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 CONFERNCE

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 - Каталогизација 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

Sistemski zahtevi: 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 Inovation
of the Republic of Serbia

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 Panias *(**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 Oráč *(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 Antonijevic *(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-Blažić *(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 Ćatić *(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 Tomaš Havlik *(Slovakia)*
Prof. Dr Velimir Radmilović *(Serbia)*
Prof. Dr Velizar Stanković *(Serbia)*
Prof. Dr Vesna Grekulović *(Serbia)*
Dr Vladan Ćosović *(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 October18th 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

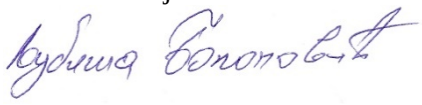

TABLE OF CONTENTS

Plenary Lectures

Invited Lectures

Conference Papers

SUSTAINABLE AND SMART MINING

Zoran Stevanović, Radmila Markovic, Ljiljana Avramovic, Vojka Gardić, Jelena Petrović, Dragana Božić

Mining and Metallurgy Institute Bor, Zeleni bulevar 35, 19210 Bor, Serbia

Abstract
This paper describes a general view of mining and impacts of mineral resources on countries economy. It presents the importance of mineral resources in the development of the country's economy, and the requirements for their sustainable development. Requirements are explained through possible principles, instruments and responsibilities. The main fact considered in this paper is that sustainable and smart mining during transition to low-carbon emissions will be most important issue that will significantly shape the development of mining in the future.

***Keywords**: mining, mineral resources, sustainability, responsibilities, BDP, low-carbon emissions*

1. INTRODUCTION

In more than 100 countries around the world, mining companies exploit minerals and metals out of the ground, satisfying continuously increasing demand from industrial production, agriculture, high-tech sectors, etc. Among those countries are more than 50 that can be considered as "mining countries," well known for the sector's contribution to export earnings. Mining countries also include those where the sector is highly relevant domestically, either because it primarily serves large domestic markets, as in the United States, or because it employs millions of workers, such as in China or India. About 3.9 billion people live in today's 56 "mining countries," 90 percent of them in the 51 developing and transition countries. Among the people in these countries, about 1.5 billion live on less than $2 a day, making up nearly two thirds of the world's poorest population. Their countries have potential mineral wealth, and thus one of the key questions for them is how they can turn this endowment into an economic asset that will help them find ways out of persistent poverty. There is practically no doubt that mining as an industry will continue to expand over the next 20 to 30 years. This especially if the World Bank "The Climate Smart Mining Initiative" for transition to low-carbon emission is taken in consideration.

2. MINING AT A GLANCE

A vibrant mining sector, just as any other sector, should provide significant opportunities for a country's growth (*Mining in Developing Countries – treasure or Trouble.* Mining Department World Bank and IFC, 2002) [1]. Yet there are a number of features that distinguish mining from sectors such as manufacturing or tourism. Mainly this is four most important issues:

- What's under the ground is a national asset. Extractive natural resources have been treated differently from other natural endowments. Many countries consider minerals to be assets belonging to the "public" as a whole. This has resulted either in state ownership of mining companies or in more-than-usual involvement of the state in the licensing of mining companies, the mining regulation, and financial matters including investments in supporting infrastructure.
- A "footprint industry." By its very nature, the mining leaves an environmental, social, and economic impact. However, even when only local or regional in nature, badly managed impacts on the environment or the social fabric of society can reflect negatively on economic parameters countrywide. It is thus important to weigh the benefits against the risks and costs surrounding the industry's operations, and to mitigate any negative impacts.

- A priority area for foreign direct investment. Many developing countries pose high risks for foreign investors. Mining operations, with their export orientation and dollar-based cost and revenues, are often the first ones to present an acceptable risk reward formula to investors.
- A large source of government revenues. A vibrant mining sector tends to generate large fiscal incomes, relative to other sectors. Since in most developing countries large parts of fiscal incomes are export-based, export sectors such as minerals and ores gain more-than proportionate weight for government incomes. In some mining countries, up to 25 or 30 percent of fiscal revenues rely directly on the mining sector.

By registered mineral resources, leading countries worldwide are [2]:
1. Russia – 75 trillion US dollars (coal, natural gas, oil, gold, timber, rare earth metals);
2. United States of America – 45 trillion US dollars (coal, timber, natural gas, gold, copper);
3. Saudi Arabia – 34,4 trillion US dollars (oil, timber);
4. Canada – 33,2 trillion US dollars (oil, uranium, timber, natural gas, phosphate);
5. Iran – 27,3 trillion US dollars (oil, natural gas);
6. China – 23 trillion US dollars (coal, rare earth metals, timber);
7. Brazil – 21,8 trillion US dollars (gold, uranium, iron, timber, oil);
8. Australia – 19,9 trillion US dollars (coal, timber, copper, iron ore, gold, uranium);
9. Iraq – 15,9 trillion US dollars (oil, phosphate rock);
10. Venezuela – 14,3 trillion US dollars (iron, natural gas, oil).

3. MINING CONTRIBUTION INDEX (MCI) TO COUNTRY ECONOMIES

International Council on Mining and Metals (ICMM's) Mining Contribution Index (MCI) synthesizes into a single number – and an associated ranking – the significance of the mining sector’s contribution to national economies.

This provides an indication of the relative importance of mining to the economic life of a country based on four indicators:
1. Exports of minerals including coal as a share of total merchandise exports;
2. The total production value at mine stage of metallic minerals, industrial minerals, and coal, expressed as a percentage of GDP;
3. Mineral rents as a percentage of GDP;
4. Exploration expenditure.

Higher value of MCI shows higher importance of mining to the economic life of a country. Figure 1 shows the Mining Contribution Index Map [3]. As it can be seen on Figure 1, MCI is significantly higher for Russia, Australia and Chile as a countries recognized as “mining developed countries”, reach with mineral resources. One of the main indicators of the mining developed countries is a significantly higher royalties and taxes and consequently higher contribution of the mining sector in GDP.

However, MCI is also very high for lot of developing countries and Africa countries as well. In these cases, even there are not huge, currently registered mineral resources, high MCI indicate dominant impact of mining on country economy, probably due to not developed other industries and presence of foreign investment in mining as explained in Chapter 2. Having on mind that mining will have to develop in the future in strict environmental limits, for the developing Countries is crucial to start sustainable mining development regarding higher mining benefits to the global country economy.

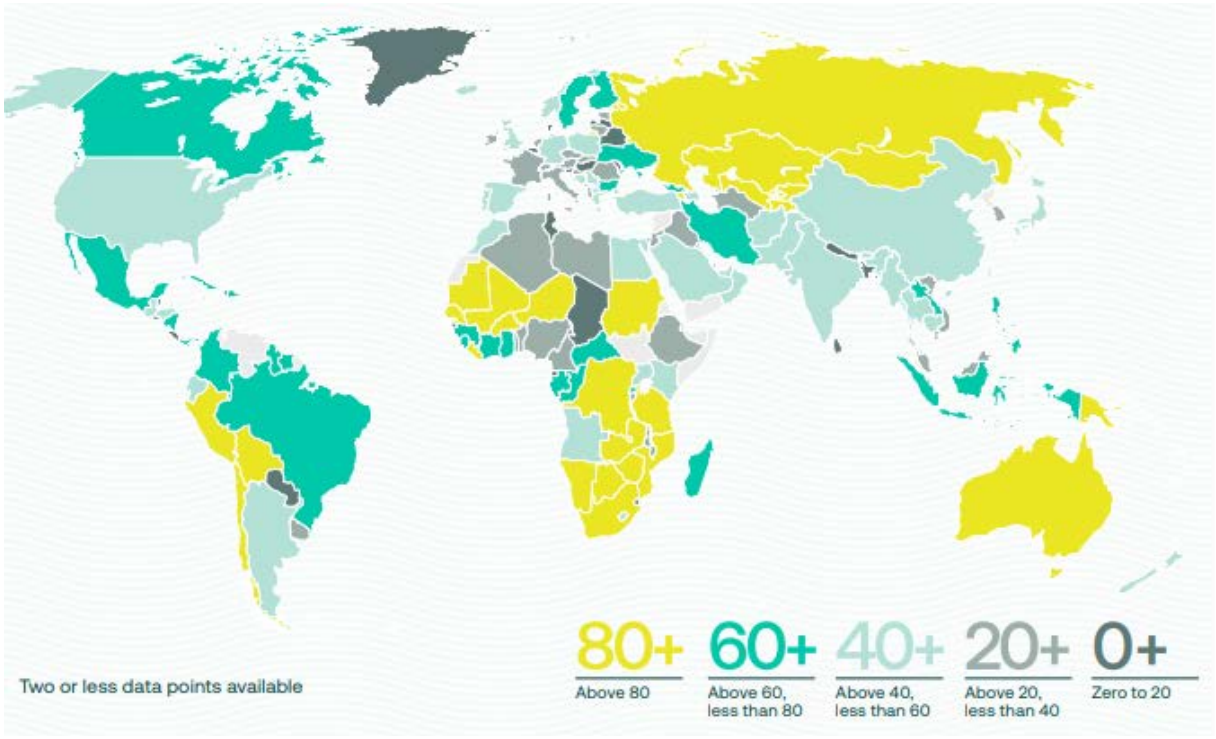

Figure 1 - Mining Contribution Index Map

4. SUSTAINABLE MINING

One of the most used definition of sustainable development linking economic development and environmental stability is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [4]. Albeit somewhat vague, this concept of sustainable development aims to maintain economic advancement and progress while protecting the long-term value of the environment, it “provides a framework for the integration of environment policies and development strategies” (United Nations General Assembly, 1987).

According to above general definition, mining sustainability could be considered on the same way, development of current mining operations without compromising the ability of future generations to develop same operations and live in same conditions as we live now. Principles of mining sustainability are based on integrated development of economic mining activity with environmental integrity and social concerns. The instruments required for environmental integrity are: environments laws, advanced mining technologies, advanced monitoring system and strong bond between mining Companies and State. From the other side, the instruments necessary for social concerns are: effective government systems, royalties and development funds. Objected on effective development on mining integrated sustainability, those instruments must be divided as responsibilities of all stakeholders influential on mining development which are State, Mining Companies, Mining Consulting Companies, Institutes and Certified Laboratories. Above principles, instruments and responsibilities are of the most importance for the development of mining integrated sustainability for developing Countries.

5. WORLD BANK “THE CLIMATE SMART MINING INITIATIVE”

Beside Sustainable mining principles and having on mind climate changes, nowadays is of the crucial importance transition to low-carbon emission industry. A World Bank Group report, "Minerals for Climate Action: "The Mineral Intensity of the Clean Energy Transition," finds that the production of minerals, such as graphite, lithium and cobalt, could increase by nearly 500% by

2050, to meet the growing demand for clean energy technologies [5]. It estimates that over 3 billion tons of minerals and metals will be needed to deploy wind, solar and geothermal power, as well as energy storage, required for achieving a below 2°C future. While the growing demand for minerals and metals provides economic opportunities for resource-rich developing countries and private sector entities alike, significant challenges will likely emerge if the climate-driven clean energy transition is not managed responsibly and sustainably.

Considering this status World Bank launched "The Climate Smart Mining (CSM) Initiative" which will help resource-rich developing countries benefit from the increasing demand for minerals and metals, while ensuring the mining sector is managed in a way that minimizes the environmental and climate footprint. CSM supports the sustainable extraction, processing and recycling of minerals and metals needed to secure supply for low-carbon technologies and other critical sectors by creating shared value, delivering social, economic and environmental benefits throughout their value chain in developing and emerging economies. CSM is a public-private partnership led by the World Bank and IFC with the aim of achieving more sustainable mineral supply chains by providing technical and policy advice, direct investment financing, leveraging private sector financing, providing risk mitigation instruments, and helping countries define and craft tangible solutions for decarbonizing and improving ESG standards for climate action minerals.

ACKNOWLEDGEMENTS

The authors are grateful for funding by the Minister of Science, Technological Development and Innovation of the Republic Serbia, the Grant No. 451-03-47/2023-01/ 200052. Also, this work was financially supported by the EU under Interreg – IPA CBC Romania-Serbia Programme and co-financed by the partner states in the Programme. Project Romania Serbia NETwork for assessing and disseminating the impact of copper mining activities on water quality in the cross-border area (RoS-NET2) eMS code RORS - 337. Also, this work was financially supported by the EU under Program 2nd EIT-HEI call: Building Ecosystem Integration Labs at HEI to foster Smart Specialization and Innovation on Sustainable Raw Materials - HEI4S3-RM.

REFERENCES

[1] M. Weber-Fahr, Mining in Developing Countries – Treasure or Trouble. Mining Department World Bank and IFC Report, Washington, 2002.
[2] D. Elis, Top 10 countries based on natural resources, Mining, Editor: Lanre-Peter Elufisan, January 31, 2022.
[3] Mining Contribution Index (MCI) (6th Edition), International Council on Mining & Metals (ICMM), London, December 2022, p.6.
[4] Bruntland Commission Report, Our Common Future, (United Nations General Assembly, New York, 1987, p. 43.
[5] K. Hund, D. La Porta, T. P. Fabregas, T. Laing, J. Drexhage, Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition, The World Bank Group Publications, Washington DC, USA, 2020, p. 11,12.

AUTHOR INDEX

Đ

E

F

G

H

I

J

K

L

M

N

O

P

R

S

Š

T

U

V

X

Y

Z

Ž

ISBN-978-86-6305-140-9

IOC M&M 2023

IOC M&M 2023

Proceedings IOC M&M 2023

УНИВЕРЗИТЕТ У БЕОГРАДУ
ТЕХНИЧКИ ФАКУЛТЕТ У БОРУ
1961

INSTITUT