



University of Belgrade
Technical Faculty in Bor,
Mining and Metallurgy
Institute Bor

**54th International
October Conference
on Mining and Metallurgy**

PROCEEDINGS

Editors:

Ljubiša Balanović

Dejan Tanikić



18-21 October 2023, Bor Lake, Serbia

**PROCEEDINGS,
54th INTERNATIONAL OCTOBER CONFERENCE
on Mining and Metallurgy**

Editors:

Prof. dr Ljubiša Balanović

Prof. dr Dejan Tanikić

University of Belgrade, Technical Faculty in Bor

Technical Editor:

M. Sc. Miljan Marković

University of Belgrade, Technical Faculty in Bor

Publisher: University of Belgrade, Technical Faculty in Bor

For the publisher: Dean Prof. dr Dejan Tanikić

Circulation: 200 copies

CIP - Каталогизacija у публикацији Народна библиотека Србије, Београд

622(082)(0.034.2)

669(082)(0.034.2)

INTERNATIONAL October Conference on Mining and Metallurgy (54 ; 2023
; Borsko jezero)

Proceedings [Elektronski izvor] / 54th International October Conference on Mining
and Metallurgy - IOC 2023, 18-21 October 2023, Bor Lake, Serbia ; [organized by]
University of Belgrade, Technical Faculty in Bor and Mining and Metallurgy Institute
Bor ; editors Ljubiša Balanović, Dejan Tanikić. - Bor : University of Belgrade,
Technical Faculty, 2023 (Niš : Grafika Galeb). - 1 USB fleš memorija ; 1 x 1 x 5 cm

Sistemske zahteve: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 200. -
Preface / Ljubiša Balanović. - Bibliografija uz svaki rad.

ISBN 978-86-6305-140-9

a) Рударство -- Зборници b) Металургија -- Зборници

COBISS.SR-ID 126659849

Bor Lake, Serbia, October 18-21, 2023



Conference is financially supported by
The Ministry of Science, Technological
Development and Innovation
of the Republic of Serbia

Platinum Donors



Gold Donors



Silver Donor



Exhibitions



Friends of the Conference



THE FOUNDATION 'B.SC. ENG. BOŠKO INJAC'

SCIENTIFIC COMMITTEE

Prof. Dr Dejan Tanikić (Serbia) - president
Prof. Dr Nada Štrbac (Serbia) - vice-president
Prof. Dr Radoje Pantović (Serbia) - vice-president

Dr Ana Kostov (Serbia)
Prof. Dr Adam Grajcar (Poland)
Prof. Dr Adina Negrea (Romania)
Dr Andrei Rotaru (Romania)
Prof. Dr Batrić Pešić (USA)
Dr Biserka Trumić (Serbia)
Prof. Dr Boštjan Markoli (Slovenia)
Dr Branislav Marković (Serbia)
Prof. Dr Cornelia Muntean (Romania)
Prof. Dr Daniela Grigorova (Bulgaria)
Prof. Dr Dejan Ivezić (Serbia)
Prof. Dr Desimir Marković (Serbia)
Prof. Dr Dimitris Pnias (Greece)
Prof. Dr Dimitriu Sorin (Romania)
Prof. Dr Dmitry Vasilyev (Russia)
Dr Dragan Komljenović (Canada)
Prof. Dr Dragan Manasijević (Serbia)
Dr Dragan Milanović (Serbia)
Prof. Dr Dragan Milovanović (Serbia)
Prof. Dr Dragoslav Gusković (Serbia)
Prof. Dr Dušan Orać (Slovakia)
Prof. Dr Duško Minić (Serbia)
Prof. Dr Endre Romhanji (Serbia)
Prof. Dr Essen Suleimenov (Kazakhstan)
Prof. Dr Farzet Bikić (Bosnia and Herzegovina)
Prof. Emeritus Fathi Habashi (Canada)
Prof. Dr Grozdanka Bogdanović (Serbia)
Prof. Dr György Kaptay (Hungary)
Prof. Dr Ivan Mihajlović (Serbia)
Prof. Dr Iveta Vaskova (Slovakia)
Prof. Dr Jakob Lamut (Slovenia)
Prof. Dr Jasmin Suljagić (Bosnia and Herzegovina)
Dr Jasmina Stevanović (Serbia)
Dr Jasna Stajić Trošić (Serbia)
Prof. Dr Jovica Sokolović (Serbia)
Prof. Dr Jožef Medved (Slovenia)
Prof. Dr Kaikun Wang (China)
Prof. Dr Karl Heinz Spitzer (Germany)
Prof. Emeritus Karlo Raić (Serbia)
Prof. Dr Kemal Delijić (Montenegro)
Prof. Dr Komnitsas Konstantinos (Greece)
Prof. Dr Kostas Matis (Greece)
Prof. Dr Krzysztof Fitzner (Poland)
Prof. Dr Luis Filipe Malheiros (Portugal)
Prof. Dr Milan Antonijević (Serbia)
Prof. Dr Milan Trumić (Serbia)
Dr Mile Bugarin (Serbia)

Dr Milenko Ljubojev (Serbia)
Prof. Dr Milovan Vuković (Serbia)
Prof. Dr Mira Cocić (Serbia)
Mirjam Jan-Blažič (Slovenia)
Prof. Dr Mirjana Rajčić Vujasinović (Serbia)
Prof. Dr Mirko Gojić (Croatia)
Dr Miroslav Sokić (Serbia)
Prof. Dr Mirsada Oruč (Bosnia and Herzegovina)
Dr Nadežda Talijan (Serbia)
Prof. Dr Natalija Dolić (Croatia)
Prof. Dr Nedeljko Magdalinović (Serbia)
Prof. Dr Nenad Radović (Serbia)
Prof. Dr Nenad Vušović (Serbia)
Prof. Dr Nicanor Cimpoesu (Romania)
Prof. Dr Nobuyuki Masuda (Japan)
Prof. Dr Onuralp Yucel (Turkey)
Prof. Dr Pavel Broz (Czech Republic)
Prof. Dr Petr Solozhenkin (Russia)
Prof. Dr Petrica Vizureanu (Romania)
Dr Sun Zhongmei (China)
Prof. Dr Ridvan Yamanoglu (Turkey)
Prof. Dr Rodoljub Stanojlović (Serbia)
Prof. Dr Rositsa Paunova (Bulgaria)
Prof. Dr Sead Čatić (Bosnia and Herzegovina)
Prof. Dr Sergey Krasikov (Russia)
Dr Slavomír Hredzák (Slovakia)
Prof. Dr Snežana Milić (Serbia)
Prof. Dr Snežana Šerbula (Serbia)
Prof. Dr Srba Mladenović (Serbia)
Dr Srećko Stopić (Germany)
Prof. Dr Stojan Groudev (Bulgaria)
Prof. Dr Sulejman Muhamedagić (Bosnia and Herzegovina)
Prof. Dr Svetlana Ivanov (Serbia)
Prof. Dr Tatjana Volkov-Husović (Serbia)
Prof. Dr Tomáš Havlik (Slovakia)
Prof. Dr Velimir Radmilović (Serbia)
Prof. Dr Velizar Stanković (Serbia)
Prof. Dr Vesna Grekulović (Serbia)
Dr Vladan Čosović (Serbia)
Vladan Mihailović (Serbia)
Dr Vladan Kašić (Serbia)
Prof. Dr Vladimir Krstić (Canada)
Prof. Dr Vladislav Kecojević (USA)
Dr Walter Valery (Australia)
Prof. Dr Xuewei Lv (China)
Prof. Dr Yong Du (China)
Prof. Dr Žarko Radović (Montenegro)
Prof. Dr Zdenka Zovko Brodarac (Croatia)
Dr Zoran Stevanović (Serbia)
Prof. Dr Željko Kamberović (Serbia)

ORGANIZING COMMITTEE

Prof. dr Ljubiša Balanović, Full Professor (UB TF Bor) - president
Prof. dr Saša Stojadinović, Full Professor (UB TF Bor) - vice-president
Prof. dr Srba Mladenović, Full Professor (UB TF Bor) - vice-president
Dr Ana Kostov, Principal Research Fellow (MMI Bor) - vice-president

Prof. dr Nada Štrbac, Full Professor (UB TF Bor)
Prof. dr Dragan Manasijević, Full Professor (UB TF Bor)
Prof. dr Vesna Grekulović, Full Professor (UB TF Bor)
Prof. dr Đorđe Nikolić, Full Professor (UB TF Bor)
Prof. dr Milan Radovanović, Full Professor (UB TF Bor)
Prof. dr Marija Petrović Mihajlović, Full Professor (UB TF Bor)
Prof. dr Zoran Štirbanović, Associate Professor (UB TF Bor)
Prof. dr Milan Gorgievski, Associate Professor (UB TF Bor)
Prof. dr Saša Marjanović, Associate Professor (UB TF Bor)
Prof. dr Ivana Marković, Associate Professor (UB TF Bor)
Prof. dr Žaklina Tasić, Associate Professor (UB TF Bor)
Doc. dr Dejan Petrović, Assistant Professor (UB TF Bor)
Doc. dr Anđelka Stojanović, Assistant Professor (UB TF Bor)
Doc. dr Uroš Stamenković, Assistant Professor (UB TF Bor)
Dr Jasmina Petrović, Assistant with PhD (UB TF Bor)
Vladimir Nikolić, Assistant (UB TF Bor)
Milica Zdravković, Assistant (UB TF Bor)
Miljan Marković, Assistant (UB TF Bor)
Milijana Mitrović, Assistant (UB TF Bor)
Milan Nedeljković, Assistant (UB TF Bor)
Avram Kovačević, Teaching Assistant (UB TF Bor)
Sandra Vasković, English Lecturer (UB TF Bor)
Oliver Marković, IT service (UB TF Bor)
Violeta Aleksić, Liquidator (UB TF Bor)

PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to welcome all esteemed participants of the 54th International October Conference on Mining and Metallurgy (IOC 2023), scheduled to take place at the picturesque Bor Lake, Serbia, from October 18th to 21st 2023.

The collaborative efforts of the University of Belgrade, the Technical Faculty in Bor, and the Mining and Metallurgy Institute Bor have meticulously organized this year's IOC. Our focus remains unwavering on showcasing the latest research findings and advancements in geology, mining, metallurgy, materials science, technology, environmental protection, and other engineering disciplines. Our primary objective is to foster a dynamic environment where academics, researchers, and industry professionals can come together to share their knowledge, experiences, and innovative ideas while exploring opportunities for collaborative research endeavors.

Our conference agenda is rich and diverse, encompassing plenary sessions, engaging invited lectures, technical presentations, enlightening oral and poster sessions, informative technical tours, a diverse exhibition, and memorable social gatherings. At the heart of this event lies our strong commitment to sustainable development within the mining and metallurgy sector. We are dedicated to exploring ecologically conscious methodologies, responsible resource extraction practices, and cutting-edge technologies that reduce the industry's environmental impact and enhance the well-being of local communities.

The conference proceedings comprise 129 papers authored by individuals from universities, research institutes, and industries in 22 countries. We are proud to welcome participants from Bosnia and Herzegovina, Bulgaria, Canada, China, Croatia, Germany, Greece, India, Iran, Kazakhstan, Libya, North Macedonia, Montenegro, Morocco, Romania, Russia, Slovakia, South Africa, Spain, Turkey, United States, and, of course, Serbia.

We are excited to host the 8th International Student Conference on Technical Sciences (ISC 2023) as part of IOC 2023. This event offers students from Serbia and the wider region a unique chance to showcase their research and discuss the future of their fields with experts.

We sincerely thank the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia for their generous financial support. In addition, we express our profound gratitude to all our sponsors, exhibitors, and friends of the Conference for their contributions and unwavering support for playing a pivotal role in ensuring the success of IOC 2023.

We would like to express our heartfelt thanks to all authors, committees, reviewers, speakers, and chairpersons for their invaluable contributions in shaping IOC 2023.

We look forward to welcoming you to the 55th International October Conference on Mining and Metallurgy (IOC 2024), which will be held in October 2024.

On behalf of the 54th IOC Organizing Committee,

Prof. dr Ljubiša Balanović

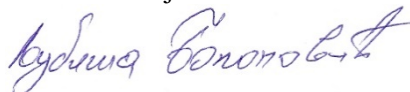


TABLE OF CONTENTS

Plenary Lectures

Velimir R. Radmilović (SERBIA)

Energy: One of the biggest challenges in 21st century 3-3

Jing Yu, Mingshui Luo, Junyi Xiang, Yang You, Zhixiong You, Xuewei Ly (CHINA)

Efficient extraction of vanadium from vanadium slag 4-8

Invited Lectures

Batrić Pešić (UNITED STATES)

The ongoing restructuring of universities to adopt the sophistication offered by internet 11-19

Yaima Filiberto, Alberto Montenegro, Eugenio Alvarez (SPAIN)

Machine learning applied to improving the scrap recycling and melting process in all types of ferrous alloys and steel 20-22

Slobodan Kostić, Qi Fenglai, Savo Pirgić, Nenad Botić, Dobrica Milovanović, Čedomir Sušić, Igor Zlatković (SERBIA)

Construction of a new sintering plant 180 m² within the HBIS Group Serbia Iron & Steel 23-26

Satyananda Patra (INDIA)

Acid activation of bentonite: Physico-Chemical characterization and application in goethitic iron ore green pelletization 27-35

Ridvan Yamanoglu (TURKEY)

Production of metal-based powders by atomization techniques 36-45

Yong Du, Rainer Schmid-Fetzer, Jincheng Wang, Shuhong Liu, Jianchuan Wang, Qiang Lu, Yuhui Zhang, Kai Li (CHINA, GERMANY)

Computational design of engineering materials: case studies for a cemented carbide and a heat resistant Al alloy 46-46

Conference Papers

Ordinartsev Denis, Nadezhda Pechischeva, Svetlana Estemirova, Andrey Rempel (RUSSIA)

Cr(VI) photosorption on composite sorbent of montmorillonite with amorphous TiO₂ 49-52

Mikhail Korovkin, Ludmila Ananyeva, Andrey Zherlitsyn, Sergey Kondratyev, Olesya Savinova (RUSSIA)

Electro-pulse crushing in high-purity quartz production 53-55

Žarko Radović, Nebojša Tadić (MONTENEGRO)

Analytical simulation of EAF dust enrichment 56-59

<u>Nebojša Tadić, Žarko Radović</u> (MONTENEGRO) <i>Thermal and mechanical relaxation of residual stresses in cold rolled aluminium alloy strips</i>	60-63
Dragan Šabaz, Miloš Stojanović, Dejan Petrović (SERBIA) <i>Selection of anchor type using AHP method</i>	64-67
<u>Miloš Stojanović, Veljko Lapčević, Ivica Vojinović</u> (SERBIA) <i>Blast fragmentation analysis in Jama Bor by using WipFrag software</i>	68-71
<u>Veljko Lapčević, Toma Jovičić, Slavko Torbica</u> (SERBIA) <i>Mine ventilation model validation by PQ survey</i>	72-75
<u>Jelena Đorđević, Jelena Stefanović, Sandra Guševac, Ivan Jelić, Stefan Trujić</u> (SERBIA) <i>Life cycle analysis (LCA) of asphalt layers containing recycled asphalt pavement</i>	76-79
<u>Jelena Ivaz, Dejan Petrović, Predrag Stolić, Mladen Radovanović, Dragan Zlatanović, Saša Stojadinović, Pavle Stojković</u> (SERBIA) <i>Occupational injuries in underground coal mining: statistical analysis of data</i>	80-83
<u>Jelena Ivaz, Dejan Petrović, Mladen Radovanović, Dragan Zlatanović, Saša Stojadinović, Pavle Stojković</u> (SERBIA) <i>Prediction of methane emissions in coalmine - Soko</i>	84-87
<u>C. Prochaska, E. Kokkinos, D. Merachtsaki, A. Lampou, E. Peleka, K. Simeonidis, G. Vourlias, A. Zouboulis</u> (GREECE) <i>Recovery of metallic fractions from medical products labelled for single use</i>	88-91
<u>Nataša Sarap, Marija Janković, Vojislav Stanić, Ivana Jelić, Marija Šljivić-Ivanović</u> (SERBIA) <i>Analysis of gross alpha and gross beta activity in samples around former uranium mine Gabrovica</i>	92-95
<u>Dragan Manasijević, Ljubiša Balanović, Ivana Marković, Uroš Stamenković</u> (SERBIA) <i>Latent heat of some aluminium based phase change alloys for thermal energy storage</i>	96-99
<u>Anđelka Stojanović, Ivica Nikolić, Isidora Milošević</u> (SERBIA) <i>Position of European countries in sustainable resource management</i>	100-103
<u>Aleksandar Đorđević, Duško Minić, Milena Zečević, Dragan Manasijević</u> (SERBIA) <i>Mechanical and electrical properties of the ternary Ag-Ge-Sn alloys</i>	104-107
<u>Milena Zečević, Duško Minić, Aleksandar Đorđević, Dragan Manasijević</u> (SERBIA) <i>Effect of chemical composition on the corrosion resistance of the ternary Ag-Ge-Sn alloys</i>	108-111
<u>Tatiana Aleksandrova, Nadezhda Nikolaeva</u> (RUSSIA) <i>Extraction of low-dimensional structures of nonferrous and noble metals from refractory raw materials</i>	112-115
<u>Viša Tasić, Tatjana Apostolovski-Trujić, Bojan Radović, Nevena Ristić, Tamara Urošević, Vladan Kamenović, Zvonko Damjanović</u> (SERBIA) <i>Air quality measurements in the Bor city during the reconstruction of the copper smelter Bor in 2022</i>	116-119

<u>Slavica Miletić, Biserka Trumić, Suzana Stanković</u> (SERBIA) <i>Application of control charts in the laboratory for testing the metallic materials</i>	120-123
<u>Alexey M. Amdur, Sergei A. Fedorov, Andrey A. Forshev, Nikolay V. Grevtsev, Vera V. Yurak</u> (RUSSIA) <i>Technological aspects of the use of peat as a component of pulverated coal fuel for blast furnaces</i>	124-127
<u>Ljiljana Avramović, Zoran Stevanović, Vanja Trifunović, Radmila Marković, Dragana Božić, Daniela Urošević, Silvana Dimitrijević</u> (SERBIA) <i>Hydrometallurgical treatment of mining waste from Bor - Serbia in aim of copper recovery</i>	128-131
<u>Daniel Kržanović, Radmilo Rajković, Ivana Jovanović, Milenko Jovanović, Miomir Mikić</u> (SERBIA) <i>Determination the final contour of the open pit Veliki Krivelj for the mining capacity 23.1 million tons of ore</i>	132-135
<u>Vladan Marinković, Miroslava Maksimović, Milenko Jovanović, Goran Pačkovski</u> (SERBIA) <i>The use of unmanned aerial vehicles for making the precise 3D topo models and orthophoto images</i>	136-140
<u>Dejan Tanikić, Anđela Stojić, Jelena Đoković, Miloš Stoljiljković</u> (SERBIA) <i>Mechanical characteristics of the shape memory alloy Cu-Zn-Al</i>	141-144
<u>Ljiljana Avramović, Vanja Trifunović, Zoran Stevanović, Radmila Marković, Dragana Božić, Dejan Bugarin, Silvana Dimitrijević</u> (SERBIA) <i>Copper recovery from RE-flotation tailings by combined process</i>	145-148
<u>Milenko Jovanović, Daniel Kržanović, Radmilo Rajković, Vladan Marinković, Miroslava Maksimović, Miomir Mikić</u> (SERBIA) <i>Application of hybrid geogrids in mining</i>	149-153
<u>Stefan Trujić, Miroslava Maksimović, Vladan Marinković, Ljiljana Avramović, Vanja Trifunović, Dragana Božić</u> (SERBIA) <i>Geological exploration of the technogenic deposit - old flotation tailing pit - Bor with the possibility of leaching</i>	154-157
<u>Zoran Stevanović, Radmila Marković, Ljiljana Avramović, Vojka Gardić, Jelena Petrović, Dragana Božić</u> (SERBIA) <i>Sustainable and smart mining</i>	158-161
<u>Snežana Ignjatović, Ivana Vasiljević, Branisav Sretković, Milanka Negovanović</u> (SERBIA) <i>Using gravity data to define structural correlation affecting the formation of Neogene basins</i>	162-165
<u>Deniz Eylül Akpınar, Batuhan Turgut, Ugur Gurol, Savas Dilibal</u> (TURKEY) <i>Characterization of wire arc additively manufactured wear-resistant bimetallic component</i>	166-169
<u>Mistreanu Sebastian, Ramona Cimpoesu, Dragoş Achiţei, Mihai Popa, Daniela Lucia Chicet, Vasile Manole, Ana-Maria Scripcariu, Nicanor Cimpoesu</u> (ROMANIA) <i>Sandblasting process influence on stainless steel cutting element properties</i>	170-174

<u>Dorđe Petrović, Katarina Stanković, Latinka Slavković Beškoski, Ksenija Kumrić</u> (SERBIA) <i>Removal of Cu(II) from aqueous solutions using adsorbent based on chitosan hydrogel beads</i>	175-178
<u>Jovan P. Šetrajčić, Siniša M. Vučenović</u> (BOSNIA AND HERZEGOVINA) <i>Modified basic properties of electrons in layered nanocrystals with a complex lattice</i>	179-182
<u>Irena Nikolić, Milena Tadić, Dijana Đurović, Nevena Cupara, Ivana Milašević</u> (MONTENEGRO) <i>Kinetic and thermodynamic aspects of strontium adsorption by steelmaking slag</i>	183-186
<u>Miomir Mikić, Milenko Jovanović, Sandra Milutinović, Daniel Kržanović, Radmilo Rajković</u> (SERBIA) <i>New flotation plant Veliki Krivelj monitoring plan</i>	187-190
<u>Miomir Mikić, Radmilo Rajković, Daniel Kržanović, Sandra Milutinović</u> (SERBIA) <i>Recultivation of open pit Veliki Krivelj</i>	191-194
<u>Farzet Bikić, Khaola Awad, Halim Prčanović, Mirnes Duraković</u> (BOSNIA AND HERZEGOVINA) <i>Analysis of influenced factors on tropospheric ozone content in the city of Zenica during 2020</i>	195-198
<u>Sandra Milutinović, Ljubiša Obradović, Daniel Kržanović, Miomir Mikić, Radmilo Rajković</u> (SERBIA) <i>Flotation tail storage methods</i>	199-202
<u>Sandra Milutinović, Milena Kostović, Ljubiša Obradović, Srđana Magdalinović, Sanja Petrović</u> (SERBIA) <i>Methods of transportation and discharge of tails to flotation tailings pond</i>	203-206
<u>Uğur Gürol, Ceren Çelik, Müesser Göçmen, Mustafa Koçak</u> (TURKEY) <i>Microstructural and mechanical characterization of armor steel joint welded with sandwich design</i>	207-210
<u>Branka Pešovski, Milan Radovanović, Vesna Krstić, Danijela Simonović, Silvana Dimitrijević</u> (SERBIA) <i>Electrochemical characteristics of the anodized titanium oxide films in sulfuric acid</i>	211-215
<u>Duško Đukanović, Nemanja Đokić, Zoran Aksentijević, Daniel Radivojević, Branisl Stakić</u> (SERBIA) <i>Methane as an untapped energy potential of the "Soko" brown coal mine</i>	216-220
<u>Žaklina Tasić, Marija Petrović Mihajlović, Ana Simonović, Milan Radovanović, Maja Nujkić, Milan Antonijević</u> (SERBIA) <i>Electrochemical methods for the determination of tryptophan and caffeine</i>	221-224
<u>Isidora Milošević, Anđelka Stojanović, Sanela Arsić, Ivica Nikolić, Ana Rakić</u> (SERBIA) <i>Circular economy in the era of Industry 5.0</i>	225-228

<u>Almaida Gigović-Gekić, Elvis Agović, Belma Fakić, Hasan Avdušinović</u> (BOSNIA AND HERZEGOVINA) <i>Effect of delta ferrite on microstructure and hardness welded joints of steel S21800</i>	229-232
<u>Radmila Marković, Dragana Bozić, Zoran Stevanović, Tatjana Apostolovski Trujić, Vojka Gardić, Ljiljana Avramović, Vesna Marjanović</u> (SERBIA) <i>Combining neutralization and adsorption methods for metals removal from Saraka stream</i>	233-236
<u>Ana Petrović, Radmila Marković, Emina Požega</u> (SERBIA) <i>CNTs as potential material for wastewater purification: a review</i>	237-240
<u>Zdenka Stanojević Šimšić, Ana Kostov, Aleksandra Milosavljević, Slavica Miletić</u> (SERBIA) <i>Experimental investigations of CuAlNi alloys with 70 at%Cu</i>	241-244
<u>Ana Kostov, Aleksandra Milosavljević, Zdenka Stanojević Šimšić, Ivan Jovanović</u> (SERBIA) <i>Determination of melt properties in Cu-Fe alloys</i>	245-248
<u>Vladimir Nikolić, Milan Trumić</u> (SERBIA) <i>A simple method of determining of bond work index for finer samples</i>	249-252
<u>Ivan Jovanović, Novica Staletović</u> (SERBIA) <i>Management of risk assessment in environmental protection in surface copper mine</i>	253-256
<u>Jovan P. Šetrajić, Stevo K. Jaćimovski, Siniša M. Vučenović</u> (BOSNIA AND HERZEGOVINA) <i>Possibility of localized electron states appearance in ultrathin layered crystalline structures</i>	257-260
<u>Jovica Sokolović, Ivana Ilić, Dragiša Stanujkić, Zoran Štirbanović</u> (SERBIA) <i>Application of VIKOR method for comparison of the washability of coals</i>	261-264
<u>Vladimir Jovanović, Dejan Todorović, Branislav Ivošević, Dragan Radulović, Sonja Milićević, Marija Ercegović, Slavica Mihajlović</u> (SERBIA) <i>The process of obtaining biochar and the development of the products thus obtained</i>	265-269
<u>Jelena Petrović, Marija Ercegović, Marija Simić, Marija Koprivica, Jelena Dimitrijević, Marija Marković</u> (SERBIA) <i>Mg/Fe-modified hydrochar with promoted adsorption performances</i>	270-273
<u>Esra Dokumaci Alkan, Nurdan Ari, Murat Alkan</u> (TURKEY) <i>A coating application of IN718 via self-propagating high-temperature synthesis method</i>	274-277
<u>Murat Alkan, Esra Dokumaci Alkan, Dilan Ugurluer, Aslihan Karakanat</u> (TURKEY) <i>Production of AlCoCrCuXFeNi alloys via self-propagating high-temperature synthesis method</i>	278-281
<u>Jarmila Trpčevská, Iveta Vasková, Katarína Pauerová, Martina Laubertová, Dušan Oráč</u> (SLOVAKIA) <i>Zinc volatilization in the primary and the secondary zinc production</i>	282-286

<u>Dragan Ignjatović, Lidija Đurđevac Ignjatović, Vanja Đurđevac, Katarina Milivojević, Ivan Jovanović (SERBIA)</u> <i>Application of the numerical method in the definition of a substrate of circular cross section</i>	287-291
<u>Dragan Ignjatović, Lidija Đurđevac Ignjatović, Vanja Đurđevac, Mladen Supić, Dušan Tašić (SERBIA)</u> <i>Influence of the subsoil bearing capacity during formation of high landfills</i>	292-296
<u>Bojana Živković, Jelisaveta Marjanović, Jelena Đokić, Maja Petrović (SERBIA)</u> <i>Soil and rock properties as a basis for the sanitary landfill settings</i>	297-300
<u>Milan Gorgievski, Miljan Marković, Nada Štrbac, Vesna Grekulović, Kristina Božinović, Milica Zdravković, Marina Marković (SERBIA)</u> <i>Adsorption kinetics for copper ions adsorption onto onion peels</i>	301-304
<u>Saba Nourozi, Fatemeh Pourasgharian, Ahmad Khodadadi Darban (IRAN)</u> <i>Recovery of copper from low-grade copper ore using organic acid</i>	305-308
<u>Maria Krasteva (BULGARIA)</u> <i>Methodology and equipment for researching corrosion cracking processes in steel 3H14L (BDS 3692-78)</i>	309-312
<u>Jasmina Nešković, Pavle Stjepanović, Nenad Milojković, Dejan Lazić, Klara Konc Janković, Svetlana Polavder, Ivana Jovanović (SERBIA)</u> <i>Testing the Bond work index on limestone from flue gas desulphurization plant in TPP Ugljevik</i>	313-317
<u>Biljana Zlatičanin, Sandra Kovačević (MONTENEGRO)</u> <i>Impact of titanium addition on microstructure and properties of as-cast Al-Cu15 alloys</i>	318-321
<u>Biljana Zlatičanin, Sandra Kovačević (MONTENEGRO)</u> <i>Effect of cooling rate on mechanical properties of binary Al-Cu23 alloys</i>	322-324
<u>Desislav Ivanov, Irena Peytcheva, Marko Holma (BULGARIA)</u> <i>Horizon Europe AGEMERA project - Agile Exploration and Geo-modelling for European Critical Raw Materials: The potential of Assarel porphyry copper deposit for critical raw materials</i>	325-328
<u>Shehret Tilvaldyev, Uzziel Caldiño Herrera, Jose Omar Davalos, Manuel Alejandro Lira Martinez, Marlenne Alejandra Hernandez Lira, Diego Adan Villordo Melendez (CANADA)</u> <i>Problems of anthropogenic pollution of space</i>	329-334
<u>Mohammed Derqaoui, Abdelmoughit Abidi, Abdelrani Yaacoubi, Khalid El Amari, Omar Oabi, Abdelaziz Bacaoui (MOROCCO)</u> <i>Apatite flotation from low-grade sedimentary phosphate ore</i>	335-338
<u>Nadezhda Kazakova, Alexandar Popov, Georgi Chernev (BULGARIA)</u> <i>Influence of the distribution and content of limestone particles on the properties of blended cements</i>	339-342

<u>Daniel Ogochukwu Okanigbe, Shade Rouxzeta Van Der Merwe</u> (SOUTH AFRICA) <i>Rocks of Obafemi Awolowo University and Environ, Nigeria: structural analysis of geological contact</i>	343-347
<u>Vladan Kašić, Ana Radosavljević Mihajlović, Jovica Stojanović, Slavica Mihajlović, Melina Vukadinović, Nataša Đorđević, Ivana Jelić</u> (SERBIA) <i>Study of thermally treated zeolitic tuffs of Serbia, deposits "Zlatokop" and "Općište"-Beočin</i>	348-352
<u>Vesna Grekulović, Aleksandra Mitovski, Milica Zdravković, Nada Štrbac, Milan Gorgievski, Milovan Vuković, Miljan Marković</u> (SERBIA) <i>Electrochemical behavior of copper in chloride medium in the presence of nettle extract</i>	353-356
<u>Marko Pavlović, Marina Dojčinović, Muhamed Harbinja, Atif Hodić, Dragan Radulović, Mirjana Stojanović, Zagorka Aćimović</u> (SERBIA, BOSNIA AND HERZEGOVINA) <i>Effects of the application of pyrophyllite in the composition of protective coatings</i>	357-360
<u>Tamara Ristić, Nenad Milosavljević, Dobrica Milovanović</u> (SERBIA) <i>Measures for the processing of iron with a higher incoming phosphorus content at the steel shop</i>	361-365
<u>Ivana Mikavica, Dragana Randelović, Milena Obradović, Jovica Stojanović, Jelena Mutić</u> (SERBIA) <i>Microplastic textile fibers in urban soils of Serbia</i>	366-369
<u>Jianbo Zhao, Xinnan Zhao, Donglai Ma, Yang You, Zhixiong You, Xuewei Lv</u> (CHINA) <i>Preparation of ferronickel by semi-molten smelting a mixture of two types of laterite ore</i>	370-374
<u>Mladen Radovanović, Dejan Petrović, Jelena Ivaz, Dragan Zlatanović</u> (SERBIA) <i>Possibility of copper ores exploitation using in situ leaching method</i>	375-378
<u>Ivan Jelić, Nikola Lekić, Nikola Stanić, Miomir Mikić</u> (SERBIA) <i>Selection of an optimal route for relocation of the Čehotina river bed</i>	379-382
<u>Milica Zdravković, Vesna Grekulović, Bojan Zdravković, Nada Štrbac, Milan Gorgievski, Miljan Marković</u> (SERBIA) <i>Electrochemical behavior of steel in 0.1 mol/dm³ HCl in the presence of potato peel juice</i>	383-386
<u>Ivana Marković, Dalibor Jović, Uroš Stamenković, Dragan Manasijević, Ljubiša Balanović, Milan Gorgievski</u> (SERBIA) <i>Microstructure and thermal properties of leaded brass after quenching</i>	387-390
<u>Mehmet Ali Yildiz</u> (SERBIA) <i>Hot strip mill walking beam slab reheating project</i>	391-394
<u>Peter Polyak</u> (SERBIA) <i>Finishing mill automation upgrade at hot strip mill</i>	395-400
<u>Branislav Potić, Ana Arifović</u> (SERBIA) <i>The metallurgical testing results of the boron mineralized material from Valjevo-Mionica basin</i>	401-406

Uroš Stamenković, Ivana Marković, Srba Mladenović, Saša Marjanović, Avram Kovačević, Milijana Mitrović, Filip Basarabić (SERBIA) <i>The influence of quenching media on different properties of C45 carbon steel</i>	407-413
Yang You, Jiabao Guo, Zhixiong You, Xuewei Lv (CHINA) <i>Investigation of the mixing and granulation behavior of iron ore fines in horizontal high-shear granulator</i>	414-417
Jovica Sokolović, Grozdanka Bogdanović, Velizar Stanković, Gracijan Strainović, Ivana Ilić, Milan Gorgievski, Miljan Marković (SERBIA) <i>Investigation on beneficiation of iron from copper ore of Mauritania Copper Mine (MCM) by magnetic separation</i>	418-421
Essen Suleimenov, Rustam Sharipov, Galymzhan Maldybayev, Zhibek Orazaliyeva (KAZAKHSTAN) <i>Investigation of the influence of pulsed electric current on the efficiency of decomposition of aluminate solution</i>	422-423
Lovro Liverić, Tamara Holjevac Grgurić, Sunčana Smokvina Hanza, Wojciech Sitek, Vedrana Špada, Marko Kršulja (CROATIA) <i>Influence of silver content on martensitic transformation of Cu-Al-Ag alloy</i>	424-427
Hasan Ali Taner, Vildan Onen (TURKEY) <i>Evaluation of the efficiency of different collectors in the chalcopyrite flotation</i>	428-434
Vesna Conić, Dragana Božić, Miloš Janošević, Ljiljana Avramović, Vanja Trifunović, Dejan Bugarin, Ivana Jovanović (SERBIA) <i>A pyro-hydrometallurgical process for the recovery of zinc from jarosite waste</i>	435-438
Maria Krasteva, Rumen Petkov (BULGARIA) <i>Research the rate of chemical corrosion of steel 3X14H2 (BDS 3692-78)</i>	439-442
Srba Mladenović, Bojan Novaković, Ivana Marković, Uroš Stamenković (SERBIA) <i>Effect of casting speed and water flow on tensile strength, elongation and microstructure of continuous cast copper wire</i>	443-447
Nadira Bušatlić, Ilhan Bušatlić, Dženana Smajić-Terzić (BOSNIA AND HERZEGOVINA) <i>Dependence of compressive strength of geopolymers based on fly ash and alkaline activator ratio</i>	448-451
Gergana Meracheva, Efrosima Zaneva-Dobranova, Nikolay Hristov (BULGARIA) <i>Hydrocarbon potential of the Lower Paleozoic sediments in NE Bulgaria by geochemistry and well-logging</i>	452-455
Dragana Marilović, Grozdanka Bogdanović, Sanja Petrović (SERBIA) <i>Leaching of flotation tailings with a solution of sulfuric acid and ionic liquid</i>	456-459
Ivana Jovanović, Vesna Conić, Dragan Milanović, Daniel Kržanović, Tanja Stanković, Daniela Urošević, Miloš Janošević (SERBIA) <i>Determination of Bond rod mill work index of a very low-grade copper ore</i>	460-463

<u>Hasan Ali Taner, Ali Aras, Muhammad Hashim Rasa</u> (TURKEY) <i>Investigation of the effect of depressant and collector conditioning times on cobalt recovery by flotation</i>	464-467
<u>Aleksandar Cvetković, Žaklina Tasić, Marija Petrović Mihajlović, Maja Nujkić, Milan Radovanović, Ana Simonović</u> (SERBIA) <i>Microplastics</i>	468-471
<u>Sanja Petrović, Srđana Magdalinović, Ljubiša Obradović, Sandra Milutinović, Bojan Drobnjaković, Slađana Krstić</u> (SERBIA) <i>Tailing management: tailings filtering equipment</i>	472-475
<u>Jelena Stefanović, Jelena Đorđević, Sandra Guševac</u> (SERBIA) <i>XRD analysis of corrosion product formed in industrial aggressive environment</i>	476-480
Muhamad Ghulam Isaq Khan, Filip Rajković, Miljana Popović, Dejan Prelević, Aleksandar Ćitić, Tamara Radetić (SERBIA) <i>Initiation of abnormal grain growth in cold-rolled sheet of AA5182 Al-Mg alloy: role of texture</i>	481-484
<u>Danijela Voza, Hesam Dehghani, Milica Veličković</u> (SERBIA) <i>The dissolved oxygen prediction based on the machine learning techniques</i>	485-488
<u>Hasan Acan, Hasan Ergin</u> (TURKEY) <i>A novel model for minimizing mine closure costs and the optimum final quarry boundry</i>	489-492
<u>Ivana Jovanović, Dragan Milanović, Oliver Dimitrijević, Vesna Conić, Igor Svrkota</u> (SERBIA) <i>Role of wing tank in DMS process. Suspension velocity through the seal leg orifice – case study</i>	493-496
<u>Dejan Petrović, Jelena Ivaz, Saša Stojadinović, Predrag Stolić, Dragan Zlatanović</u> (SERBIA) <i>Risk management and mining machines maintenance – a brief review</i>	497-500
<u>Stefan Đorđievski, Dragana Adamović</u> (SERBIA) <i>History of surface water pollution by mining and metallurgical activities in Bor, Serbia</i>	501-504
<u>Olivera Dragutinović, Vaso Manojlović, Đorđe Veljović, Stefan Dikić, Marko Simić</u> (SERBIA) <i>Investigation of the properties of Co-Cr-W and Co-Cr-Mo alloys coated with hydroxyapatite for use in dental implants</i>	505-509
<u>Zoran Karastojković, Dragoslav Gusković, Ognjen Ristić, Zorica Kovačević</u> (SERBIA) <i>About the “relative plasticity” between steel matrix and non-metallic inclusions</i>	510-513
<u>Aleksandar Jovanović, Mladen Bugarčić, Milena Milošević, Marija Vuksanović, Muna Abdualatif Abduarahman, Miroslav Sokić, Aleksandar Marinković</u> (SERBIA, LIBYA) <i>Modified hybrid cellulose membrane for Nickel(II) ions removal from industrial wastewater</i>	514-517
<u>Elena Todorova, Nadezhda Kazakova, Georgi Chernev</u> (BULGARIA) <i>Structural investigation via SEM analysis of silica hybrid materials</i>	518-521

<u>Tanja Kalinović, Jelena Kalinović, Jelena Milosavljević, Ana Radojević, Snežana Šerbula (SERBIA)</u> <i>Atmospheric bulk deposition as environmental quality indicator</i>	522-526
<u>Gordana Marković, Vaso Manojlović, Miroslav Sokić, Jovana Ružić, Dušan Milojkov (SERBIA)</u> <i>Designing biocompatible high entropy alloys using Monte Carlo simulations</i>	527-530
<u>Tatjana Volkov-Husović, Sanja Martinović, Ana Alil, Milica Vlahović (SERBIA)</u> <i>Application of image analysis for cavitation erosion resistance monitoring of some engineering materials</i>	531-534
<u>Milan Nedeljković, Srba Mladenović, Jasmina Petrović, Milijana Mitrović (SERBIA)</u> <i>Changes in the structure and density of copper during the refining smelting process</i>	535-538
<u>Jasmina Petrović, Srba Mladenović, Ivana Marković, Milan Nedeljković, Milijana Mitrović (SERBIA)</u> <i>Microstructure analysis of EN AW 6061 alloy using a SEM microscope after artificial aging</i>	539-542
<u>Milijana Mitrović, Saša Marjanović, Biserka Trumić, Jasmina Petrović, Milan Nedeljković (SERBIA)</u> <i>Effects of cold rolling and annealing processes on the microstructure and properties of micro-alloyed copper</i>	543-546
<u>Makedonka Dimitrova, Jasminka Dimitrova Kapac (NORTH MACEDONIA)</u> <i>Unlocking energy efficiency: financing preferences for SMEs in the Republic of North Macedonia</i>	547-555
<u>Zoran Štirbanović, Vesna Vojinović, Jovica Sokolović, Maja Trumić (SERBIA)</u> <i>Analysis of the effectiveness of different methods for cutting samples</i>	556-559
<u>Ivica Nikolić, Isidola Milošević, Anđelka Stojanović (SERBIA)</u> <i>Land turnover increases due to mining: An empirical analysis of Bor, Serbia, 2013-2022.</i>	560-563
DONORS	565-590
AUTHOR INDEX	591-596

SELECTION OF ANCHOR TYPE USING AHP METHOD

Dragan Šabaz¹, Miloš Stojanović¹, Dejan Petrović²

¹Mining and Metallurgy Institute Bor, Zeleni Bulevar 35, 19210 Bor, Serbia

² University of Belgrade Technical Faculty in Bor, Vojske Jugoslavije 12, 19210 Bor, Serbia

Abstract

Underground drift construction in underground mines affects the disturbance of the balance that prevails in the primary rock mass. In such an environment, there is a redistribution of stress in the rock medium and the formation of a secondary field stress around the underground drift. Importance of the supporting underground drifts is reflected in the fact that only by installing an optimal support structure, safe conditions can be ensured for the continuation of work. Total installation costs and required installation time can be highly rationalized by choosing the right type of support. Comparison and ranking of anchors in this paper was carried out according to different criteria: stability of the drift, required installation time and costs of support installing. In order to evaluate the precision of the obtained results and to ascertain whether the prescribed support structures imparted requisite safety to the subterranean enclosure, stability analysis was created utilizing Rocscience Phase software. Selection of the optimal type of anchor according to the above criteria was carried out using the Analytic Hierarchy Process (AHP) method. The analysis and evaluation of the obtained results according to the specified criteria was performed using the Expert choice software.

Keywords: *underground mining, drift support, anchor type, AHP method*

1. INTRODUCTION

The natural balance that prevails in the rock mass is disturbed by the construction of underground mining objects. It is necessary to mitigate the resulting changes and establish a state of equilibrium similar to the one that existed before [1]. By installing an appropriate support structure, conditions are created for uninterrupted and safe utilization of the underground objects.

Application of modern techniques and technology in the support installation process, the reliability, stability and speed of constructing of underground objects are increased. In mines around the world, the implementation of anchoring system has proven to be a highly effective method of support. Anchoring system represent a network of embedded anchors within the rock mass, designed to increase the load-bearing capacity of the surrounding portion of the rock mass around the excavated underground object [2].

A universal procedure for selecting elements of anchoring system does not exist yet. For this reason, this paper presents a methodology for selecting the optimal anchor type that can be used in the construction of different shapes and dimensions of the underground objects. The methodology involves comparing and ranking anchors according to several important criteria: stability of the drift, required installation time and costs of support installing.

The adopted shape and size of the cross-section of the drift (dimension 5,3×5,3 m) and the technical characteristics of different anchor types (Swellex, Split Set and SN) were used to define parameters of anchoring system. A stability analysis of underground drift was conducted using the Rocscience Phase 2 software, considering the different anchor type. The time required for installation supporting elements was calculated, after considering all the individual operations involved in the support process.

Additionally, the total installation costs for supporting of 1 m of the underground drift were determined by considering the individual prices of the supporting elements. The results obtained according to the given criteria are shown in Table 1.

Table 1 – The input data for AHP method is defined in accordance with the criteria

Criteria	Parameters	Swellex	Split Set	SN
Supporting system	Anchor diameter (cm)	4,10	3,90	2,00
	Anchor length (m)	3,00	2,80	2,80
	Load-bearing capacity (t)	9,00	7,00	13,00
	Number of anchors in a row (com)	12	16	8
	Wire mesh	100×100×8		
	Thickness of shotcrete (cm)	5	4	6
Stability of the drift	Minimum displacements (mm)	3,00	3,30	2,60
	Maximum displacements (mm)	7,70	8,00	7,40
Installation time	Total installation time (min)	83,51	101,61	124,23
Costs of support	Anchor (din)	12.461,54	10.467,69	14.030,80
	Wire mesh (din)	7.959,69	7.959,69	7.959,69
	Shotcrete (din)	6.242,76	4.995,50	7.498,51
	Total costs (din)	26.663,99	23.422,88	29.489,00

The selection of the optimal type anchor based on the mentioned criteria was performed using the Analytical Hierarchy Process (AHP) method. Method involves evaluating the weight of the criteria and evaluating the types of anchors according to the criteria. The analysis and evaluation of the obtained results according to the mentioned criteria were performed using the Expert Choice software.

2. APPLICATION OF THE AHP METHOD IN THE PROCESS OF SELECTING SUPPORTING ELEMENTS

The AHP method is multi-criteria decision-making method that is used to solve complex problem, which consist of goals, criteria and alternatives. This method enables the interactive creation of a problem hierarchy, which serves as preparation for decision making. Pairs of criteria and alternatives are compared, a synthesis of all comparisons is made and the weight coefficients of all in the hierarchy are determined. The sum of weight coefficients for elements at each level of the hierarchy is 1. For the comparison of individual criteria or alternatives, the Saaty's scale is used, which consists of nine numerical ratings [3]. Decision maker uses ratings to distinguish the intensity of the relationship between the two elements. A hierarchical structure of the multi-criteria decision-making model was created based on the given criteria and alternatives (Figure 1).

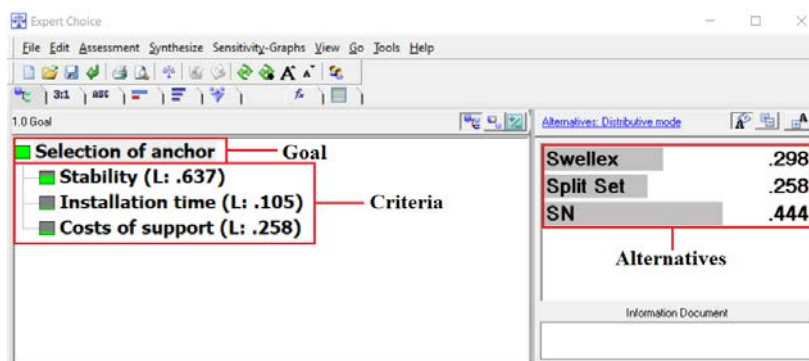


Figure 1 – The hierarchical structure of the multi-criteria decision-making model

The criteria are evaluated by importance and then compared in pairs based on Saaty's scale. After that, the weight of the criteria is determined and consistency is checked (Figure 2).

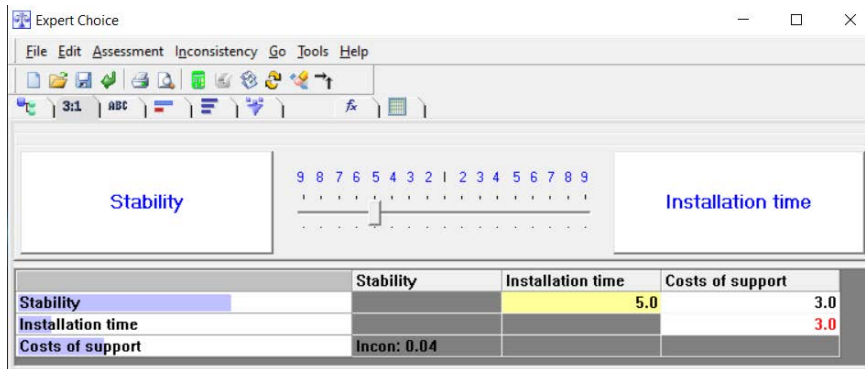


Figure 2 – Pairwise comparison of criteria

Value for pairwise comparisons of criteria is entered into the software, a consistency ratio is obtained ($CR \leq 0,10$). This achieves a more objective assessment of the importance of criteria. In this case, the stability criterion is the most important, followed by cost of support, and finally installation time. The consistency level is below the threshold value, which means that the evaluation is correct.

After defining the weight coefficients of the criteria, it is necessary to define the final hierarchical level of alternatives. The formation of alternatives is carried out by selection in the main Expert Choice window, under the Alternative distributive mode (Figures 3,4,5). By comparing pairs of alternatives based on specified criterion, the weight coefficient of the alternative is determined, based on the data presented in Table 1.

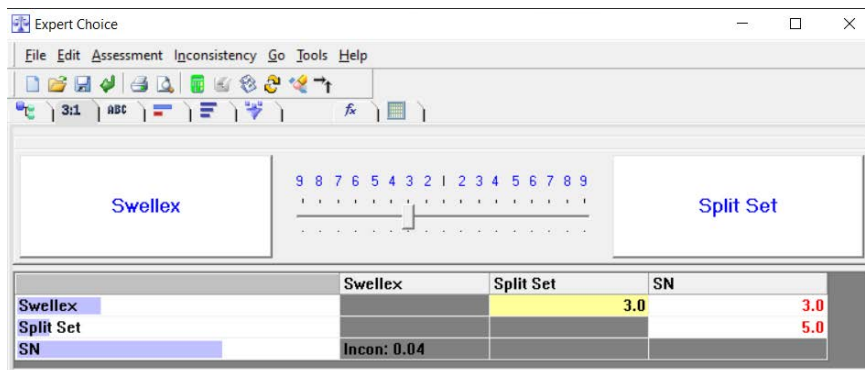


Figure 3 – Pairwise comparison of alternative based on the criterion of stability

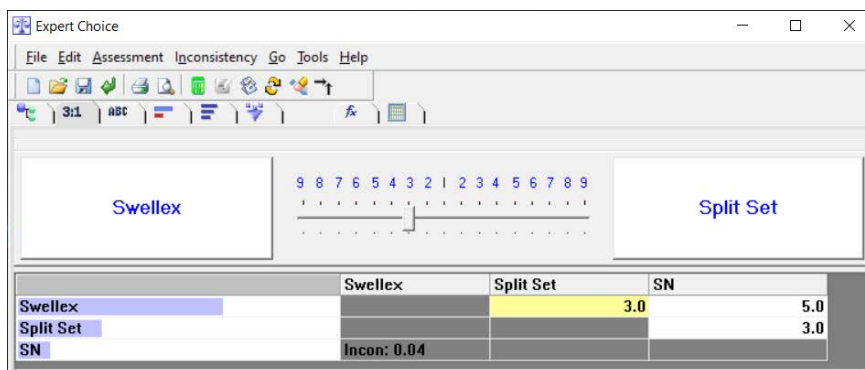


Figure 4 - Pairwise comparison of alternative based on the criterion of installation time

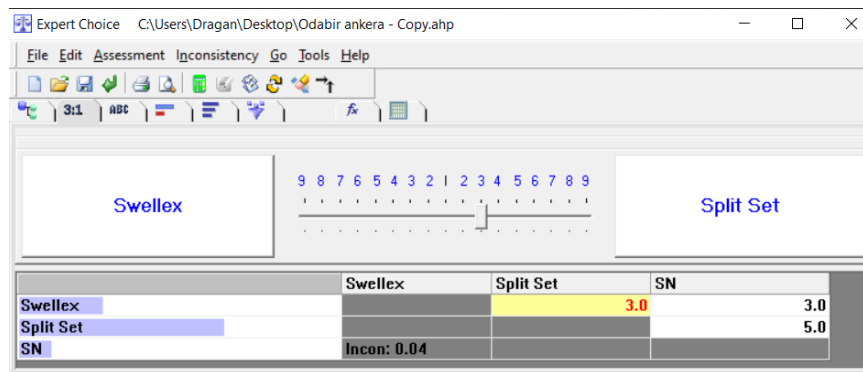


Figure 5 - Pairwise comparison of alternative based on the criterion of costs of support

Based on the previous figures, it is evident that the consistency coefficient is satisfactory in all cases ($0,04 \leq 0,1$). According to the stability criterion SN anchors have proven to be the best choice, while for the installation time criterion Swellex anchors are preferred. The lowest costs were achieved using Split Set anchors.

Considering the obtained results of the relationship between alternatives and criteria, it can be conducted that SN anchors have proven to be the best solution for supporting (Figure 6).

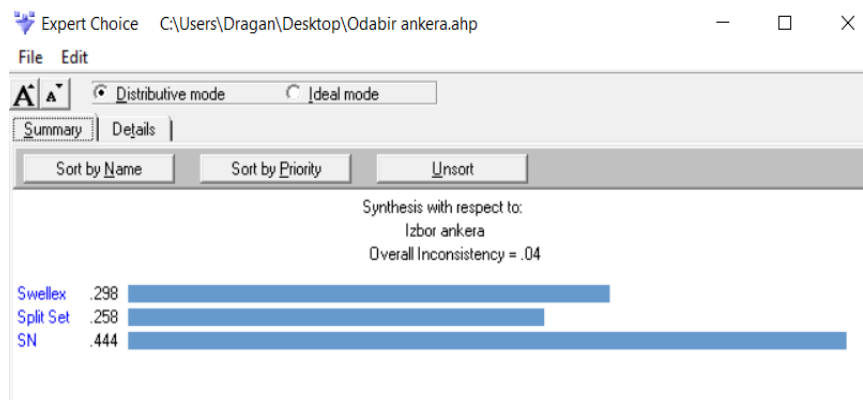


Figure 6 – Comparison of anchors based on three criteria

3. DISCUSION AND CONCLUSION

The selection of the optimal type of anchor for support is complex process. In order to facilitate this decision, the paper presents the application of the analytic hierarchy process (AHP) method. The weight of the criteria has been evaluated and the types of anchors have been evaluated according to these criteria. Based on the results obtained through this method, it has been concluded in the specific case, that using SN anchors achieves the best results for support an underground drift. Therefore, by applying the presented methodology for anchors selection, it significantly influences cost reduction, construction time, and achieves the necessary stability.

REFERENCES

- [1] Kovačević J., Savremeno građenje u podzemlju, AGM knjiga, Beograd, 2014, p.467.
- [2] Milisavljević B., Primena AT višeće podgrade u rudnici Srbije, University of Belgrade – Faculty of Mining and Geology, Beograd, 2015, p.3.
- [3] T.L.Saaty, EJOR, 48(1990) 9-26.

ISBN-978-86-6305-140-9

