

Description Of Underground Mining In Latin America

Christian Adrian Ordóñez Guaycha¹, Fabian Ricardo Ojeda Pardo², Marco Antonio Mejia Flores³

¹Escuela Superior Politécnica del Chimborazo (ESPOCH) <https://orcid.org/0000-0003-0111-8476>

²Escuela Superior Politécnica del Chimborazo (ESPOCH) <https://orcid.org/0000-0003-3192-5084>

³Escuela Superior Politécnica del Chimborazo (ESPOCH) <https://orcid.org/0000-0002-7566-2063>

Abstract

A documentary review was carried out on the production and publication of research papers related to the study of the variable Description of underground mining in Latin America. The purpose of the bibliometric analysis proposed in this document is to know the main characteristics of the volume of publications registered in Scopus database during the period 2015-2020 in Latin American countries, achieving the identification of 169 publications. The information provided by this platform was organized by means of graphs and figures categorizing the information by Year of Publication, Country of Origin, Area of Knowledge and Type of Publication. Once these characteristics were described, a qualitative analysis was used to refer to the position of different authors in relation to the proposed topic. Among the main findings of this research, it is found that Brazil, with 85 publications, is the Latin American country with the highest production. The area of knowledge that made the greatest contribution to the construction of bibliographic material referring to the study of underground mining in Latin America was earth and planetary sciences with 85 published documents, and the type of publication that was most used during the period mentioned above was the journal article, which represents 54% of the total scientific production.

Keywords: underground mining, Latin America, research dissemination.

1. Introduction

Underground mining is the process by which resources are extracted through underground exploitations in which economic, social and environmental aspects must be taken into account since the mining sector is one of those that most needs regulation due to the socio-environmental problems that emerge in its execution, so in Latin America studies must be conducted to identify environmental damage to land and water sources and determine whether these can become permanent. Although underground mining is in search of optimization to obtain as many resources as possible and in the places where these operations are carried out, they generate jobs and stimulate the local economy that help the social development of the community, the impact on the environment must also be taken into account, because although it is a reality that the environment is affected in some way, it is sought that increasingly these processes are more sustainable, achieving a balance between economic development and the protection of natural resources.

Chávez Bernaola (2011) defines underground mining as operations carried out when open pit extraction is not possible for economic, social or environmental reasons, with operating conditions of underground mines which vary depending on the mine according to: type of deposit, method of exploitation, geo-structural, hydrogeological and climatic conditions, age of the mine, ventilation and drainage, etc. This in order to obtain the highest productivity of soil and extracted resources depending on the needs that arise in each mine.

In addition to the aforementioned elements that are part of the execution of the processes related to underground mining, the importance of safety at work must also be taken into account for the companies that carry out this activity, since underground mining is very susceptible to accidents, as studied by Giraldo Paredes (2016) in his article "Identification of factors to reduce rockfall accidents in underground mining", in which he identifies the different situations in which rockfall accidents are caused in underground mining. In his article "Identification of factors to reduce accidents due to rock falls in underground mining", this author identifies the different situations in which accidents are caused by rock falls in underground mining, showing that the main factor that causes these accidents is the lack of continuous training of the actions and conditions of close work for drillers or assistants who have recently started to work. Therefore, it is important to know in terms of bibliographic resources, the current state of research concerning the description of underground mining in Latin America, so a bibliometric analysis of the scientific production registered in Scopus database during the period 2015-2020 is proposed in order to allow answering the question: How has been the production and publication of research papers related to the study of the variable description of underground mining in Latin America during the period 2015-2020?

2. General Objective

To analyze from a bibliometric and bibliographic perspective, the production of high impact research papers on the variable Description of underground mining in Latin America during the period 2015-2020.

3. Methodology

Quantitative analysis of the information provided by Scopus under a bibliometric approach on the scientific production concerning the description of underground mining in Latin America is carried out. Also, it is analyzed from a qualitative perspective, examples of some research papers published in the area of study mentioned above, from a bibliographic approach to describe the position of different authors on the proposed topic.

The search is carried out through the tool provided by Scopus and the parameters referenced in Table 1 are established.

3.1 Methodological design

	PHASE	DESCRIPTION	CLASSIFICATION
PHASE 1	DATA COLLECTION	The data collection is carried out by means of the Search tool in the Scopus web page, by means of which a total of 169 publications are identified.	Published papers whose study variables are related to the Description of underground mining in Latin America. Research papers published during the period 2015-2020. Limited to Latin American countries. Without distinction of area of knowledge. Without distinction of type of publication.
PHASE 2	CONSTRUCTION OF ANALYSIS MATERIAL	The information identified in the previous phase is organized. The classification will be done by means of graphs, figures and	Word Co-occurrence. Year of publication Country of origin of the publication. Area of knowledge. Type of publication

PHASE 3	DRAFTING OF THE CONCLUSIONS AND FINAL DOCUMENT	tables based on data provided by Scopus.	
		After the analysis carried out in the previous phase, the study proceeds to the drafting of the conclusions and the elaboration of the final document.	

Table 1. Methodological design.

Source: Own elaboration (2021)

4. Results

4.1 Co-occurrence of words

Figure 1 shows the co-occurrence of keywords within the publications identified in the Scopus database.

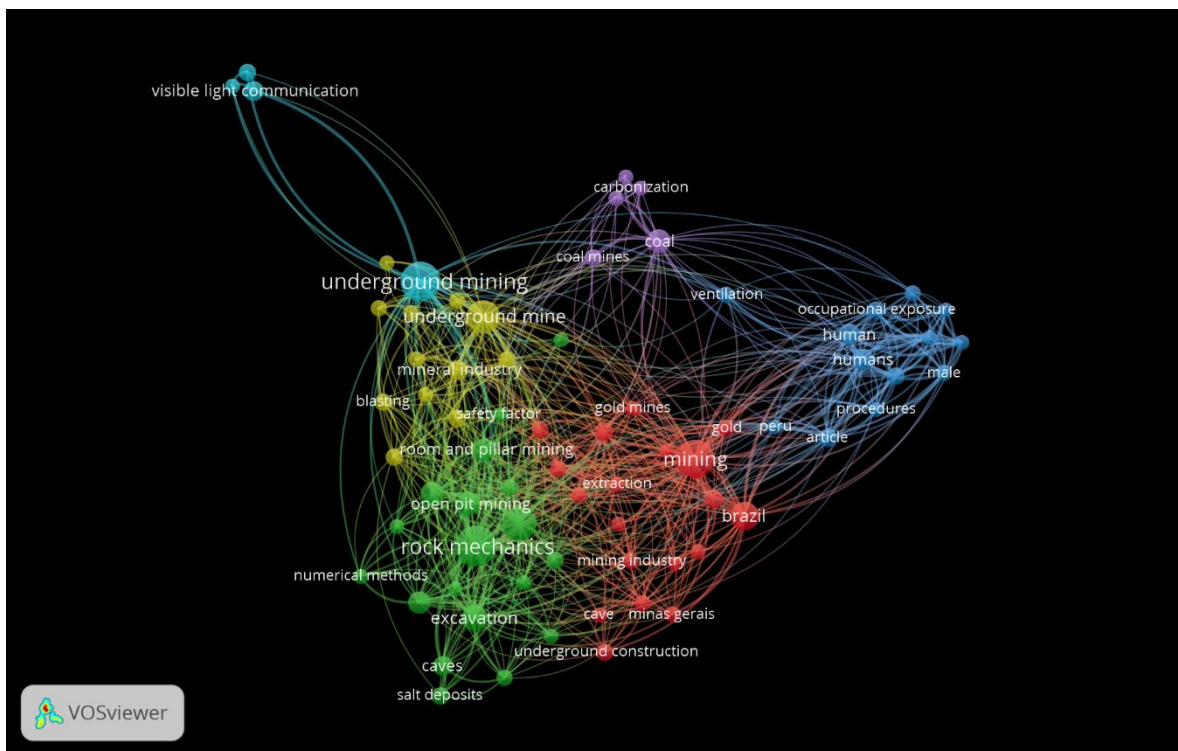


Figure 1. Co-occurrence of words

Source: Own elaboration (2021); based on data provided by Scopus.

As shown in Figure 1, the most used keyword is underground mining which is the main variable of the study and refers to all underground exploitation processes in order to obtain the greatest number of resources mitigating the harmful effects that this can cause in the short, medium and long term. There are keywords such as mining industry, numerical methods, geo-mechanical extraction, rock mechanics, research and mineral resources which refer to the sector to which underground mining belongs and the processes it must go through to comply with the required regulations and ensure a safe execution of these tasks by implementing the study of soil, rocks and mineral resources that become particular needs depending on the mine which are studied which are of great importance to achieve the best use of resources. In the human component there are key words such as occupational exposure, transactional studies, safety factors and procedures which are the safety studies at work that should be carried out as underground mining is susceptible to serious accidents in the execution of their activities, so it is necessary to take into account the high rate of accidents and find ways to mitigate them through training workers preparing them for any kind of mishap that may occur.

4.2 Distribution of scientific production by year of publication.

Figure 2 shows how the scientific production is distributed according to the year of publication, taking into account that the period between 2015 and 2020 is taken.

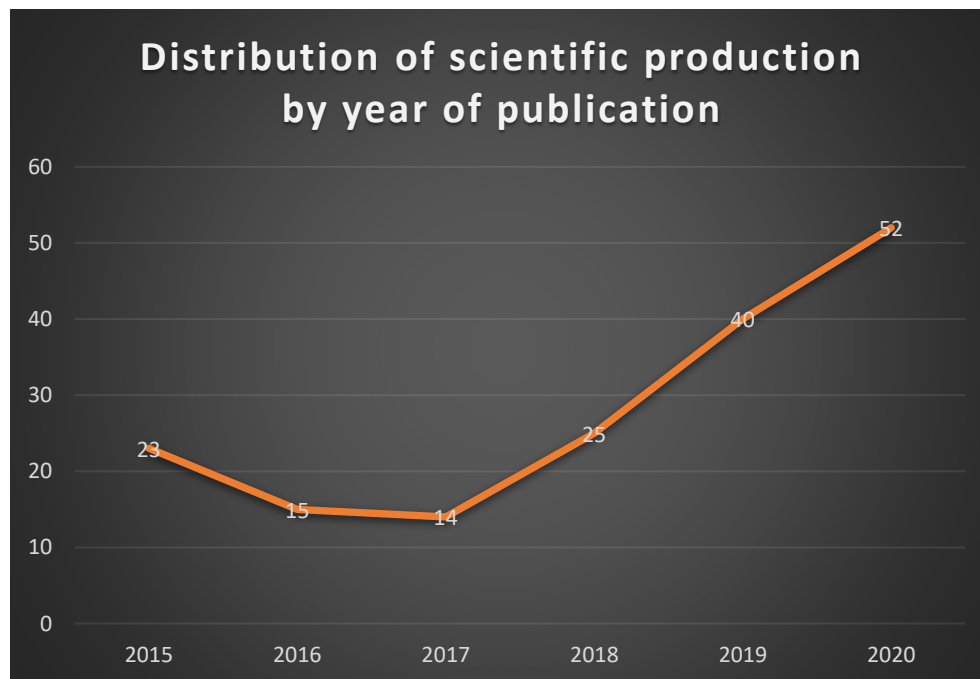


Figure 2. Distribution of scientific production by year of publication.

Source: Own elaboration (2021); based on data provided by Scopus.

2021 is the year with the highest number of publications registered in Scopus in relation to the variables under study having a total of 52 documents within which is “Strategic planning of an underground mine with variable cut-off grades” (Martinelli, Collard, & Gamache, 2020) . In this study, the authors present a model that solves the long-term planning problems of underground mines through a mining sequence for a 20-year horizon starting from the point where a specific cut-off grade must be selected to maximize the net present value proposing different acceleration strategies and a Fix-and-Optimize heuristic. As a result, the quality of the solution found by each method is evaluated and presents the impact of the variable cutoff law. In second place is the year 2019 with a total of 40 papers identified, among which is the title “Optimized ventilation model to improve operations in polymetallic mines in Peru”(Flores, Arauzo, Jara, & Raymundo, 2019) where a system that seeks to avoid the recirculation of stale air or air with toxic gases is proposed, as this causes an increase in ventilation costs and electricity consumption for mining organizations since conventional and practical solutions simply include options such as buying a larger number of fans. So Ventsim software is proposed to develop efficient coverage, routing, flow, circuit characterization and air balancing in conjunction with avoiding stagnation of toxic gases in underground workings which resulted in the reduction of ventilation costs related to electricity consumption.

In third place is 2018 with a total of 25 publications related to the variables under study within which is the document entitled “Extraction of crown pillars in Pino Altos Mine - Geomechanical aspects of risk assessment, design and implementation “ (Kalenchuk, Falmagne, Gelover, Montiel, & Luzania, 2018). This research conducted an extensive study to evaluate the extraction of the crown pillar remaining between the open pit and underground mine workings in which it considered numerous factors influencing mine safety, operations and economics.

4.3 Distribution of scientific production by country of origin.

Figure 3 shows how scientific production is distributed according to the nationality of the authors.

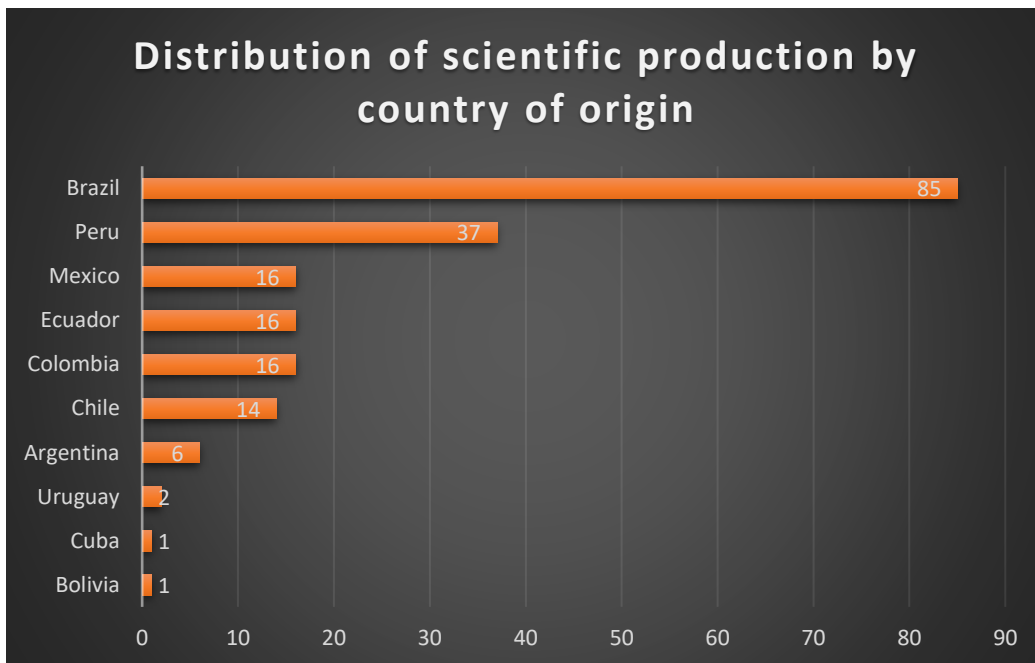


Figure 3. Distribution of scientific production by country of origin.

Source: Own elaboration (2021); based on data provided by Scopus.

Brazil is the Latin American country with the largest contribution to research related to the variables under study having a total of 85 publications, within which is “Geostatistical analysis applied to the estimation of geotechnical parameters-case study: mine Córrego do sítio” (Vilca, et al., 2018) . This document aims to identify the best estimation method to represent the quality of the rock mass, made by extrapolating the geotechnical database of the Córrego do Sítio gold mine of Anglo Gold Ashanti, starting from the premise that geostatistical methods are widely used for the estimation of mineral resources (grade), but only recently have been applied to other types of variables, such as geotechnical parameters. This research presented that the method studied aims to provide better support for mine planning and operation with more reliable stability analyses.

In second place is Peru with a total of 37 papers, within which is the title “Optimized model for pre-cut blasting in mining operations in underground mining in Peru” (Pomasoncco, Trujillo, Arauzo, & Raymundo, 2019). This document explains how, as a consequence of large-scale mineral extraction and a dynamic process of ore conditioning, the different activities of the operation are neglected. These oversights affect structures, generate extra costs, and result in constant rockfall accidents and delays in the mining cycle activities and those that follow. Therefore, this study concludes that by modifying the design of the mine mesh, the blasting method and the type of explosive used, the current scenario and the results could be modified, giving the possibility of reducing maintenance costs in underground mining through pre-splitting blasting.

At this point it is worth noting that the production of scientific publications, when classified by country of origin, presents a special characteristic and that is the collaboration between authors with different affiliations to both public and private institutions, and these institutions can be from the same country or from different nationalities, so that the production of an article with co-authorship of different authors from different countries of origin allows each of the countries to add up as a unit in the general publications. This is best explained in Figure 4, which shows the flow of collaborative works from different countries.

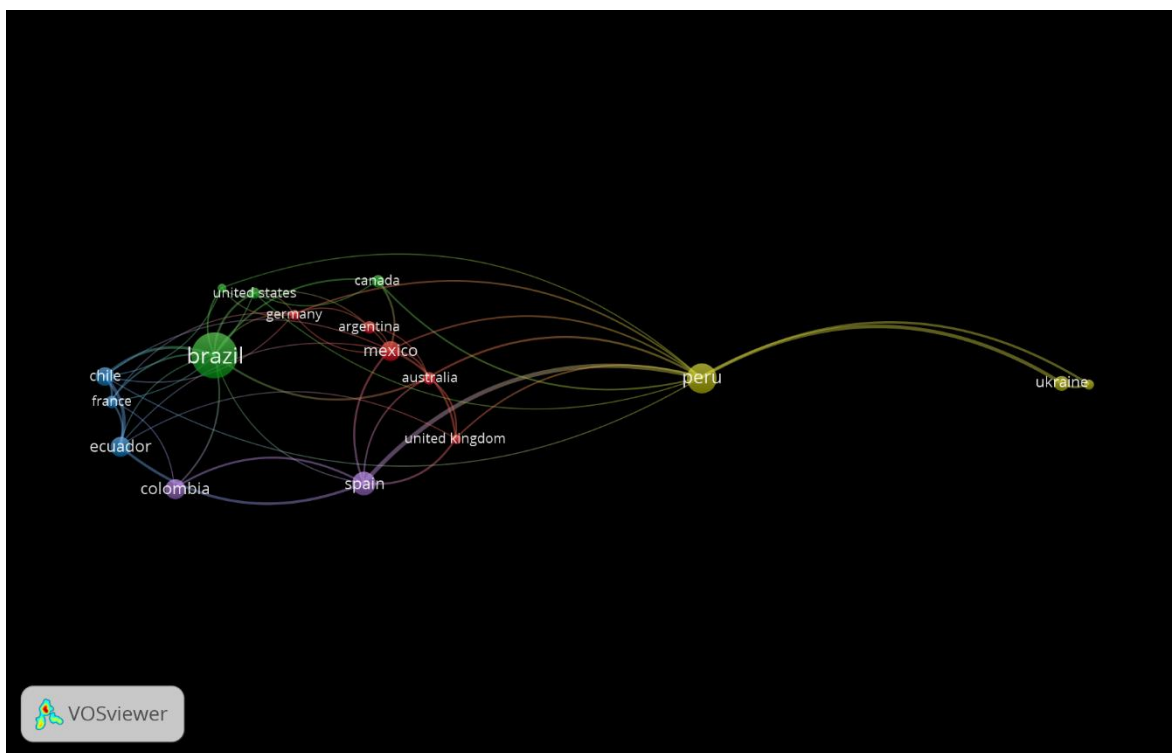


Figure 4. Co-citations between countries.

Source: Own elaboration (2021); based on data provided by Scopus.

As mentioned above, Brazil and Peru are the countries with the highest number of publications registered with authors affiliated to organizations that do not belong to Latin American countries such as Germany, United States and Ukraine. Mexico, Ecuador and Colombia have 16 publications each, presenting publications with Canada, Australia, United Kingdom, France and Spain. In the publications from Mexico is the paper entitled “Analysis and evaluation of risks in underground mining using the decision matrix risk assessment (DMRA) technique, in Guanajuato, Mexico”. (Domínguez, Martínez, Piñón, & Rodríguez, 2019). This article studies the importance of underground mining worldwide, in the Country of Mexico and in the State of Guanajuato, thus generating the hiring of operating personnel to perform the main activities of this sector, so corrective actions are proposed that can help prevent the occurrence of accidents presented, through the application of safety and occupational health standards issued by the Ministry of Labor and Social Welfare, which is

a government entity that is responsible for both the issuance and enforcement of such regulations.

In the papers that belong to Colombia is the paper named “Geotechnical design of pillars in underground gold vein mines in Colombian cases” (Castro-Caicedo, Alejano, Monsalve, & Bernal, 2019). This paper presents an empirical-analytical method for the design of rock pillars in underground gold vein mining in Colombia with the intention of facilitating its adoption by small and medium mining through the observation of existing pillar failure mechanisms from real mines, field surveys, experimental rock mechanics and static analysis.

4.4 Distribution of scientific production by area of knowledge

Figure 5 shows how the production of scientific publications is distributed according to the area of knowledge through which the different research methodologies are executed.

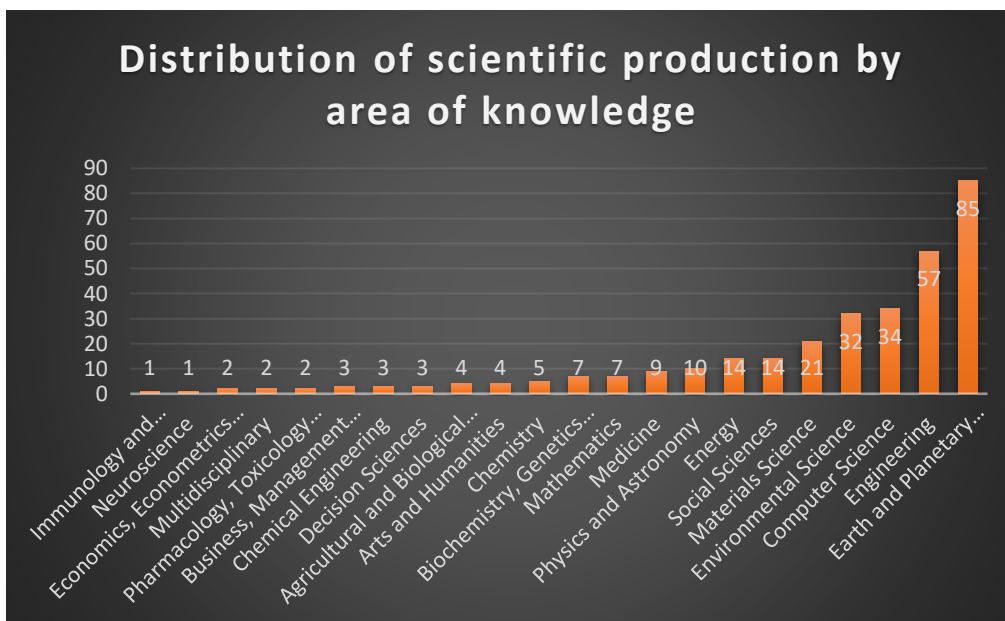


Figure 5. Distribution of scientific production by area of knowledge.

Source: Own elaboration (2021); based on data provided by Scopus.

The area of knowledge with the highest number of registered publications is earth and planetary sciences with a total of 85 papers registered in Scopus, among which is the one entitled “Empirical path loss distribution for visible light communications in underground mines” (Jativa, et al., 2020) . This paper presents visible light communications as an emerging technology to provide reliable communication in hostile environments, such as underground mines so the phenomenon of signal propagation is analyzed, to analyze possible problems with the optical signal, the graphical and numerical results demonstrate the linear behavior of the mining path loss distributions. In second place is Engineering with 57

publications in total, among which is “Cost savings in electrical energy consumption in underground ventilation through the use of ventilation on demand” In which ventilation on demand is presented as a way to reduce electricity expenditure in underground mining which can save up to 31% but taking into account that despite the energy savings that can be achieved by providing air only when/where it is needed, the costs of automation, software and infrastructure make it impractical to apply this technique at a more advanced level.

In third place is computer science with a total of 34 publications registered, among which is “Evaluation of the stability of small diameter mining excavations through geomechanical classifications and empirical analysis: The case of the San Juan mine, Ecuador” (Cuervas-Mons, Jordá-Bordeore, Nazareth, & Escobark, 2015), where the classification of rock masses is raised as it is a methodology for the evaluation of pre-feasibility of the stability of underground openings, so by this study a new empirical table is identified using the previous ones and considering the results of the study presenting the validation of Barton's index for small holes.

4.5 Type of publication

Figure 6 shows how the bibliographic production is distributed according to the type of publication chosen by the authors.

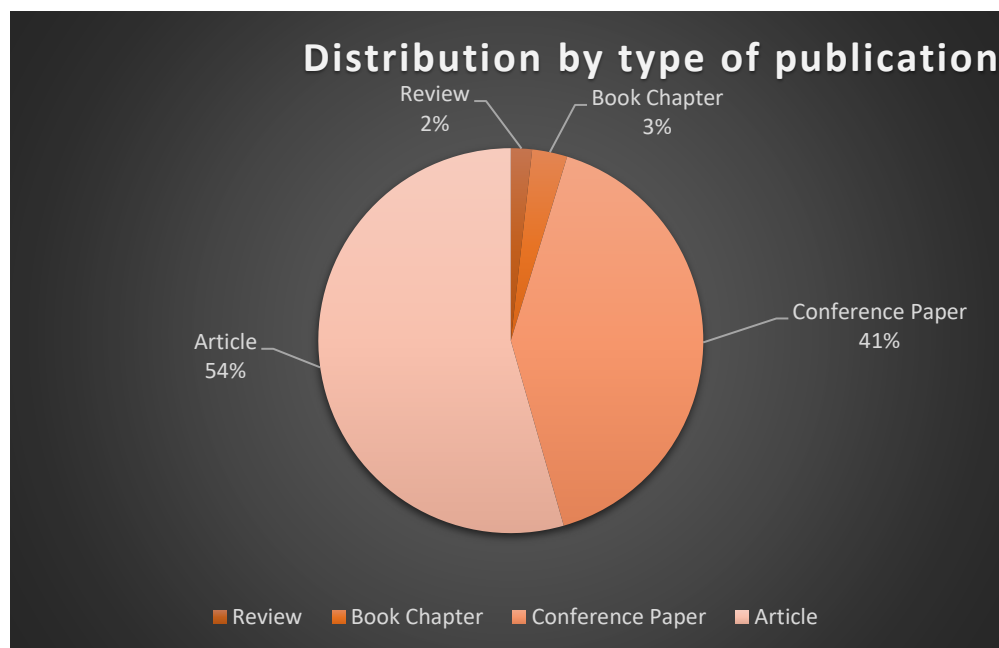


Figure 6. Distribution by type of publication

Source: Own elaboration (2021); based on data provided by Scopus.

As shown in Figure 6, within the different types of publications, 54% of the total number of documents identified through Phase 1 of the Methodological Design, correspond to Journal Articles, among which is the one entitled “Evaluation of the stability of the open stope using artificial intelligence” (Santos, Amaral, Mendonça, & da Silva, 2020). which first defines underground mining as a set of methods that allows the extraction of ore at depth, ensuring sustainability and economic viability, identifying its biggest problem as the stability of open stopes through a stability graph proposed by Mathews in 1981. Therefore, the main objective of this study is to use artificial intelligence techniques, specifically artificial neural networks, to process the data and classify the open stopes according to the stability regions of the graph.

In second place are conference proceedings representing 41% of the total number of papers identified, within which is “Fundamental Criteria of Blasting Engineering Methodology in Grain Mining to Reduce Mineral Dilution in Peruvian Underground Polymetallic Mining” (Fuentes-Rivera-Yon, Arauzo-Gallardo, Raymundo, Mamani-Macedo, & Moguerza, 2020) . This paper analyzes the applicability of an appropriate blast engineering design for an underground mine through an analysis of a mining company's database regarding geological conditions for the classification of the roof and floor box rock massif to determine rock quality, ore grades, vein strength and dilution percentage. In third place is the book chapters with 3% of total registered documents within which is “The concept of mining enterprises advances on the basis of the characteristic of underground coal gasification method” (V., et al., 2019) This book chapter is based on the study of physical and chemical processes of conversion of solids to gaseous state: coal → gaseous fuels so it was established that the main basis of development of mining regions is a mining chemical-energy complex coming to the conclusion that additional energy resources can be obtained by involving segments of alternative forms of energy supply to the life cycle of the mining enterprise.

5. conclusions

Thanks to the bibliometric analysis proposed in this research, it can be determined that Brazil is the Latin American country with the largest number of bibliographic records in Scopus database during the period between 2015 and 2020 with a total of 85 documents. The scientific production related to the study of Management Accounting for Decision Making has presented an important growth during the period previously indicated, going from 23 publications in 2015 to 52 units in 2020, that is to say, the creation of bibliographic records was doubled in a period of 5 years, which indicates the importance of the description of underground mining and the processes that are carried out within them in Latin America for the understanding of the scope of this activity in the communities where it is carried out.

When describing underground mining it is important to consider the economic, social and environmental factors that this activity entails, because although it is a process through which various resources are obtained, it has greater implications than open pit mining as it can cause major damage to the soil. The execution of underground mining depends on the

characteristics of each mine since the procedures and tools to be used must be selected depending on the state of the soil, the type of resource to be extracted and the classification of the rock mass in order to obtain the greatest possible benefit. When studying underground mining, it is also necessary to study the laws that regulate this activity and its implication with environmental legislation, since although it is not possible to avoid damaging natural resources in one way or another, it is possible to try to mitigate these effects, since they are necessary for economic development and also for social development by generating direct and indirect employment in the communities where this activity is carried out, as well as contributing to the dynamization of the local economy.

All of the above allows to conclude highlighting the importance of knowing the theory or bibliographic resources that seek to arouse interest in organizations, to learn more about underground mining and study it from all aspects that concern it which are economic, as a commercial activity to obtain primary resources, social as an important role in social and environmental transformation through the implementation of sustainable measures that seek to harm the environment to a lesser extent. This is why it is important to highlight the need for studies such as the one presented in this document, which make a tour of those texts that address the aforementioned topic, in order to give the reader a broad view of the current situation of the bibliography on the description of underground mining in Latin America.

References

- Castro-Caicedo, A., Alejano, L., Monsalve, J., & Bernal, A. (2019). Geotechnical design of pillars in underground mines of gold veins in cases of Colombia. *DYNA (Colombia)*, 337-346.
- Chavez, H. G. (2011). Total productivity management in underground mining.
- Cuervas-Mons, J., Jordá-Bordehore, L., Nazareno, J., & Escobark, K. (2015). Evaluation of the stability of small diameter mining excavations using geomechanical classifications and empirical analysis: The case of the san Juan mine, Ecuador. *Trabajos de Geologia*, 19 - 28.
- Domínguez, C., Martínez, I., Piñón, P. P., & Rodríguez, O. A. (2019). Analysis and evaluation of risks in underground mining using the decision matrix risk-assessment (DMRA) technique, in Guanajuato, Mexico. *Journal of Sustainable Mining*, 52 - 59.
- Flores, V., Arauzo, L., Jara, J., & Raymundo, C. (2019). Optimized ventilation model to improve operations in polymetallic mines in peru. 4th Brazilian Technology Symposium, BTSym 2018, (pp. 515 - 522). Campinas.
- Fuentes-Rivera-Yon, N., Arauzo-Gallardo, L., Raymundo, C., Mamani-Macedo, N., & Moguerza, J. (2020). Fundamental Criteria for Methodology of Blasting Engineering

- in Mining Grains to Reduce Mineral Dilution in Peruvian Polymetallic Underground Mining. *Advances in Intelligent Systems and Computing*, (pp. 335 - 341). San diego.
- Giraldo Paredez, E. M. (2016). Identification of factors to reduce rockfall accidents in underground mining. *Rev. of the Research Institute (RIIGEO), FIGMMG-UNMSM*, 47-55.
- Jativa, P., Azurdia, C., Roman, M., Zabala-Blanco, D., Seguel, F., & Soto, I. (2020). Empirical Path Loss Distribution for Visible Light Communications in Underground Mines. 2020 12th International Symposium on Communication Systems, Networks and Digital Signal Processing, CSNDSP 2020. Porto.
- Kalenchuk, K., Falmagne, V., Gelover, A., Montiel, I., & Luzania, J. (2018). Crown pillar extraction at Pino Altos Mine - Geomechanical aspects of risk evaluation, design and implementation. 52nd U.S. Rock Mechanics/Geomechanics Symposium. Seattle.
- Martinelli, R., Collard, J., & Gamache, M. (2020). Strategic planning of an underground mine with variable cut-off grades. *Optimization and Engineering*, 803 - 849.
- Pomasoncco, A., Trujillo, C., Arauzo, L., & Raymundo, C. (2019). Optimized model for pre-cut blasting in mining operations in underground mining in Peru. *IMCIC 2019 - 10th International Multi-Conference on Complexity, Informatics and Cybernetics, Proceedings*, (pp. 75 - 80). Orlando.
- Santos, A., Amaral, T., Mendonça, G., & da Silva, D. (2020). Open stope stability assessment through artificial intelligence. *Revista Escola de Minas*, 395 - 401.
- V., F., R, D., Saik, P., Lozynskyi, V., Sulaiev, V., & Cabana, E. (2019). The concept of mining enterprises progress on the basis of underground coal gasification method characteristic. In *Solid State Phenomena* (pp. 137 - 147).
- Vilca, Y., Ortiz, C., Lana, M., Pereira, F., Canabrava, R., Chaves, S., & Lima, T. (2018). Geostatistical analyses applied to estimating geotechnical parameters-study case: Córrego do sítio mine. *Rock Mechanics for Natural Resources and Infrastructure Development- Proceedings of the 14th International Congress on Rock Mechanics and Rock Engineering, ISRM 2019*, (pp. 2926 - 2933). Foz do Iguaçu.
- Alfonso, I., Gómez, C., Garcés, K., & Chavarriaga, J. (2018). Lifetime optimization of wireless sensor networks for gas monitoring in underground coal mining. Paper presented at the 2018 7th International Conference on Computers Communications and Control, ICCCC 2018 - Proceedings, 224-230. doi:10.1109/ICCC.2018.8390462 Retrieved from www.scopus.com

- Almeida, E. P. L., Caldwell, G., Rodriguez, I., Abreu, S., Vieira, R. D., Barbosa, V. S. B., . . . Garcia, L. G. U. (2018). Radio propagation in open-pit mines: A first look at measurements in the 2.6 GHz band. Paper presented at the IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, PIMRC, , 2017-October 1-6. doi:10.1109/PIMRC.2017.8292345 Retrieved from www.scopus.com
- Altamirano-Soto, P., Supa-Urrutia, J., Pehovaz-Alvarez, H., Raymundo, C., Mamani-Macedo, N., & Dominguez, F. (2020). Filling method implementing hydraulic lime for reusing mine tailings and improve sustainability in conventional peruvian underground mines doi:10.1007/978-3-030-50791-6_41 Retrieved from www.scopus.com
- Ammirati, L., Mondillo, N., Rodas, R. A., Sellers, C., & Martire, D. D. (2020). Monitoring land surface deformation associated with gold artisanal mining in the zaruma city (ecuador). *Remote Sensing*, 12(13) doi:10.3390/rs12132135
- Andrade, A. B., Faria, A. R. C., & Rampazzo, P. C. B. (2019). Economic optimization of rib pillars placement in underground mines. Paper presented at the Mining Goes Digital - Proceedings of the 39th International Symposium on Application of Computers and Operations Research in the Mineral Industry, APCOM 2019, 292-299. doi:10.1201/9780429320774-34 Retrieved from www.scopus.com
- Andrade, A. B., & Rampazzo, P. C. B. (2019). Understanding plan's priorities: Short term scheduling optimization. Paper presented at the Mining Goes Digital - Proceedings of the 39th International Symposium on Application of Computers and Operations Research in the Mineral Industry, APCOM 2019, 386-392. doi:10.1201/9780429320774-44 Retrieved from www.scopus.com
- Cuervas-Mons, J., Jordá-Bordehore, L., Nazareno, J. A., & Escobark, K. F. (2015). Evaluation of the stability of small diameter mining excavations using geomechanical classifications and empirical analysis: The case of the san juan mine, ecuador. [Evaluation of the stability of small diameter mining excavations using geomechanical classifications and empirical analysis: The case of the san juan mine, ecuador] *Trabajos De Geologia*, 35, 19-28. doi:10.17811/tdg.35.2015.19-28.
- Curi, P., Gonzales, D., Diaz, G., & Raymundo, C. (2018). Viability analysis method based on the mineral prices for the exploitation of peruvian mineral resources. Paper presented at the Proceedings of the 2018 IEEE Sciences and Humanities International Research Conference, SHIRCON 2018, doi:10.1109/SHIRCON.2018.8593150 Retrieved from www.scopus.com

- da Silva Ribeiro, P. C. P., Oliveira, M. M., & Nelson, P. (2016). Correlation between uniaxial compressive strength and brazilian tensile strength using different rock types. Paper presented at the ISRM VII Brazilian Symposium on Rock Mechanics, SBMR 2016, Retrieved from www.scopus.com
- da Silva, L. A. A. A., & da Silva, A. L. M. A. (2016). The design of rock pillars in underground mines by considering discontinuities. Paper presented at the Rock Mechanics and Rock Engineering: From the Past to the Future, , 2 739-744. Retrieved from www.scopus.com
- Daltro, R. R., Anjos, J. Â. S. A., & Rabelo Gomes, M. D. C. (2020). Evaluation of heavy metals in water resources of the municipality of boquirá, in semi-arid of bahia - brazil [Avaliação de metais pesados nos recursos hídricos do município de Boquirá, no semiárido Baiano-Brasil] *Geociencias*, 39(1), 139-152. doi:10.5016/geociencias.v39i1.14013.
- De Almeida, R. P., Leite, A. D. L., & Borghetti Soares, A. (2015). Reduction of acid rock drainage using steel slag in cover systems over sulfide rock waste piles. *Waste Management and Research*, 33(4), 353-362. doi:10.1177/0734242X15572178. doi:10.1177/0734242X15572178.
- Moreira, A. L. M., Campos, B. I. D. S. S., Campos, P. H. A., Barbosa, V. D. S. B., & Casagrande, P. B. (2020). Comparison of methods to define the final pit-a case study doi:10.1007/978-3-030-33954-8_14 Retrieved from www.scopus.com
- Moreira, C. A., Casagrande, M. F. S., de Siqueira Büchi, F. M., & Targa, D. A. (2020). Hydrogeological characterization of a waste rock pile and bedrock affected by acid mine drainage from geophysical survey. *SN Applied Sciences*, 2(7) doi:10.1007/s42452-020-3021-8.
- Motta, R., Porto, C., Machado, D., & Souto, O. C. (2019). Parametric analysis of the optimal depth of an open-pit gold mine. Paper presented at the Mining Goes Digital - Proceedings of the 39th International Symposium on Application of Computers and Operations Research in the Mineral Industry, APCOM 2019, 264-271. doi:10.1201/9780429320774-30 Retrieved from www.scopus.com
- Munoz Martinez, C. J., Castro Salguero, R., Palomares, R., & Cornejo, J. (2020). Mechatronics development of terrestrial mobile robot for exploring and monitoring environmental parameters at mine analogue sites using IoT platform. Paper presented at the Proceedings of the 2020 IEEE 27th International Conference on Electronics, Electrical Engineering and Computing, INTERCON 2020, doi:10.1109/INTERCON50315.2020.9220227 Retrieved from www.scopus.com

Napa-García, G. F., Câmara, T. R., & Navarro Torres, V. F. (2019). Optimization of room-and-pillar dimensions using automated numerical models. *International Journal of Mining Science and Technology*, 29(5), 797-801. doi:10.1016/j.ijmst.2019.02.003.

Napa-García, G. F., Câmara, T. R., & Torres, V. F. N. (2019). Development and application of a flexible numerical model to evaluate the safety of room-and-pillar mines. *Revista Escola De Minas*, 72(1), 133-139. doi:10.1590/0370-44672018720030. doi:10.1590/0370-44672018720030.