMMENDATIONS

Fire resistance of continuous reinforced concrete beams, depends on: geometrical characteristics of the beams, temperature dependent mechanical and thermal properties of the materials, concrete cover thickness, steel ratio and fire scenario. Dimensions of the cross sections play an important role in determining the fire resistance of the beams.

Two types of continuous reinforced concrete beams, with cross-section dimensions 30/40 cm and 40/40 cm, and permanent load "q", are analysed and the fire resistance is defined. The Reduced Cross Section Method, given in EN1992-1-2 is used, and the results are compared.

The analyses showed that the width of the cross section of the beam has a positive effect on it’s fire resistance. In case of wider beam the fire resistance is little higher due to the slower temperature penetration into the beam cross section. In case of fire exposed beam from three sides, the height of the beam is expected to have much better effect. Tis problem will be investigated in future.

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CONCEPTS AND FEATURES OF SEISMIC ISOLATION

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Abstract. *In recent years seismic isolation technologies in Armenia were extensively applied in construction of multi-story residential, medical, hotel, airport, and business center complexes with parking floors and with floors envisaged for offices, shopping centers, fitness clubs, etc. To date there are 55 seismic isolated buildings in the country newly constructed or retrofitted by base or roof isolation systems. Of this number of buildings 48 were erected thanks to the works of the author and in nowadays Armenia is well known as a country where seismic (base and roof) isolation systems are widely implemented in civil construction. The number of seismically isolated buildings per capita in Armenia is one of the highest in the world. Several remarkable projects on construction of new base isolated buildings are described to demonstrate the experience accumulated in Armenia. Based on the gained experience further developments take place and unique base isolation structural concepts and technologies created by the author are applied more and more in civil construction. Exceptional features of the seismic isolation systems give the opportunity to apply them to steel, stone, reinforced masonry, reinforced concrete (R/C) frame, and braced-frame buildings with the number of stories from 1 to 20. In this paper base isolation design and analysis by the Armenian Seismic Code for the 7-story apartment building is described. This will be a first application of base isolation technology to a building the bearing system of which consists of R/C monolithic load-bearing walls and building has an asymmetric plan. It is stated that suggested seismic isolation strategy will reduce the cost of construction of the given building on about 35% in comparison with the cost of conventional construction. Obtained results indicate the high effectiveness of the proposed structural concept of isolation system. Input acceleration of 0.4g-0.5g at the foundation bed get damped about 2.5-3.0 times in the superstructures. Almost uniform distribution of the vertical loads (not exceeding 1500 kN) upon the rubber bearings could be easily achieved. In seismic isolated buildings the approach suggested by the author on installation of the clusters of small rubber bearings instead of a single large bearing was used. Comparative analyses have shown that suggested seismic isolation strategies are reducing the consumption of concrete by about 2 times and steel – 2.7 times. Also, reduction of the strength of the concrete on one grade takes place bringing to decreasing of the consumption of cement. Therefore, the cost of construction of new seismic isolated buildings is decreasing on about 35-40% in comparison with the cost of conventional construction. This magnitude of the cost reduction includes the cost of manufacturing, testing, and installation of SILRSBs.*

Keywords: *seismic (base) isolation 1, extensive experience 2, structural concept 3, monolithic R/C walls 4, asymmetric plan 5, seismic code analysis 6*

1. INTRODUCTION

Base isolation of multistory buildings in Armenia is developing mainly through the projects financed by private companies. The original and innovative structural concepts were developed and implemented in construction of new buildings during the last 20 years. All the mentioned buildings (Table 1) were analyzed using the provisions of the Armenian Seismic Code, as well as using different time histories.

In Table 1 the buildings from "c" to "l" have the structural system with R/C bearing frames and shear walls and were constructed in Yerevan. The number of seismically isolated buildings per capita in Armenia is one of the highest in the world – second after Japan. In (Martelli A., Forni M. & Clemente, 2012) it is stated that: "Armenia remains second, at the worldwide level, for the number of applications of such devices per number of residents, in spite of the fact that it is still a developing country". Together with that SILRSBs different by their shape and dimensions, as well as by damping (low, medium, and high) were designed and more than 5000 SILRSBs were manufactured in the country, tested locally, and applied in construction. The seismic isolation plane in all the mentioned buildings is designed above two or three parking floors, although there is a case (see Table 1f) where there are four floors below the isolation plane, of which two floors are underground and two floors are above ground.

The soil conditions in all cases are good and the soils here are of category II with the predominant period of vibrations of not more than 0.6 sec. Dynamic analyses were carried out by SAP 2000. The results of the analyses of some of these buildings based on the Code were presented and discussed earlier (Melkumyan, 2005, 2013). For the time history non-linear earthquake response analysis, a group of accelerograms was used including synthesized accelerograms. They were chosen so that the predominant periods of the Fourier spectra do not exceed 0.5-0.6 sec. Carried out analyses brought to conclusions that the total shear forces on the level of isolation system, the maximum displacements of the isolators, and the maximum story drifts of the superstructure calculated based on the Code provisions are differing from the same values calculated by the time histories in about 1.75 times in average (Melkumyan, 2009).

This means that some further measures should be taken in order to more realistically reflect characteristics of seismic isolated buildings in the design models during the calculations based on the Code. In other words, further improvement of the Code provisions is needed regarding the reduction factors K_1 for seismic isolation systems, as well as for the dynamic coefficient $\beta(T)$. Anyway, comparative analyses carried out for the mentioned complexes for cases with and without application of seismic isolation clearly show the high efficiency of seismic isolation. They prove once again that if properly designed seismic isolation brings to rational structural solutions of high reliability.

Table 1 Views of some newly constructed base isolated buildings in Armenia with seismic isolation systems located at different levels

a.	b.	c.
		
d.	e.	f.
		
g.	h.	i.
		
j.	k.	l.
		

a - 4-story apartment building with reinforced masonry bearing walls in Huntsman Village of Gyumri city (Melkumyan, 2011), b - 3-story clinic building in Stepanakert (Melkumyan, 2004), c - 6-story hotel/commercial center building (Melkumyan, 2011), d - 11-story building of the multifunctional residential complex “Cascade” (Melkumyan, 2002), e - 16- and 10-story buildings of the multifunctional residential complex “Our Yard” (Melkumyan, Gevorgyan & Hovhannisyan, 2005), f - 16- and 14-story buildings of the multifunctional residential complex “Arami” (Melkumyan, 2006), g - 18-story buildings of the multifunctional residential complex “Northern Ray” (Melkumyan & Gevorgyan, 2010), h - 16- and 13-story buildings of the multifunctional residential complex “Dzorap” (Melkumyan, 2011), i - 20-story business center “Elite Plaza” (Melkumyan & Gevorgyan 2011), j - 17-story building of the multifunctional residential complex “Baghramian” (Melkumyan & Gevorgyan, 2008), k - 17-story building of the multifunctional residential complex “Avan” (Melkumyan, 2014), l - 15-story building of the multifunctional residential complex “Sevak” (Melkumyan, 2014).

2. STRUCTURAL CONCEPT OF THE 7-STORY BASE ISOLATED APARTMENT BUILDING "STEPANAKERT-SECTIONS-4-5"

One of the recent projects financed by the government of Artsakh is the analysis and design of the residential complex in the city of Stepanakert consisting of six base isolated buildings. Construction of this complex is planned to start in 2020 and design of one of the buildings in this neighborhood (Fig. 1) named "Stepanakert-Sections-4-5" was accomplished in 2019. Structural concept of this 7-story building with R/C monolithic load-bearing walls and asymmetric plan is presented below.

Fig. 1 Design view of the residential complex consisting of 9- and 7- story base isolated buildings to be constructed in the city of Stepanakert in 2020

Architectural design of this complex was carried out by the "Maxim Atayants' Architectural Studio" LLC based in Saint-Petersburg. Bearing structure of the building under consideration is different than of the buildings briefly described above. For the first time the base isolation technology will be applied to a building the bearing system of which consists of R/C monolithic load-bearing walls. The considered building has strip foundations with the width and height of footstep equal to 1200 mm and 300 mm, respectively. The width of main strip and the total height of strip foundations are equal to 800 mm and 1000 mm, respectively. Seismic isolation interface is designed within the basement floor. Structures below the isolation plane are designed using strong and rigid R/C structural elements, namely, lower pedestals and shear walls. The cross-sections of lower pedestals envisaged under the SILRSBs are different and designed to accommodate one, two or three isolators (Fig. 2). Generally, the lower pedestals are connected to each other by the 200 mm thick shear walls, although, some of them are designed as the separate columns.

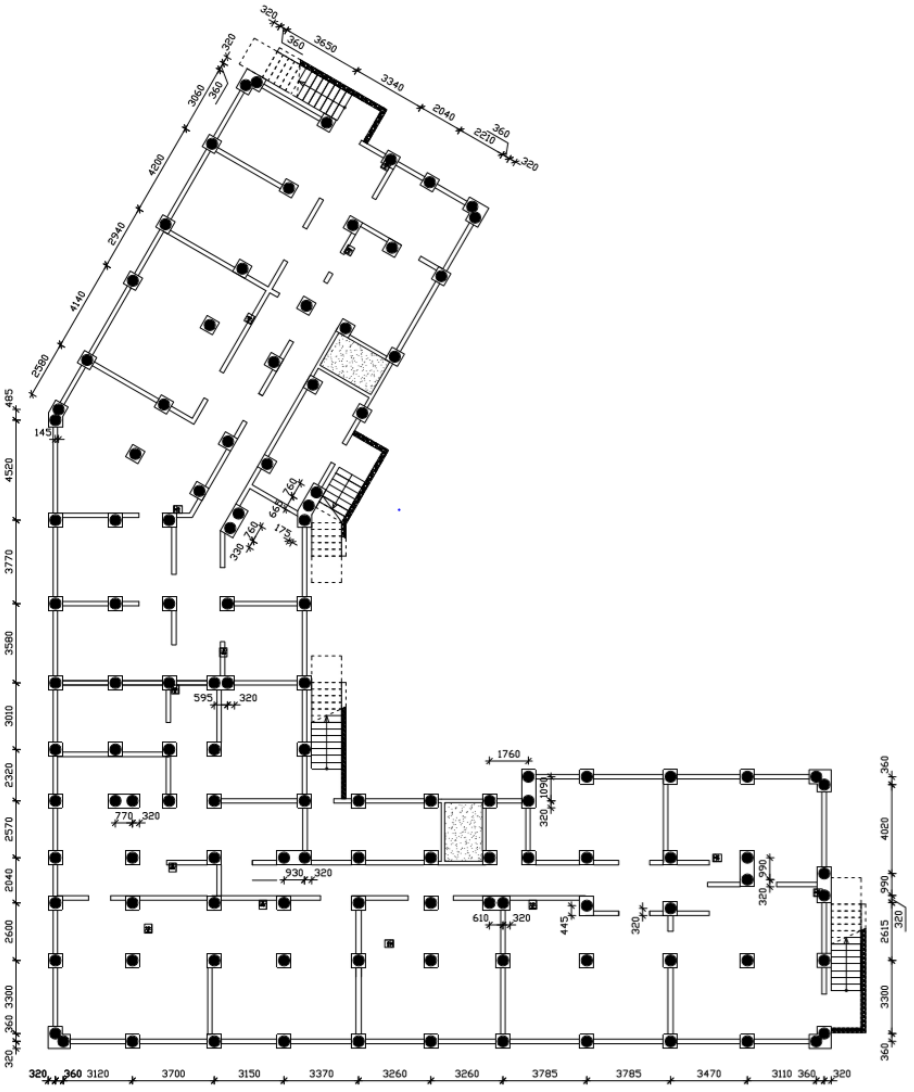


Fig. 2 Plan of location of SILRSBs on the lower pedestals in the basement of the 7-story apartment building "Stepanakert-Sections-4-5" with R/C monolithic load-bearing walls

There are upper beams designed above the seismic isolators with the cross-section equal to 640×780(h) mm. These beams are unified by 120 mm thick R/C slabs. The accepted structural solution allowed obtaining a rigid system below the isolation plane, which provides a good basis for effective and reliable behavior of isolators during the seismic impacts. Of course, the superstructure (the part of building above the isolation plane, which consisted of 7 residential floors) should also have substantial rigidity for the

same purpose. This was achieved by designing the walls in the form of 160 mm and 200 mm thick R/C monolithic load-bearing walls in mutual perpendicular directions (Fig. 3).

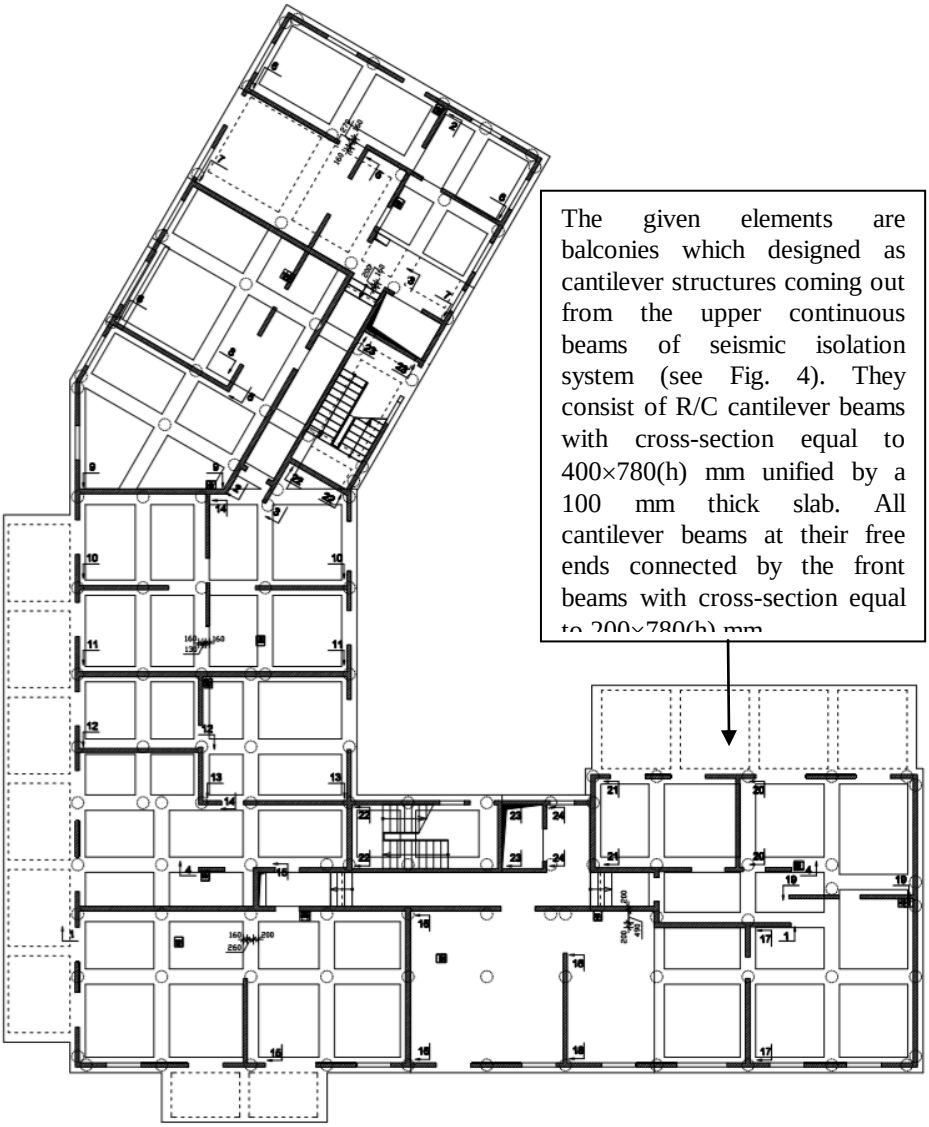


Fig. 3 Plan of location of the first floor's R/C monolithic load-bearing walls on the upper beams of seismic isolation system of the 7-story apartment building "Stepanakert-Sections-4-5"

The thickness of R/C slabs for all floors was set at 120 mm and these slabs are unifying the floor beams with the cross-section equal to 600×250(h) mm. The drawing provided in Fig.

4 presents, as an example, the vertical elevation of the building's seismic isolation system in one of longitudinal directions.

Fig. 3 shows that in the middle part of the plan the upper beams are absent and the slab here was designed thicker (150 mm) on the level just above the SILRSBs. This was dictated by architectural solution requiring creating here the main entrance to the building (see also Fig. 4, mark 766.27).

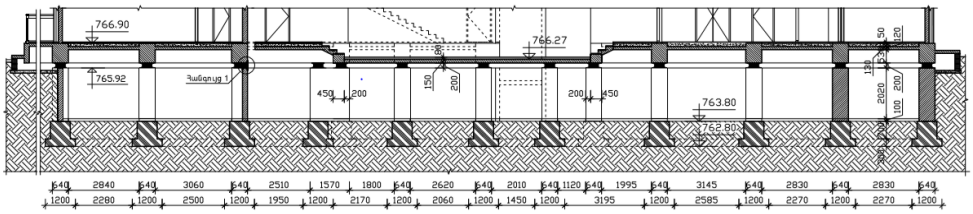


Fig. 4 Vertical elevation of the building's seismic isolation system in one of longitudinal directions of the 7-story apartment building "Stepanakert-Sections-4-5" with R/C monolithic load-bearing walls

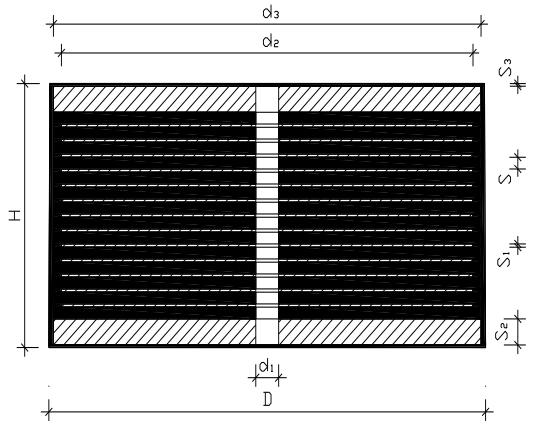
From the latter it is easy to notice that the level of the seismic isolation system in the basement of this building is lower comparing to the outside ground level. That is why a gap is envisaged around the perimeter of the building. To create the possibility for free horizontal displacement of seismic isolation system, the works are performed in a specific sequence. First, earthworks are implemented and according to the design, trenches are dug along the outer perimeter of the building. Afterwards, around the basement retaining walls are built, which are covered by cantilever slabs coming out from the upper continuous beams to protect the formed gap from precipitations and avoid possible accumulation of trash. However, the main purpose of this gap is to ensure unhindered movement of the superstructure, as well as effective action of the seismic isolation system and accommodation of its horizontal displacement during any seismic impact.

In the considered building the approach suggested earlier (Melkumyan & Hovhannisyan, 2006, Melkumyan, 2007, 2009) on installation of the cluster of small rubber bearings instead of a single large bearing was used. Figure 2 shows that different numbers of SILRSBs are installed at different locations of the seismic isolation system. However, all of them are of the same size and characteristics given in Section 3. They are made from neoprene and were designed and tested locally (Melkumyan 2001, Melkumyan & Hakobyan, 2005). The advantages of the approach on installation of the clusters of small rubber bearings instead of a single large bearings are the following: increased seismic stability of the building; more uniform distribution of the vertical dead and life loads as well as additional vertical seismic loads on the rubber bearings; small bearings can be installed by hand without using any mechanisms; easy replacement of small bearings, if necessary, without using any expensive equipment; easy casting of concrete under the steel plates with anchors and recess rings of small diameter for installation of bearings; neutralization of rotation of buildings by manipulation of the number and location of bearings in the seismic isolation plane, etc. (Foti & Mongelli, 2011, Melkumyan, 2011). One more advantage was pointed out by Prof. Kelly during the 11th World Conference on

Seismic Isolation in Guangzhou, China. Positively evaluating the suggested approach he mentioned that in the course of decades the stiffness of neoprene bearings may increase, and in order to keep the initial dynamic properties of the isolated buildings the needed number of rubber bearings can be dismantled from the relevant clusters. Thus, thanks to the suggested approach, more rational solution can be achieved, which is increasing the effectiveness of isolation system in general.

3. Parameters of the Used SILRSBs and Analysis of the Base Isolated 7-Story Apartment Building with Monolithic Load-Bearing Walls

From the above given information, it follows that seismic isolation system of the considered building consists of lower pedestals connected by shear walls, of SILRSBs and the upper beams unified by the floor slab. Total 119 SILRSBs were used with aggregate horizontal stiffness equal to 0.81×119=96.39 kN/mm. These are manufactured in Armenia according to the Republic of Armenia Standard HST 261-2007 with the dimensions and physical/mechanical parameters given in Fig. 5.



External diameter of the bearing (D): (380 ± 2.0) mm; Internal diameter of the bearing's central hole (d1): (19 ± 1.0) mm; Height of the bearing (H): (202.5 ± 2.5) mm;
Thickness of the rubber layers (S): (9 ± 0.1) mm; Thickness of the steel shim plates (S1): (2.5 ± 0.1) mm;
Diameter of the steel shim plates (d2): (360 ± 0.5) mm;
External diameter of the upper and lower flanges (d3): (376 ± 0.5) mm;
Thickness of the upper and lower flanges (S2): (20 ± 0.2) mm;
Thickness of the upper and lower flanges' protective layer (S3): (2 ± 0.1) mm;
Mass of the bearing: (77.5 ± 2.5) kg;
The bearing must withstand a maximum (design) permissible vertical loading of 1500 kN;
Shear modulus of the bearing's rubber must be (0.97 ± 0.15) MPa;
Vertical stiffness of the bearing: no less than 300 kN/mm;
Horizontal stiffness of the bearing: (0.81± 0.1) mm;
The bearing must withstand a maximum (design) permissible horizontal displacement of 280 mm, without causing cracks greater than 3 mm deep and 6 cm long;
Shore A hardness of the bearing: 70 ± 5 points; Damping coefficient of the bearing: 13-15%.

Fig. 5 Dimensions and physical/mechanical parameters of the seismic isolation

laminated rubber-steel bearing

Analysis of the seismic isolation system and the whole structure was performed in accordance with the Armenian Seismic Code RABC II-6.02-2006 assuming the following parameters:

- Seismic zone 3 and soil category II;
- Soil conditions coefficient is K_0=1.0 and the site prevailing period of vibrations $0.3 \leq T0 \leq 0.6$ sec;
- Permissible damage coefficient for determining displacements – K_1=0.8;
- Permissible damage coefficient for analysis of seismic isolation system and reinforced concrete structures below it – K_{1z}=0.8;
- Permissible damage coefficient for analysis of the superstructure – K_1=0.4;
- Coefficient of seismicity – A=0.4.

Armenian Seismic Code requires that any base isolated building should be analyzed twice: first, by applying K_1=0.8 and the obtained results will serve as a basis to design the isolation system and structures below it, and then the second analysis should be carried out by applying K_1=0.4 and the derived results will serve as a basis to design the superstructure, to check the values of the inter-story drifts, as well as receiving the values of floors' accelerations, inertial forces, etc. It is also assumed that vibration period (T) of the base isolated building should be around 2 sec. According to the RABC II-6.02-2006 horizontal displacement of the base isolation system must be calculated by the formulas (6) and (32) of the Code:

$$D= K_1 \times (T/2\pi)^2 \times A \times K_0 \times [\beta(T)/B(n)] \times K_{1z},$$

where dynamic coefficient β (T) depends on soil category and determined by the formulas given in the Code. In this case β (T) =0.95. B(n) depends on the damping of isolation system and for the value of 15% Code suggests this coefficient equal to 1.56. Thus:

$$D=0.8 \times (2/6.28)^2 \times 400 \times (0.95/1.56) \times 0.8=15.36 \text{ cm.}$$

Considering that the building has asymmetric plan Code requires increasing the obtained value of horizontal displacement by 10%. Therefore, the total displacement will be equal to:

$$D_{total}=1.1 \times 15.36=16.9 \text{ cm.}$$

This value of horizontal displacement is 1.66 times smaller than the maximum permissible displacement suggested by the Standard HST 261-2007 (28 cm), which means that high reliability of the designed seismic isolation system will be provided. According to the RABC II-6.02-2006 total seismic force on the top of isolation system (base of superstructure) must be calculated by the formula (35) of the Code:

$$S=K_{eff} \times D_{total}=96.39 \times 169=16290 \text{ kN.}$$

To calculate the vibration period of the base isolated 7-story building with monolithic load-bearing walls the masses of its floors were computed: the mass of the first floor is

equal to 1215 t, the masses of 2÷7 floors are equal to each other and equal to 1008 t, and the mass of the 7^{th} floor was calculated together with the mass of the attic floor and was equal to 2250 t. Thus, the total mass M of the building is equal to 9513 t. According to the RABC II-6.02-2006 vibration period for the base isolated 7-story building with monolithic load-bearing walls is determined by the formula (31) of the Code using the values of the total mass of this building (superstructure) and effective stiffness of isolation system:

$$T=2\pi\times\sqrt{Q/(K_{eff}\times g)}=6.28\times\sqrt{9513/96390}=1.97 \text{ sec.}$$

This value differs from the initially assumed period of only 1.5%. Using the obtained values, it is possible to calculate the magnitude of acceleration just above the seismic isolation interface:

$$a=S/M=16290/9513=1.71 \text{ m/sec}^2.$$

From this it follows that due to application of base isolation acceleration at the level of the first floor of superstructure decreases by about 2.3 times in comparison with the ground acceleration (4.0 m/sec^2). This is very typical result showing the high effectiveness of base isolated structures. In comparison with the fixed base buildings, seismic isolation significantly reduces the maximum spectral acceleration, proving to be cost effective for the isolated structures and ensuring high reliability of their behavior under seismic impacts (Naeim & Kelly, 1999, Fujita, 1999, Saito, 2006, Martelli, Forni & Rizzo, 2008, Melkumyan, 2011).

Before the customer approached us with the request to develop the base isolation design for the considered 7-story apartment building using innovative technology, a prototype conventional design for construction of the same building was examined. In the conventional design the foundations were in the form of 800 mm thick solid slab, the thickness of the monolithic load-bearing walls was equal to 300 mm at the basement and 200 mm in all the residential floors. Their slabs were also designed with the thickness of 200 mm. Comparative analysis has shown that suggested seismic isolation strategy reduces the consumption of concrete by about 2 times and steel – 2.7 times. Therefore, the cost of construction of the given building decreases on about 35% in comparison with the cost of conventional construction. This magnitude of the cost reduction considers the cost of manufacturing, testing, and installation of SILRSBs.

4. CONCLUSIONS

Several remarkable projects on construction of base isolated buildings like residential complexes, hospital and hotel buildings are briefly mentioned in the paper to demonstrate the experience accumulated in Armenia in construction of new buildings.

For the first time base isolation technology is considered for application to a building the bearing system of which consists of R/C monolithic load-bearing walls and building has an asymmetric plan. Suggested structural concept of the 7-story base isolated apartment building “Stepanakert-Sections-4-5” and the approach on installation of clusters of

SILRSBs bring to rational solution of the whole bearing structure. It increases overall stability of the superstructure and effectiveness of the isolation system.

The developed design and conducted analysis confirm that base isolation is one of the most effective technologies in earthquake resistant construction. It brings to simultaneous reduction of floor accelerations and inter-story drifts, as well as to significant reduction of shear forces in comparison with the fixed base buildings.

Total 119 SILRSBs are used in seismic isolation system with the aggregate horizontal stiffness equal to 96.39 kN/mm. These are manufactured in Armenia according to the Republic of Armenia Standard HST 261-2007. Their dimensions and physical/mechanical parameters are given in the paper.

Some results of analysis of the base isolated 7-story apartment building "Stepanakert-Sections-4-5" by the Armenian Seismic Code are given, showing that the structural elements below and above the seismic isolation plane will work only in the elastic phase. Total horizontal displacement comprises 16.9 cm, period of vibration – 1.97 sec and acceleration at the level above the seismic isolation interface – 1.71 m/sec2. An input acceleration of 0.4g at the foundation bed gets damped about 2.3 times in the superstructure. Almost uniform distribution of the vertical loads (not exceeding 1500 kN) upon the rubber bearings was achieved.

Comparative analysis has shown that suggested seismic isolation strategy reduces the consumption of concrete by about 2 times and steel – 2.7 times. Therefore, the cost of construction of the given building decreases on about 35% in comparison with the cost of conventional construction. This magnitude of the cost reduction considers the cost of manufacturing, testing, and installation of SILRSBs.

Comparison of the Code based analyses results with those obtained by the time history analyses indicates that the shear forces at the level of isolation systems, the maximum displacements of the isolators, and the maximum inter-story drifts in the superstructures calculated based on the Armenian Seismic Code provisions are considerably higher (by a factor of 1.75 in average) than the same values calculated by the time histories. This means that some further measures should be taken in order to more realistically reflect characteristics of seismic isolated buildings in the design models during the calculations based on the Code. In other words, further improvement of the Code provisions is needed regarding the reduction factors K1 for seismic isolation systems, as well as for the dynamic coefficient $\beta(T)$.

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SEISMIC RESISTANCE ASSESSMENT OF EXISTING BRIDGE STRUCTURE

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Abstract: *The main goal of this paper is assessment of the level of seismic resistance of chosen representative existing bridge under the impact of the earthquake from Ulcinj-Albatros, common for the Balkan region. Carried out is iterative nonlinear analytical procedure, applying successively in small increments different levels of PGA of the earthquake, and analyzing the real behavior of the bridge, with aim to detect the maximal PGA level to which the bridge does not collapse. It was concluded that since the bridge was designed with dated regulations, it has very low and non-satisfactory seismic resistance, and seismic improvements are extremely necessary.*

Keywords: *RC bridge, seismic resistance, nonlinear analysis, nonlinear behavior*

1. INTRODUCTION

Large number of the existing bridge structures in Republic of Macedonia and the countries of south-eastern Europe are built more than 40 years ago using dated and inadequate regulations for aseismic design. Their seismic resistance levels do not satisfy the actual seismic safety and stability requirements. There is a great need of evaluation of their seismic capacity, as well as of their seismic strengthening and upgrading. According to this, in this paper an analytical procedure is carried out in order to determine the nonlinear behavior prior failure and to assess the seismic resistance level of chosen representative bridge structure in Macedonia.

2. DESCRIPTION OF THE BRIDGE STRUCTURE

The chosen representative structure is a reinforced concrete viaduct with five spans and total length of L = 2*16.9 + 3 * 21.1 m = 97.1 m. The viaduct is located at km 10+524.85 of the M-26 road, section Gostivar-Kicevo, Fig. 2.1. According to the project documentation, the bridge is designed as a classical frame structural system cast in place. The superstructure of the bridge consists of two main longitudinal girders with height h=1.40 m constructed at a distance of e=6.10 m, secondary transverse girders in every span (three or four) and above every support and reinforced concrete deck with width of b=9.6 m and thickness of d_p=0.18 m. The longitudinal section of the bridge is shown on Fig. 2.5.

Fig 2.1. View of the RC deck of the existing bridge in R. Macedonia constructed as classical structural system

Fig. 2.2. View of one abutment of the chosen representative bridge

The bridge substructure includes box type abutments with wing walls cast in place, Fig. 2.2 and middle supports consisting of two RC middle piers with circular cross section (D=1.0 m) connected to the ground with single footings, Fig. 2.3 and Fig. 2.4. The pier heights vary between 10.1 m and 17.9 m. The both end supports of the bridge are movable bearings in longitudinal direction, while the connection between the upper and lower structure at the middle piers position is fixed. In plane, the bridge forms a horizontal curve with small radius of R=70.0 m, Fig. 2.6. The transverse slope of the bridge is 6.4%. The vertical alignment of the bridge has a small gradient also. The piers and the abutments of the bridge are founded on stiff rock foundation with bearing capacity of σ_{doz} = 3.5 MPa.

Fig. 2.3. View of substructure of classical bridge structure

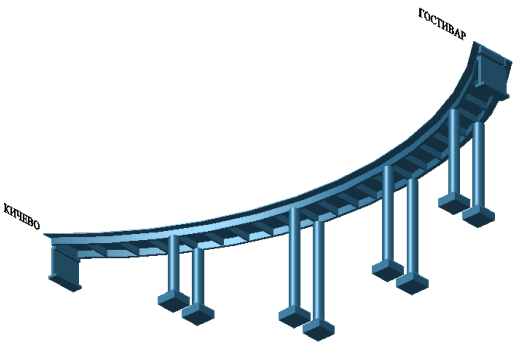

Fig. 2.4. Animated 3D view of the chosen curved bridge structure

The whole RC structure is constructed with concrete grade MB30, except for the wing walls which are built with concrete grade MB45 and the footings which are built with concrete grades MB10 and MB22.

The reinforcement steel used for the whole structure is grade C 240/360.

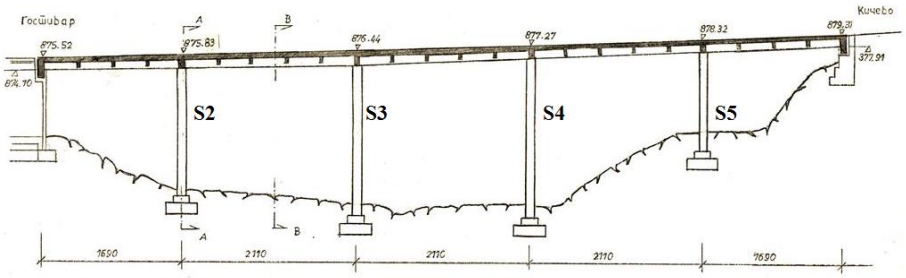

Fig. 2.5. Longitudinal section of the chosen bridge in horizontal curve constructed in R. Macedonia as classical structural system at the road section Gostivar-Kicevo

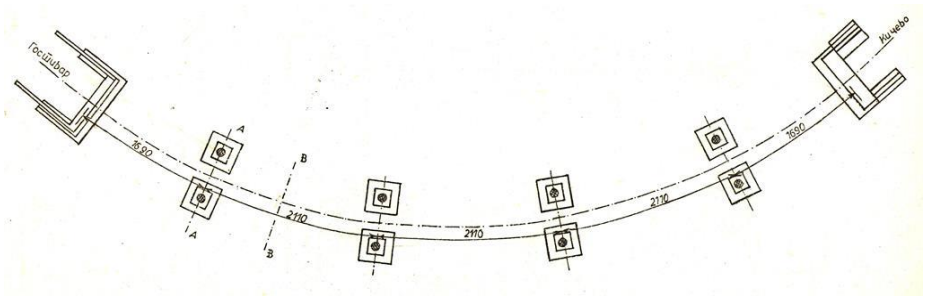

Fig. 2.6. Foundation plan of the curved bridge structure

The existing viaduct, chosen for the following carried out analytical procedures is built about 40 years ago and is in regular function and available for traffic.

3. FORMULATION OF MODEL FOR NONLINEAR ANALYSIS. DYNAMIC CHARACTERISTICS OF THE STRUCTURE

A 3D mathematical model incorporating the real geometrical, physical and material characteristics of the bridge was formulated. The connection between the super-structure and the sub-structure is modeled as fixed, except for the positions of the abutments where the superstructure rests upon RC movable bearings.

Simulated are potential plastic hinges in all middle piers, located at the cross-sections at the level of foundation and the cross-sections at the contact with the longitudinal (and transverse) girders of the superstructure. The cross-sections where occurrence of plastic hinges is expected have been formulated using detailed moment – axial force (M-N) interaction diagrams, Fig. 3.1 and Fig. 3.2 and a corresponding number of moment - curvature (M-φ) relationships, Fig. 3.3 and Fig. 3.4 for defined different levels of axial force in the piers.

Fig 3.1. Moment-Axial force (M-N) interaction diagram for the piers S2 and S5

Fig 3.2. Moment-Axial force (M-N) interaction diagram for the piers S3 and S4

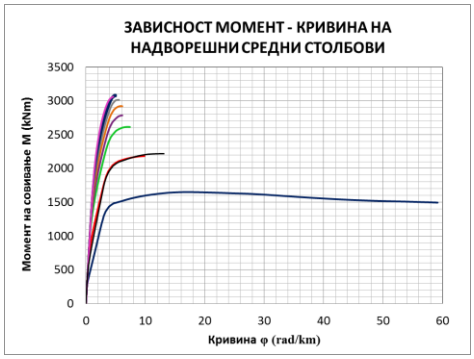

Fig. 3.3. Moment-curvature (M-φ) relationships for the piers S2 and S5 for different levels of axial (N) forces

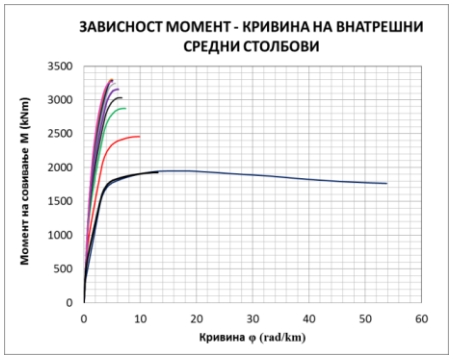

Fig. 3.4. Moment-curvature (M-φ) relationships for the piers S3 and S4 for different levels of axial (N) forces

Due to the high bearing capacity of the soil, the boundary conditions of support of the middle piers and the abutments were modeled as fixed, while the support of the superstructure upon the abutments was modeled by springs that simulate the behavior of the RC movable bearings. The main purpose was to enable a realistic insight into the seismic resistance of the structure, i.e., providing a realistic estimation of the minimal seismic intensity, expressed as PGA level, at which total failure of the structure occurs.

After the formulation of the mathematical model, in the first phase, the necessary analysis of the dynamic characteristics of the structure was carried out in order to be able to proceed with the second analytical phase of determination of the seismic safety of the structure. The value of the first period of vibration is T_1=0.850 sec, with mode shape of vibration in the transverse direction of the bridge, Fig. 3.5a. The second period of vibration is T_2=0.778 sec, with the mode shape of vibration in the longitudinal direction of the bridge, Fig. 3.5b. The third period of vibrations is T_3=0.517 sec, with mode shape dominantly torsional, expressed in the form of rotation of the bridge superstructure.

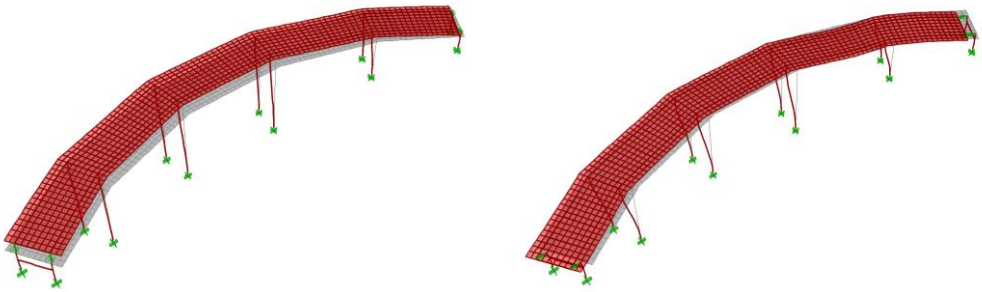

Fig. 3.5. Results obtained from the analysis of the dynamic characteristics of the bridge structure: a) Mode shape 1 and b) Mode shape 2

4. REPRESENTATIVE RESULTS AND ASSESSMENT OF THE SEISMIC RESISTANCE LEVEL

In the second phase, specific research of the seismic resistance capacity of the structure was carried out by implementation of an iterative nonlinear analytical procedure. The main purpose was to define at which maximum level of the ground acceleration (PGA), the structure remains non-collapsed, i.e., to define the stage of the structure immediately before failure.

In this paper presented are selected characteristic results obtained from the iterative nonlinear analysis of the bridge by application of the Ulcinj-Albatros earthquake record acquired during the Montenegro earthquake of 1979.

By carrying out several subsequent seismic analyses, the following findings can be noted:

(1) If the maximum acceleration in the global direction has a value greater than 0.14 g (PGAgl>0.14g), complete failure of the structure occurs;
(2) If the maximum acceleration in the global direction has a value equal or lower than 0.14 g (PGAgl≤0.14g), failure of the structure does not occur – the immediate stage prior to failure is reached.

The seismic effect was simulated by simultaneous application of two scaled accelerograms in the transversal x-direction and longitudinal y-direction of the bridge in the form of projections from the global direction acceleration. Accordingly, the stage immediately prior to failure under the Ulcinj-Albatros earthquake has been determined with the following maximum acceleration values in the longitudinal (x) and transversal (y) direction of the bridge: PGAx = PGAy = 0.10 g.

Fig. 4.1. Time history response of the displacement dx (m) at the top of pier S4L in longitudinal direction of the bridge

Fig. 4.2. Time history response of the acceleration ay (m/sec^2) at the top of pier S4L in transversal direction of the bridge

On Fig. 4.1 is shown the time history response of the displacement dx (m) at the top of pier S4L in longitudinal direction of the bridge from the Ulcinj-Albatros earthquake with PGA=0.14g, at the moment immediately prior to failure. The maximum displacement value is dx,max=0.032 m. On Fig. 4.2 is shown the time history response of the acceleration ay (m/sec^2) at the top of pier S4L in the transverse direction of the bridge, from the Ulcinj-Albatros earthquake with PGA=0.14g, at the moment immediately prior to failure. The maximum acceleration value is ay,max=1.39 m/s^2.

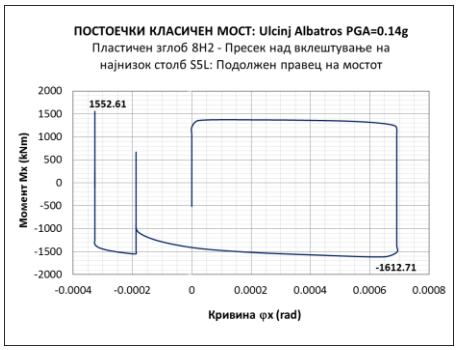

Fig. 4.3. Nonlinear hysteretic response MX(kN)-φX(m) of plastic hinge at the bottom of pier S5L in long. dir.-no failure

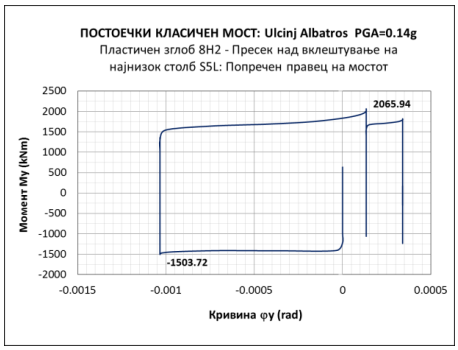

Fig. 4.4. Nonlinear hysteretic response MY(kN)-φY(m) of plastic hinge at the bottom of pier S5L in tran. dir.-no failure

On Fig. 4.3 is shown the nonlinear hysteretic response MX(kN)-φX(m) in longitudinal direction of the bridge, at the bottom cross-section of pier S5L, i.e., the behavior of the plastic hinge immediately prior to failure due to the effect of the Ulcinj-Albatros earthquake with PGA=0.14g. Respectively, on Fig. 4.4 is shown the nonlinear hysteretic response MY(kN)-φY(m) of the same plastic hinge, but in transverse direction of the bridge. From the obtained results, the developed nonlinear behavior prior to failure can be observed.

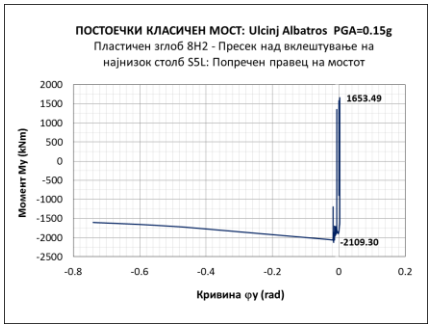

Fig. 4.5. Nonlinear hysteretic response MX(kN)-φX(m) of plastic hinge at the bottom of pier S5L in long. dir.-failure

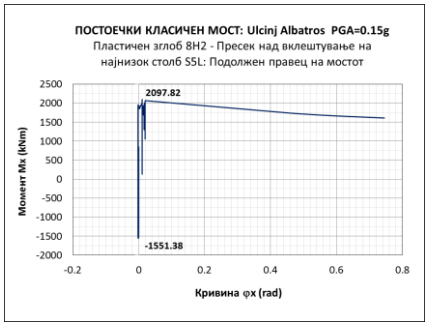

Fig. 4.6. Nonlinear hysteretic response MY(kN)-φY(m) of plastic hinge at the bottom of pier S5L in tran. dir.-failure

On Fig. 4.5 is shown the nonlinear hysteretic response MX(kN)-φX(m) in longitudinal direction of the bridge, at the bottom cross-section of pier S5L, showing failure due to the effect of the Ulcinj-Albatros earthquake with increased PGA of 0.15g. Respectively, on Fig. 4.6 is shown the nonlinear hysteretic response MY(kN)-φY(m) of the same plastic hinge, but in transverse direction of the bridge. From the obtained results, the occurred failure in the shortest middle pier can be observed.

Fig. 4.7. Time history response of axial force N (kN) at the bottom of pier S5D: Axial direction

Fig. 4.8. Time history response of shear force FX (kN) at the bottom of pier S5L: Longitudinal direction

On Fig. 4.7 is shown the time history response of the axial force N (kN) at the base of pier S5D, under the effect of the Ulcinj-Albatros earthquake with PGA=0.14g. The values of the axial force range from N_{min}=-1280.60 kN to N_{max}=-2523.79 kN. Presented in Fig. 4.8 is the time history response of the shear force FX (kN) at the base of pier S5L in longitudinal direction of the bridge under the effect of the Ulcinj-Albatros earthquake with PGA=0.14g. The values of the shear force range from FX_{min}=-387.45 kN to FX_{max}=289.91 kN.

5. CONCLUSIONS

From the performed detailed nonlinear analyses of the existing bridge designed as a classical structural system, several considerably important conclusions can be drawn:

1) The classical structural system of the analyzed existing bridge is characterized by very low seismic resistance, or more precisely, it shows a very high and economically unacceptable seismic risk due to the high level of vulnerability to earthquake effects;
2) Under the effect of the Ulcinj-Albatros earthquake, the classical structural system experiednces total failure at unacceptably small PGAs. More precisely, under all levels higher than PGA>0.14g, i.e., PGAx>0.10g and PGAy>0.10g, the structure experiences failure in the shortest pair of middle piers, as presented on Fig. 4.7 and Fig. 4.8. The failure occurs when the PGA of the Ulcinj-Albatros earthquake is PGA=0.15g, i.e., PGAx=PGAy=0.106g. The maximal value of the bending moment at the bottom critical cross-section at the moment of failure is M_{max}=2097.8 kNm.
3) With such realistic insights, it can be concluded that many infrastructure networks in the Balkans and Southeast Europe are characterized with high to very high seismic risk since most of the existing bridges are designed as classical structural systems and do not possess a satisfying level of seismic safety;
4) To reduce the high seismic risk of existing bridge structures, it is necessary to perform detailed reevaluation of their seismic resistance levels in order to define optimal measures for their extremely necessary seismic revitalization and upgrade.

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ADVANCED SEISMIC PROTECTION OF BUILDINGS WITH NEW GOSEB-SK SEISMIC ISOLATION SYSTEM

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Abstract: *Improvement of seismic protection of building structures in Kosovo region is recognized as very important task and strategic research activity. Development of advanced seismic isolation method for seismic protection of buildings in Kosovo region is never considered before. The present research actually represent the first attempt and pioneering research effort toward development of new technology for efficient seismic protection of different types of important building structures in the well known seismically prone Kosovo region. In this paper presented is basic concept of the developed new GOSEB-SK seismic isolation system for seismic protection of existing and new multi storey buildings. The proposed system is applicable for economical earthquake protection of building structures of different usability categories and different types under destructive effects of the strongest future earthquakes. Particular emphasis is put on development of seismic isolation and vibration control devices providing high practical efficiency and effective application capability.*

Keywords: *seismic isolation, nonlinear response, passive control, shaking table tests*

1. INTRODUCTION

It seems that earthquake catastrophes have lately become increasingly devastating. The world is simply shocked while watching the TV broadcasts on different regions in the world stricken by earthquakes. Ordinary people wonder and cannot accept to believe that such severe consequences from each new earthquake are still possible today, at the present level of technological development.

In our minds, there are strong memories of the stirring pictures of the latest earthquakes that have occurred around the world. The most recent event was the

earthquake in Turkey with over 18 000 victims, many more injured and thousands of heavily damaged and collapsed buildings. Similar devastating effects have been also observed in the latest earthquakes that struck many other countries like Greece, Taiwan, Japan, China, United States, Russia, Italy, Montenegro, Algeria, Mexico, Peru, etc. The losses caused by the earthquake that took place in the city of Kobe, Japan in 1995, is estimated at more than 200 billion dollars and all this happened within only 20 – 30 seconds. More than 5500 people lost their lives and even more were injured.

The prevention of such heavy earthquake catastrophes in the future was the main and challenging motivation of the first author, to start with the realization of the original innovation (pilot) project entitled "Seismically Safe Cities of the Future". This project actually represents the author's "creative vision for construction of seismically safe structures in the twenty-first century", without increase of total construction cost. To provide the necessary basic technical conditions for practical realization of his visionary idea about an efficient seismic protection of structures in future, promoted is application of a new and qualitatively improved technology.

The advanced technology for a qualitatively improved seismic protection of buildings in future is based on application of new "GOSEB-SK" seismic isolation system efficient for construction of seismically safe structures. The "GOSEB-SK" seismically resistant system is based on the concept of global optimization of seismic energy balance. This has been achieved by integration of the advantages of seismic isolation systems and the new concept for multi-level seismic energy absorption, realized with new "GOSEB-SK" System (Fig. 1.1. and Fig. 1.2.).

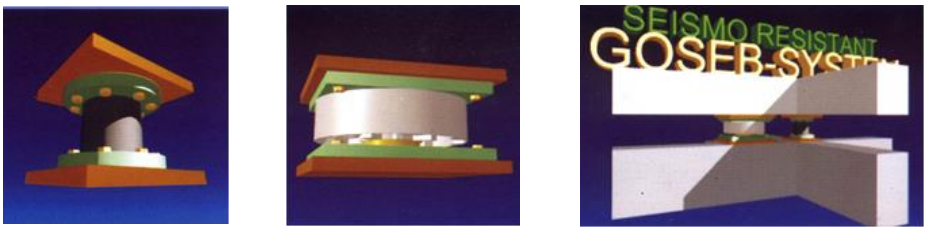

Figure 1.1 Concept of The New "GOSEB-SK" Seismo-Resistant System Based On Multi-Level Seismic Energy Absorption and Global Optimization of Seismic Energy Balance

Seismic isolator is available on the market and it is produced in different proportions and with diverse physical characteristics. This enables wide and universal application of seismic isolators in all kinds of structures.

The new multi-level "GOSEB-SK" hysteretic seismic energy absorber has extraordinary features as to adapting its behavior to the actual level of seismic input energy. Actually, "GOSEB-SK" hysteretic energy absorber possesses the following features of multi-level earthquake response:

1. If there is no earthquake excitation, the "GOSEB-SK" hysteretic seismic energy absorber enables behavior of the structure analogous to the behavior of any traditionally constructed structure.

2. If a relatively slight earthquake occurs, the "GOSEB-SK" hysteretic seismic energy absorber reacts with an adequate level of dissipation of the input seismic energy, making the structure thoroughly safe and avoiding even micro-cracks.

3. If a moderate earthquake occurs, the "GOSEB-SK" hysteretic seismic energy absorber reacts with an adequately increased level of dissipation of the input seismic energy. This enables complete protection of the structure.

4. Finally, in the case of the most severe earthquake, the "GOSEB-SK" hysteretic energy absorber reacts with its full capacity for dissipation of the increased seismic input energy level.

The required full capacity for seismic energy dissipation has been defined by advanced design analyses, in the theoretical part of the investigations of the optimal seismic performances of the "GOSEB-SK" multi-level seismic energy absorber.

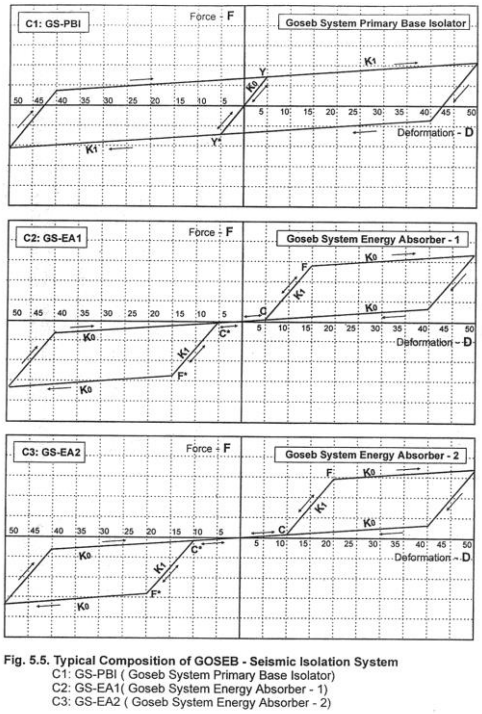

Fig. 5.5. Typical Composition of GOSEB - Seismic Isolation System
C1: GS-PBI (Goseb System Primary Base Isolator)
C2: GS-EA1(Goseb System Energy Absorber - 1)
C3: GS-EA2 (Goseb System Energy Absorber - 2)

Figure 1.2 Concept of the Invented Multi-Level Seismic Energy Absorber

The multi-level response of the "GOSEB-SK" system in compliance with the input seismic energy provides a complete seismic protection of structures, even under the strongest recorded earthquakes.

In the present paper presented are created four important innovative products of the new GOSEB-SK System: (1) Prototypes of new hysteretic energy dissipation components (EDC V-Type), (2) Prototypes of new hysteretic energy dissipation devices (EDD V-Type), (3) Prototypes of innovative GOSEB-SK System and (4) Advanced design

procedure providing application of new GOSEB-SK System for seismic protection of new and existing buildings. The proposed innovative GOSEB-SK System actually represents new advanced technology, integrating response modification and seismic isolation into new system for efficient seismic protection of all types of buildings.

2. TESTING OF NEW V-CLASS ENERGY DISSIPATION COMPONENTS

The basic experimental laboratory test program included nonlinear quasi-static tests, Table 2.1., of constructed prototype models of the developed new specific vertical class (V-Type) of seismic energy dissipation components (EDC), used in creation of new energy dissipation devices (EDD).

Table 2.1 Tested prototypes of seismic of energy dissipation components (EDC) of new V-Class energy dissipation devices (EDD) under simulated earthquake-like reversed cyclic loads.

No.	Tested types of energy dissipation components (EDC) of created new energy dissipation device (EDD)	Designed EDC prototypes	Produced EDC specimens	Completed EDC tests
1	ED Components of Energy dissipation devices (EDD) of vertical V-class	12	92	13
TOTAL		12	92	13

All EDC prototypes are tested up to strong nonlinearity under cyclic loads (Table 2.1.), since they represent the most basic parts of the developed new type of energy dissipation device (EDD).

3. TESTING OF NEW V-CLASS ENERGY DISSIPATION DEVICES

The developed new GOSEB-SK System can be successfully applied for seismic protection of new buildings and seismic upgrading of a dominant number of important existing buildings with classical system constructed in Kosovo region and SE Europe in general. The presently conducted extensive experimental program included also the construction and testing of new type of energy dissipation device (EDD), Table 3.1, under simulated reversed cyclic loads.

Table 3.1 Prototypes of constructed and tested new energy dissipation devices (EDD) of vertical V-class under simulated earthquake-like reversed cyclic loads

No.	Prototypes of innovative energy dissipation devices (EDD)	Number of designed EDD	Number of produced EDD	Completed exp. tests
1	ML-MD Energy dissipation devices (EDD) of vertical V-class	2	2	2

TOTAL	2	2	2

Figure 3.1 Laboratory tested model prototypes of new seismic energy dissipation devices (EDD) of vertical V-Class under simulated earthquake-like reversed cyclic loads: Type 1: EDD-V-T1 and Type 2: EDD-V-T2

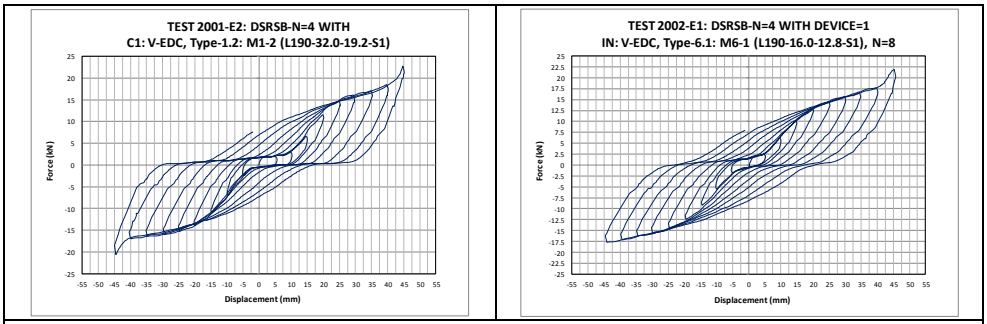

Figure 3.2 Experimentally defined original hysteretic relations of the developed two specific innovative types of energy dissipation devices (EDD) of vertical V-Class

The basic structure of new ML-MD Energy Dissipation Devices of vertical V-Class is shown in Fig. 3.1. In the following Fig. 3.2, presented are original hysteretic relations defined experimentally for the tested two specific innovative types of energy dissipation devices (EDD) of V-Class.

4. TEST MODEL OF PROTOTYPE BUILDING WITH NEW GOSEB-SK SYSTEM

The actual experimental program included creation, construction and testing of representative prototype of building shaking table model composed of innovative type of seismic protection system. In this paper presented is one representative building test model with integrated innovative so called GOSEB-SK System. To define set-up parameters for this innovative large-scale shaking table building model and to conduct final dynamic shaking table test under simulated effects of the selected real and strong earthquake

ground motions, specific and representative experimental quasi-static tests have been firstly completed. The results obtained from the completed experimental seismic shaking table tests represent highly valuable basis for realistic experimental validation of the actual response modification performances and efficiency of the created innovative GOSEB-SK seismic isolation system for seismic upgrading of existing and seismic protection of new buildings.

Figure 4.1 View of constructed large-scale building model tested on seismic shaking table (a) and detail of seismic isolation and energy dissipation devices (b) of the proposed seismic protection system for buildings

The innovative building model 2 exists of GOSEB-SK energy dissipation devices and basic seismic isolation system composed of double sferical ruler seismic bearings (DSRSB) and is denoted as GOSEB-SK-DSRSB. Test set-up and all quasi-static and dynamic tests are realized based on defined optimal test program for building model-2. In Figure 4.1 presented is constructed innovative large-scale building model tested on seismic shaking table with incorporated new GOSEB-SK seismic protection system. In IZIIS dynamic testing laboratory was organized valuable public workshop representing laboratory test demonstration day. With conducted representative shaking table model tests, demonstrated was to the audience real advantage of the developed new GOSEB-SK seismic isolation system for seismic protection of buildings.

5. SEISMIC TESTING OF BUILNING MODEL WITH NEW GOSEB-SK SYSTEM

To generate basic results for new system verification, extensive experimental seismic tests been performed using the constructed innovative laboratory building test model prototype with incorporated an optimized GOSEB-SK seismic isolation system.

The building model was constructed in the scale 1:3, so planed seismic tests have been carried out using time compressed real earthquake recorts by factor $1/\sqrt{3}$. The building model was constructed as two storey building frame structure with brick masonry infill and represent isolated segment of selected typical real building from Kosovo and wider region of south-east Europe.

The dimensions of the model in plan are a=3.14m and b=1.74m., while hights of the stories are h=1.08m. The model superstructure was supported by four (4) DSRSB seismic

isolators installed on the top of four specially designed steel supports installed at four model corners for simulation of supporting system above fundations.

At both model ends between supports, new innovative seismic energy absorbers of the type GOSEB-SK are installed. During seismic tests, seismis isolation system is activated directly in longitudinal direction by simulated earthquake input motion.

The tested building model with integrated innovative GOSEB-SK seismic isolation systems is presented in Figure 4.1. Extensive seismic tests have been performed considering as input the effects of very strong earthquake ground motions. The superstructure of the tested building model did not received any damage during all seismic tests. Intersory drifts have been reduced to a minimum and only significant displacements have been recorded at the level of building supporting system. Seismic tests of the building model have been performed using several different very strovg earthquake records. However, in this paper are included only selected experimental results to demonstrate the main contribution of the conducted tests for realistic evaluation of the achied very favourable seismic performances if the developed system.

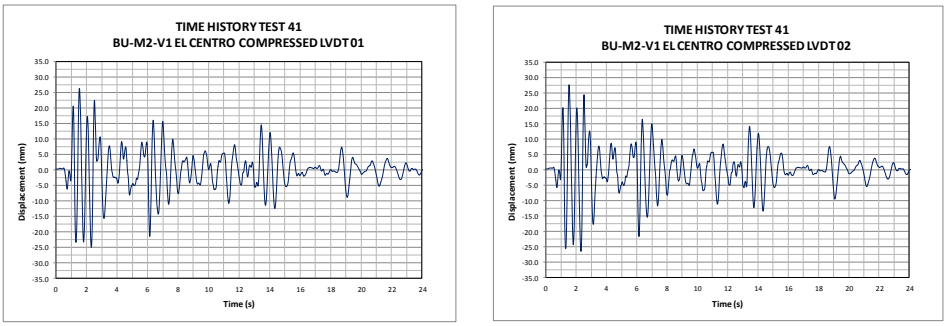

Figure 5.1 Experimentally defined original displacement response history of points NP=1 and NP=2 of building model with the developed innovative type of building seismic protection system GOSEB-SK with energy dissipation devices (EDD) of vertical V-Class

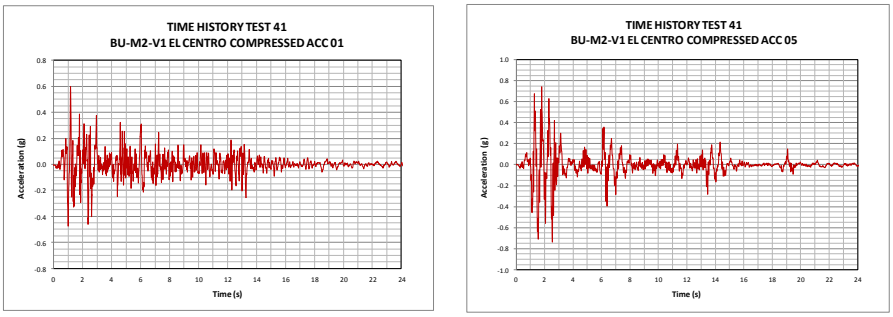

Figure 5.2 Experimentally defined original acceleration response history of points NP=1 and NP=2 of building model with the developed innovative type of building seismic protection system GOSEB-SK with energy dissipation devices (EDD) of vertical V-

Class

In Figure 5.1, presented are experimentally defined original displacement response history of points NP=1 and NP=2 of building model with the developed innovative type of building seismic protection system GOSEB-SK with energy dissipation devices (EDD) of vertical V-Class. In the next Figure 5.2, presented are experimentally defined original acceleration response history of points NP=1 and NP=2 of the model with the developed innovative type of building seismic protection system.

From the observed integral experimental results, evident is very favorable behavior of the developed building system denoted as GOSEB-SK seismic protection system.

6. CONCLUSIONS

The most important conclusion from this extensive study is experimental confirmation that the proposed new seismo-resistant GOSEB-SK system can be used as efficient system for complete seismic protection of buildings based on innovative multi-level seismic reaction and globally-optimized seismic energy balance. This is achieved by simultaneous application of the advantages of seismic isolation systems and newly developed "GOSEB-SK" multi-level hysteretic seismic energy absorber. The "GOSEB-SK" multi-level seismic energy absorber has extraordinary features as to adapting its behavior to the actual intensity of the input seismic energy. It means that newly proposed "GOSEB-SK" multi-level seismic energy absorber shows advanced features of multi-level earthquake response.

The full capacity and advances of seismic energy dissipation device has been defined by advanced design analyses in the theoretical part of the investigations. The optimal seismic performances of the new "GOSEB-SK" ML-MD seismic energy absorber have been defined.

The multi-level response of the "GOSEB-SK" system in compliance with the input seismic energy provides a complete seismic protection of the structure even under the strongest recorded earthquakes.

The most important advantage of the new seismically resistant "GOSEB-SK" system for seismic protection of building structures actually is provided condition for its simple application localized only at the base of the structure for which the "GOSEB-SK" seismic protection is designed.

The skill of the design engineer is reflected through the determination of an optimal number, optimal physical characteristics and optimal position of the seismic isolators and multi-level seismic energy dissipaters to achieve the optimized seismic energy balance for each specific structure.

The present research practically will open a wide field of practical application of the patented globally optimized system of seismic energy balance and realization of the creative vision for construction of seismically resistant structures in the 21st century, as well as further realization of the innovative project "Seismically Safe Cities of the Future".

Awards received:

The originality and high potential of this specific innovative project are very well recognized up to date. This is directly confirmed by received the highest awards in the area of inventions:

• First, the invention was awarded with gold medal in the field of civil engineering at the 23-rd International exhibition of inventions held in Geneva, Switzerland from 31.03. to 09.04 1995;

• Second, in 1996 the invention was awarded with distinguished unique national award "Patent of the Year" in the Republic of Macedonia;

• Third, in February 1998 the innovation was awarded with "Gold medal with mark" at the International exhibition of inventions held in Casablanca, Morocco;

• Forth, on September 1999 the innovation was awarded with the highest national award "Patent of the Decade" by the Government of the Republic of Macedonia;

• Finally, this project was promoted at EXPO-2000, the millennium world exhibition of inventions and new technologies for the 21st century, held in Hanover, Germany, (June 1 to October 31, 2000). The project was officially nominated by the Government of the Republic of Macedonia to represent new and advanced national achievements in the field of INVENTIONS AND SCIENCE. At present related theoretical and experimental research activities are continued by the first author, research team and active MSc and PhD students.

***Acknowledgement**: To successfully realize the creative and complex research activities in the area of development of this specific innovation (by the first author), great and highly appreciated support to was extended by many individuals and institutions, both domestic and from abroad. Particularly, the first author is pleased to mention the Industrial Property Protection Office-Skopje, Ministry of Economy and Macedonian Ministry of Education and Science, for initial financing his innovative three-year scientific project involving basic development of the innovative GOSEB-System.*

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PINUS SPP. FROM NORTH MACEDONIA- PROMISING SOURCE FOR ANTIMICROBIAL SUBSTANCES

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Abstract. *The antimicrobial properties of extracts from Pinus spp. grown in North Macedonia were investigated using broth-microdilution assay. For in vitro antimicrobial screening the tested concentrations of substances were within 50 - 0.390 %. As a test microorganisms we used E. coli ATCC 8739, Ps. aeruginosa ATCC 9027, S. typhimurium, B. subtilis ATCC 6633, B. pumillus NCTC 8241, S. citrus, S. aureus and L.monocytogenes. The tested extracts showed antimicrobial activity against tested bacteria. Ps. aeruginosa ATCC 9027 was the most sensitive among Gram negative bacteria (MIC=0.39% and MBC=1.562 %), and from Gram positive bacteria S. citrus showed biggest sensitivity against tested substances, with MIC=0.39% and MBC= 6.25%. Compared to antibiotics, the tested substances showed promising antimicrobial activity against tested microorganisms.*

Keywords*: Antimicrobial, Pinus, Broth-microdilution assay*

INTRODUCTION

The genus *Pinus* belongs to the family Pinaceae and comprises about 115 species. It is the largest genus of conifers occurring naturally in the Northern hemisphere, especially in the Mediterranean region, Caribbean area, Asia, Europe, North and Central American (Graikou et al., 2012). The territory of central Balkans is inhabited by many conifers, including four autochthonous pines: *P. mugo* Turra (dwarf mountain pine), *P. nigra* Arnold (black pine), *P. sylvestris* L. (Scots pine), which have wide European or Eurasian distribution, and *P. peuce* (Macedonian pine), a Balkan endemic of the high mountains of Bulgaria, Macedonia, Serbia, Montenegro, Albania and Greece (Gaussen et al., 1993). Accordingto the Flora of the R. Macedonia (Micevski, 1995), in Macedonia genus *Pinus* include *P. nigra* Arnold, *P. sylvestris* L., *P. mugo* Turra, *P. heldreichii* Christ. subsp. *leucodermis (*Antoine*)* Blecic and *P. peuce* Grisebach.

Pines are considered as significant source of structurally diverse, bioactive compounds, and have provided contributions to the discovery of pharmaceutical agents and other biomedical applications (Politeo et al., 2011). The needles of the genus *Pinus* contain essential oils and the components of their essential oils have been established through chromatographic techniques (Yang et al., 2002; Bo et al., 2010; Zafar et al.,

2011). On the other hand, increasing incidence of multiresistant microbial strains represents the major issue in medical microbiology, which raises the need for new, efficient and safe antimicrobial agents. Therefore, there are many studies focused on finding new molecules with antimicrobial properties, which are, in many cases, inspired by traditional utilization of medicinal plants. One of the most studied properties of essential oils and plant extracts are their antimicrobial activity, important for both food preservation and control of human and animal diseases of microbial origin.

The aim of the present study was to define and compare the *in vitro* antibacterial activities of crude extracts isolated from needles of *Pinus nigra* J.F. Arnold and *Pinus sylvestris* L. compare with α- and β- pinene from Macedonia.

MATERIAL AND METHODS

Plant material

The needles of 50 year old *Pinus nigra* J.F. Arnold and *Pinus sylvestris* L.were collected during October 2013 (autumn season) from Berovo region in Macedomia. The needles from lower third of crown of ca. 30 randomly selected trees in each of the populations were collected. Plant material was deposited in polyethylene bags, transferred to a freezer and stored at −20 °C prior to further analysis.

Tested microorganisms

As a test microorganisms we used a panel of different bacteria, including four Gram negative bacteria (*E. coli* ATCC 8739, *Ps. aeruginosa* ATCC 9027, *S. typhimurium*) and nine Gram positive bacteria (*B. subtilis* ATCC 6633, *B. pumillus* NCTC 8241, *S. citrus*, *S. aureus*, *L. monocytogenes*). The tested microorganisms in this study were provided from the culture collections of Department of Microbiology and Microbial Biotechnology, Faculty of Natural Sciences and Mathematics, UKIM, Skopje.

Chemicals and reagents

Resazurin, DMSO (Dimethyl sulfoxide), α– pinene, β– pinene, pentane were purchased from Merck (Darmstadt, Germany). Mueller Hinton agar and Mueller Hinton broth were purchased from Sigma-Aldrich.

Isolation of the extracts

The needles, stored until extraction in a freezer at -20^{0}C, were cut in to pieces of 2–3 mm length, and extracted with pentane (1 g of needles per ml of solvent). The extracts were kept at 4–6^{0}C for 24 h and then filtered. After evaporation of the solvent, the obtained essential oil samples were subjected to subsequent analysis.

Agar diffusion assay

The antimicrobial activities were screened using the agar diffusion assay. Each microbial suspension was adjusted to a turbidity equivalent to 0.5 McFarland turbidity standard. Aliquots (0.1 mL) of each microbial suspension were spread in Mueller Hinton agar. Filter paper disks were placed on the agar surface and filled with 30 µL of each extracts. Discs (6 mm diameter) containing chloramphenicol (30 µg $disc^{-1}$) were used as positive control. The plates were incubated at 37°C for 24 h. After incubation, the diameters of the inhibition zones were measured. All experiments were performed in triplicate and the results are expressed as means ± SD.

Broth-microdilution assays

Broth-microdilution assays were used for the *in vitro* antimicrobial screening, and the tested concentrations of substances were within 50 - 0.390 % (v/v).
Cultures of bacterial species were maintained on Mueller Hinton agar at appropriate optimal temperature (37^0C). Antimicrobial activity was tested using broth microdilution method, where minimum inhibitory concentrations (MIC) determination was performed by a serial dilution method in 96 well microtitre plates. After 18 h of cultivation, bacterial suspensions were made in Mueller-Hinton broth and their turbidity was standardized using McFarland 0.5. Each well contained the final bacterial concentration of 10^6 CFU/mL.

Stock solutions of the essential oils were made in dimethylsulfoxide (DMSO, 10%) (1:1) and than serially diluted. The highest concentration of the solvent (DMSO) in any well was 5% (v/v), which was previously confirmed as concentration which does not affect the growth of the tested bacteria. After making dilutions of the extracts, the inoculum was added to all wells and the plates were incubated at 37^oC during 24 h. Chloramphenicol served as positive control, while the solvent (5% DMSO) was used as a negative control. To ensure medium sterility, each plate contained one non-inoculated well without antimicrobial agent. Experiments were performed in triplicate against each strain. MIC was defined as the lowest concentration of essential oils and extracts at which microorganisms showed no visible growth after addition of the redox indicator resazurin. Determination of MBC was performed by inoculation of broth taken from all clear wells on Mueller Hinton agar (MHA), which were further incubated for 24 h at 37°C. The MBC is defined as the lowest concentrations of the pine essential oils and extracts at which inoculated microorganisms were killed.

RESULTS AND DISCUSSION

World-wide, it is estimated that up to 70,000 species are used in folk medicine (Farnsworth and Soejarto, 1991). The WHO reports over 21,000 plant taxa used for medicinal purposes (Groombridge, 1992). Macedonian flora is rich in plants which are used in various forms as folk medicine and herbal tea.

Essential oils of plants are good candidates for pharmaceutical and cosmetic ingredients, due to their low toxicity. The most attractive aspects of using essential oils that they are very low mammalian, fish, and environment toxicities compared with synthetic chemicals and their nonpersistence in fresh water and soil (Lai et al., 2006).

Agar diffusion assay

The antimicrobial activities were initially tested by the agar diffusion method in comparison to chloramphenicol (30 μg disc^{-}1) as positive control. The extracts showed high activity against all tested bacteria with inhibition zones mostly larger than 11 mm (Table 1). Anyway, as most sensitive bacterial strains were *Ps. aeruginosa* ATCC 9027 (from the Gram – bacteria) with 16±0.8 mm for extract from *P. nigra* J.F. Arnold and *S. citrus* (from the Gram + bacteria) with 10±0.8, also from extract *P. nigra* J.F. Arnold. From tested extracts the best results generally showed extracts from *P. nigra* J.F. Arnold, and from essential oils - α- pinene.

Table 1 Zone of inhibitions (ZI) (mm±SD) from agar diffusion assay of the extracts and oils against tested bacteria.

ZI (mm±SD)	α- pinene	β- pinene	*P. nigra* J.F. Arnold extract	*P. sylvestris* L. extract	chloramphenicol (30 μg disc^{-}1)
E. coli ATCC 8739	9±0.5	10±0.1	11±0.5	12±0.5	25±0.7
Ps. aeruginosa ATCC 9027	17±0.9	17±0.3	16±0.8	19±0.9	18±03
S. tiphymurium	15±0.8	12±0.2	13±0.6	9±0.7	0
B. subtilis ATCC 6633	9±0.2	15±0.6	12±0.8	13±0.8	18±0.4
B. pumilus NCTC 8241	9±0.5	14±0.8	10±0.9	11±0.8	21±0.3
S. citrus	13±0.3	12±0.6	15±0.4	6±0.9	21±0.1
S. aureus	11±0.8	15±0.5	12±0.4	16±0.1	26±0.9
L. monocytogenes	13±0.6	16±0.5	12±0.7	14±0.6	8±0.2

Broth microdilution method

Using a broth microdilution method, the isolated essential oils were screened for their *in vitro* antimicrobial activity against four Gram negative bacteria (*E. coli* ATCC 8739, *Ps. aeruginosa* ATCC 9027, *S. typhimurium*) and nine Gram positive bacteria (*B. subtilis* ATCC 6633, *B. pumillus* NCTC 8241, *S. citrus, S. aureus*, *L.monocytogenes*). The results of the MICs and MBCs determination are presented in Table 2 and 3. Among the tested strains, one bacterial strains from the Gram positive strains (*S. citrus*) showed sensitivity against all tested extracts, with 0.390% (MICs) and 1.56% (MBCs) of extracts from *P. nigra* J.F. Arnold. Considering bacteria tested, Gram- positive strains showed

higher susceptibility, where *S. citrus* was the mosts sensitive one. Among the tested Gram negative strains, *Ps. aeruginosa* ATCC 9027 showed higher sensitivity to the action of the extracts with active concentrations of 0.390% (MICs) and 1.562 % (MBCs) of extracts from *P. nigra* J.F Arnold.

Table 2 MICs and MBCs of tested extracts and essential oils against Gram negative bacteria.

	E. coli ATCC 8739		*Ps. aeruginosa* ATCC 9027		*S. tiphymurium*	
% (v/v)	MIC	MBC	MIC	MBC	MIC	MBC
α- pinene	0.390	0.781	0.390	1.562	0.390	0.781
β- pinene	25	50	3.125	12.5	25	50
P. nigra J.F. Arnold extract	0.390	0.781	0.390	1.562	12.5	25
P. sylvestris L. extract	25	50	0.390	1.562	25	50

Table 3 MICs and MBCs of tested extracts and essential oils against Gram positive bacteria.

	α- pinene		β- pinene		*P. nigra* J.F. Arnold extract		*P. sylvestris* L. extract	
% (v/v)	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC
B. subtilis ATCC 6633	0.390	0.781	25	50	3.125	6.25	1.56	3.125
B. pumilus NCTC 8241	0.390	0.781	25	50	0.390	0.781	0.390	0.781
S. citrus	0.390	0.781	3.125	6.25	0.390	1.56	0.390	1.56
S. aureus	0.390	0.781	6.25	12.5	0.390	1.56	0.390	0.781
L. monocytogenes	0.781	1.56	12.5	25	0.390	0.781	0.390	0.781

Tested extracts, isolated from two Pinus species, have shown to possess inhibitory action against tested isolates in the range of 0.39-25% (MICs) and bactericidal effect (MBCs) at concentrations ranging from 0.78-50%. Among the tested extracts, the one isolated from *P. nigra* J.F. Arnold exhibited the higher and *P. sylvestris* L. the lower antimicrobial action. According to the obtained activities, the tested essential oils and extracts can be arranged in the following order: α- pinene > *P. nigra* J.F Arnold > β- pinene > *P. sylvestris* L. for Gram negative bacteria. For Gram positive bacteria the tested essential oils and extracts can be arranged in the following order: α- pinene > *P. nigra* J.F Arnold > *P. sylvestris* L. > β- pinene.

Antimicrobial properties of the essential oils and various extracts from many plants have recently been of great interest in both academia and food industry, because of their

possible use as natural additives emerged from a growing tendency to replace synthetic antimicrobials with natural ones.

Considering cell wall composition, there are significant differences in sensitivity between Gram positive and Gram negative strains. This is clearly visible from the fact that Gram negative showed the highest susceptibility to the action of the tested essential oils and extracts.

Also, it is reported that antimicrobial potential of the pure compounds can be completely different when they act in essential oil, which is a mixture of different compounds (Delaquis et al., 2002). It has been determined that antimicrobial activity of essential oils depends on complex interactions among their compounds, which might exhibit additive, synergistic or antagonistic effects (Xianfei et al., 2007).

CONCLUSION

The tested extracts in this paper showed promising antimicrobial activity against tested Gram positive and Gram negative bacteria. The results of this study provided an important contribution to development of potential ingredients for natural antimicrobial agents.

The development of natural antimicrobial agents would help to decrease the negative impact of synthetic agents such as antibiotic resistance. In this respect, essential oils and plant extracts, as natural antimicrobial agents, present two main characters: the first is their natural origin which means more safety to the people and the environment, and the second is that they have be considered at low risk for resistance development. It is believed that it is difficult to develop resistance to such a mixture of oil components with apparently different mechanisms of action. However, this investigation will be completed with evaluation of antioxidative activities of these extracts.

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