Politechnika Częstochowska
Wydział Zarządzania

Zeszyty Naukowe Politechniki Częstochowskiej. Zarządzanie
Research Reviews of Czestochowa University of Technology. Management

No 51 (2023), pp. 136-145, ISSN: 2083-1560
DOI: 10.17512/znpcz.2023.3.10, https://znz.pcz.pl/

Received: 04.07.2023; Revised: 07.08.2023;
Accepted: 13.08.2023; Published: 30.09.2023.

DATABASE TO IMPLEMENT SMM IN THE MINING SECTOR IN MEXICO

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Abstract: An applied research project is presented, expressed in the design and creation of a database for the company Minera Tierra Adentro (MTA), which belongs to the mining-metallurgical sector of Mexico. This database is designed to implement a Sustainable Management Model (SMM) in the operating units of the sector. The SMM provides an opportunity to observe, measure, and evaluate four Sustainable Development Goals (SDGs) and 16 legislative parameters. Divided into two modules, the database is based, in the first instance covering the territorial sector in Mexico, on an algorithm that represents a qualitative selection technique: pairwise comparison, which allows prioritizing more than 3000 active units, so that MTA offers the implementation of the model. As a second module, the database shows the record of quantifiable elements of the SDGs and legislative parameters collected, This allows, through calculation algorithms, to interpret and express the obtained information in different formats, since by means of an export of data to Excel, the unit staff can use, interpret, include the information in registers, assessments or official documents,

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DOI: 10.17512/znpcz.2023.3.10

such as the Environmental Impact Statement (EIM) requested by government agencies. Therefore, this document presents the interfaces created for the two modules that complement the database in which MTA will manage the implementation of the SMM.

Keywords: mining sector, sustainability, technological innovation

JEL Classification: M140, O320, L720

Introduction

Mining is an important sector in the Mexican economy since Mexico is considered a potent country in the production of both metallic and non-metallic mineral. That is why, faced with an industry that is aggressive with the environment, affects natural environments and even the health of people close to the extraction and metallurgical process, various authors affirm that the legislation in the country is permissive, which places it as a target of political and social conflicts. Regarding the problems involving legislation based on the environment, it is necessary to accelerate strategies that adopt best practices (Azamar & Telles, 2022) and are aligned with international standards.

Environmental Management, a platform in which, through strategic planning, efforts to link with public policy and strategies for the effectiveness of the programs to be implemented could coincide, is considered the implementation of a Sustainable Management Model (SMM), which seeks to evaluate current environmental practices and propose substantial improvements (CEPAL, 2018).

Implementing this SMM in the mining sector in Mexico has an extensive and large-scale dynamic. There are around 3,200 active units in the country (SEMARNAT, 2002), so it is essential to have a database that, with the use of a qualitative technique derived from the theory of creative thinking (Dym & Little, 2015), allows, in addition to having general information on the units, to organize and prioritize it in order to select and propose to its leaders the implementation of the model. It also implies that it will be the appropriate digital platform to safeguard the information obtained from current environmental practices. Once the SMM has been implemented, it will be presented in an orderly manner for a correct interpretation by the evaluators or those responsible for environmental management before the relevant authorities.

For the development of this database, valid and relevant algorithms were required in the search for cohesion of concepts and requirements, which resulted in a database presented in two modules. This strategy, considered in the field of information technology, seeks to innovate the process of selection of mining units and presentation of sustainable findings in the field, through a programmable digital format, to show the relevant authorities the current environmental practices, for compliance and improvement in favor of the guarantee of resources for future generations.

Minera Tierra Adentro (MTA), a Mexican company in the mining sector, promotes research and products derived from it in terms of applicability to the guild and promotes it in agreement with researchers and members of Academic Body 7 (CA for its Spanish acronym), belonging to the Technological Institute of San Luis Potosi.

Literary basis

To achieve optimal classifications and selections, the theory of creative thinking has developed techniques that, depending on the objectives set, can create simple or complex exercises or programs. The *technique of comparison by pairs* is used to optimally select units, based on hierarchizations; it classifies subjective criteria in a systematic way, attempting not to mix goals, functions, means, or restrictions (Dym & Little, 2015).

It is assumed that these could be equal in level for all stakeholders because they have not made an effort to distinguish between them the perceived value. In this way, criteria considered in the previous hierarchy are selected, providing a value or relative importance one by one and ordering them later within a matrix (Dym & Little, 2015).

The *Sustainable Management Model (SMM)* (Martínez et al., 2020) is created expressly for the metallurgical mining sector of Mexico, which participates in efforts at the international level through Sustainability Principles and complies with the requirements demanded by the Mining Law of the country, through observable and evident parameters. It is a model that, due to its foundation, can adhere to the strategic plans of Mexican mining units to strengthen their environmental management. The conservation of a safe, clean, healthy, and sustainable environment is vital for the well-being of human beings and the guarantees offered by the right to enjoy them. The SMM contemplates in its construction, two principal axes:

a) There are four sustainable principles that are valued within the fieldwork, extracted from the Agenda 2030 (CEPAL, 2018): SDG 9 *Industry, Innovation and Infrastructure*, SDG 11 *Sustainable Cities and Communities*, SDG 12 *Responsible Production and Consumption,* and SDG 13 *Life of terrestrial ecosystems*.
b) 16 legislative parameters are observed, which are extracted from the Environmental Impact Manifest (EIM), in which the companies have the obligation to describe in the greatest detail how they will carry out the activities requested (SEMARNAT, 2002): *useful lifetime, technical responsible, nature of the project, dimensions, land use, urbanization of the area, site preparation, construction of works, operation and maintenance, abandonment, use of explosives, waste generation and management, infrastructure for waste management and disposal, abiotic aspects, biotic aspects, and landscape*.

Reffering to technological innovation, defined in 1934 by Schumpeter as new ways in which methods or processes, services, or products are commercialized, technological innovation has been gaining strength in economic growth through the substitution of products or technology. Drucker (2006) posited that innovation must present characteristics of utility, simplicity, conceptuality, and perception to be able to generate value while meeting customer expectations and needs.

Thus, when creating new services and goods, produced by technology, companies also tend to create programs that improve performance through productivity, operation, and decision-making.

A sector exploited by technological innovation is related to the digital industry, which has allowed organizations and companies to innovate their processes, concentrating activities and information in general, under schemes of management models

in digital formats. The use of software defined as ICTs (information technologies) has gestated agility, precision, and flexibility to companies, placing these technological models as strength through progress and impacting the economy (Kijek & Kijek, 2019).

For its part, a database is a collection of related files that allows the management of the information of a company. Each such file can be viewed as a collection of records, and each record is composed of a collection of fields. Each of the fields allows you to carry information on some attribute of a real-world entity. A database is a collection of useful information organized in a specific way (Cruz, 2011).

Companies base their activity on information systems, largely with technological support. The systems are formed by interrelated elements: hardware, software, communications, processes, and people that allow transforming data into information and then into knowledge, making all this available to employees and managers of the organization for decision-making at different levels (INCIBE, 2020).

Within the technical tools used for database development, various programming languages are used: HTML, CSS, JavaScript, PHP, and XAMPP (Gauchat, 2012).

Methodological basis

It is considered a research project that involves a technological innovation within the area of systems programming; the present document handles a mixed approach with explanatory information management, which allows one to demonstrate the interface of the database designed with the systematic, sustainable, and legislative requirements that the MTA company has specified.

Development

The fieldwork carried out is based on the specifications that the MTA company expresses to meet its objectives, so two modules were developed in the database, which allows dosing the information and implementation:

1. Module 1, algorithmic design to prioritize units of analysis through prioritization of qualitative criteria.
2. Module 2, algorithmic design for data concentration that arises from field observations of the unit analyzed according to the environmental practices they perform.

Module 1. Criteria and their levels are classified and a prioritization is made according to them. The expert staff of the company intervenes to carry out this categorization and describes in detail the justification of the arguments.

Considering the metallogenic provinces of the country and the diversity of both metallic and non-metallic minerals, as well as the type of operations for their extraction, are selected, by their nature and availability for fieldwork, division of the various units, corporate to know the financial source, the main and secondary mineral as well as regions that channel the area of expertise of employees and, distance between the unit in question and San Luis Potosi, to consider budgets and profitability.

The criteria and their levels are presented in summary form after documenting them and converting them into algorithms through the programming design (Table 1).

Table 1. Selection criteria

Unit Type	Corporate	Mineral	Trend	Zone	Operation	Distance (km)
Underground Mine	Group--Campaign	Metallic	Cu-Mo-Au	Northeast	Underground mining	≥ 645
Open pit mine	Small Miner	Non--metallic	Zn-Pb-Ag--Cu	Occident	Exploitation Sky Open	< 645 North
Closure stage	Foreign in-vestment	Alloy	Zn-Pb-Ag--Cu	North	Metallurgy	< 645 South
Refinery	Subsidies	Quarries	Ag-Zn-Cu--Pb	North Central		Baja California
			Precious basics	Central East		Peninsula
			Iron deposits	Central West		
				South		

Source: Own study based on research

The development of the system was based on Progressive Web Apps (PWA), which allows working both on the traditional web and on native applications for mobile phones and tablets. Ribas (2018) states that the process of booting a PWA is the most important part because it allows the application manifest to be in JSON format. The manifest allows for up-to-date viewing of the app in places where users typically have native apps.

The Service Workers is based on scripts that allow working in offline channels, by lowering the base elements for the operation of the system, as well as presenting push notifications, which are a combination of CSS, HTML, and JavaScript, and behave like the most used native controls.

Web services are a set of applications or technologies with the ability to interoperate on the Web. They exchange data with each other to deliver services. Rest web services are models with a design based on architectural constraints applied to the components, connectors, and data of a distributed hypermedia system. Rest focuses on functions, constraints on their interaction with other components, and interpretation of data (Ribas, 2018).

The interface resulting from the design of Module 1 of the database shows screens that allow to record information regarding the mining units so that the designed algorithm presents a data table that allows one to identify the optimal unit according to the hierarchical criteria, to request the implementation of the SMM. Figure 1 (a, b and c), correspond to the sequence that the user observes on the screen.

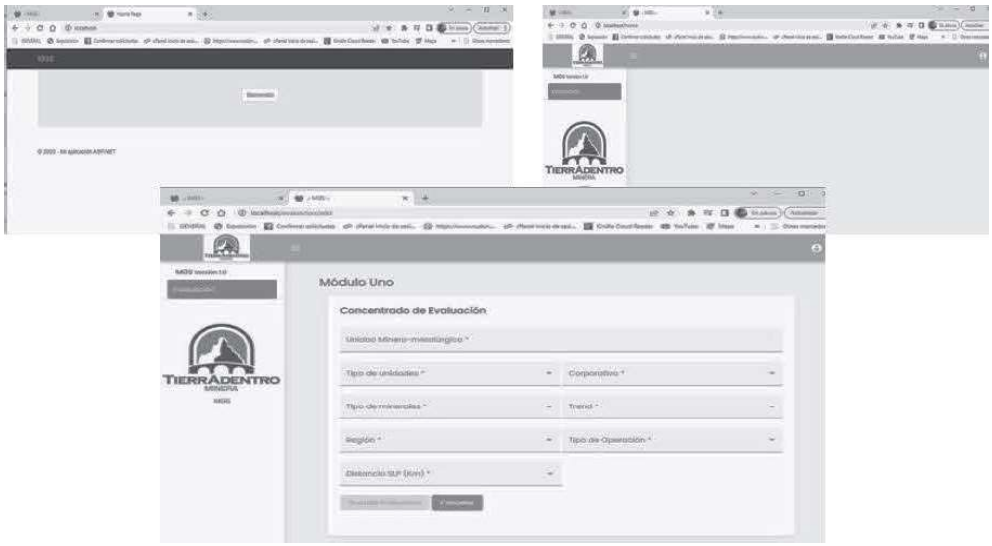

Figure 1. a) User welcome screen; b) Main menu screen; c) Screen to record information of mining units

Source: Own study based on research

The information on the units allows the database to analyze the criteria and yields a calculated value according to the pairwise comparison designed with the algorithms. This is the starting point for the hierarchization of mining units to provide the optimal option for linkage management. Figure 2, allows us to visualize this concentration, which can be exported to Excel so that the user can order and organize according to their needs.

I20

	A	B	C	D	E	F	G	H	I
1	Unidad Minero-metalúrgica	Tipo de unidades	Corporativo	Tipo de Minerales	Trend	Región	Tipo de Operación	Distancia SLP (KM)	Puntaje
2	Ponderación	1	1	4.5	4.5	2	2	6	21
3	El Cubo	0.4	0.3	0.5	0.2	0.025	0.4	0.2	5.9
4		0.4	0.3	2.25	0.9	0.05	0.8	1.2	
5	Compañía Minera Fresnillo	0.4	0.3	0.5	0.2	0.025	0.4	0.3	6.5
6		0.4	0.3	2.25	0.9	0.05	0.8	1.8	
7	Mina San José	0.4	0.3	0.5	0.2	0.025	0.4	0.3	6.5
8		0.4	0.3	2.25	0.9	0.05	0.8	1.8	
9	Compañía Minera Cuzcatlán	0.4	0.3	0.5	0.2	0.025	0.4	0.4	7.1
10		0.4	0.3	2.25	0.9	0.05	0.8	2.4	
11	Unidad Minera Velardeña	0.4	0.3	0.5	0.2	0.025	0.4	0.3	6.5
12		0.4	0.3	2.25	0.9	0.05	0.8	1.8	
13	Refinería Electrolítica de Zinc	0.1	0.3	0.5	0.05	0.025	0.2	0.3	5.13
14		0.1	0.3	2.25	0.225	0.05	0.4	1.8	
15	Unidad Minera Navidad	0.4	0.1	0.3	0.05	0.2	0.4	0.4	5.68
16		0.4	0.1	1.35	0.225	0.4	0.8	2.4	
17									
18									
19									
20									

Concentrado

Figure 2. Information exported to Excel: Decision-making according to the score obtained

Source: Own study based on research

Module 2. Once the mining unit – hereinafter referred to by MTA as the analysis unit – that yields Module 1, is contacted by company personnel (or a subsequent one as they accept the labor and financial agreement) and it accepts the contract, the SMM is implemented through field observations, interviews with personnel, tours, and review of programs, official documents, and various internal records. This information is deposited in Module 2.

Based on the indicators to be measured for the SDGs, quantifiable elements were identified and their corresponding calculations were introduced by algorithms to the database design in Module 2. These basic percentage calculations are exported after being concentrated in a table that adapts to a template prepared expressly in Excel to be manipulated in graphs or descriptions as required by the unit of analysis, and even the government agencies to which reports, records, or official evaluation documents must be presented, such as the Environmental Impact Manifests (EIM).

The development of the programming included a selection of information or dropdowns (legislative parameters), descriptions (text), and registration of quantitative data (calculation of indicators of the SDGs) as main operation functions; this was achieved with a series of instructions embedded in sequences under the CSS code or language that allows the end user to have visual displays on a *webhost.*

Figure 3 represents the interface in which the user records specific information on the indicators that represent each of the four SDGs evaluated in the SMM. Once concentrated, they are exported to the template designed for further interpretation and evaluation. The registration is carried out by SDGs and by legislative parameters, so the implementation is orderly and organized, but systemic, which allows to see the relationship that exists between sustainable elements and inherent legislative parameters.

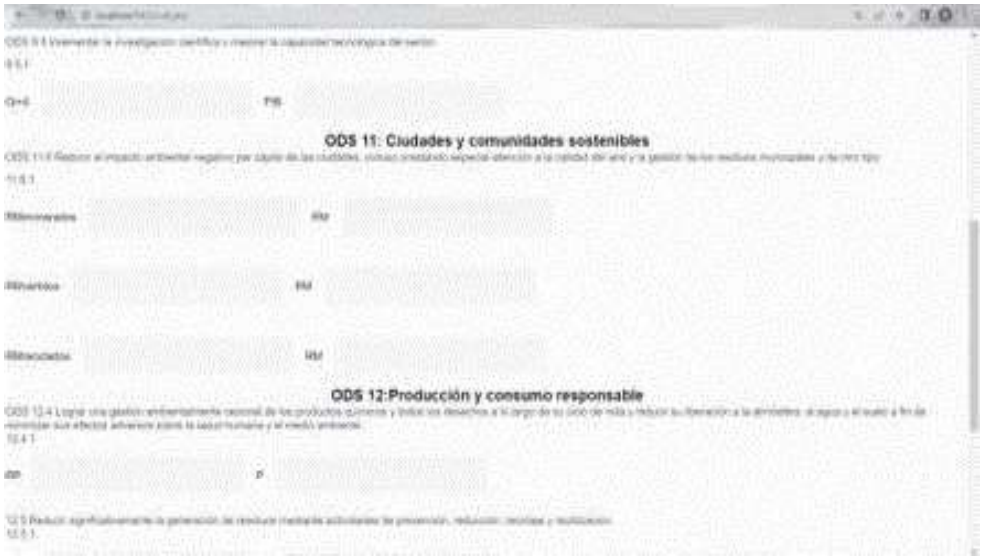

Figure 3. Data registration screens by SDGs

Source: Own study based on research

By performing the export that converted the database into quantitative information regarding SDG´s indicators, a template is obtained that can be used as required by the owners of the environmental process in the analysis unit. The first intention is that it is evidence of compliance with both the international suggestions described in the 2030 Agenda, and the records that the government agency in Mexico, SEMARNAT, through the EIM, requires for the evaluation and issuance of operating permits for the analysis unit.

Figure 4 presents an example of the template once exported to Excel for easy and quick handling of the information obtained from the field, once the SMM has been implemented.

	A	B	C	D	E	F	G	H
1	Grupo Mexico							
2	ODS 9:Industria, Innovacion e Infraestructura							
3	9.2.1							
4	VABmanufact		P	VABmanufact		PIB	Valor añadido del sector manufaturero per capita	$ 1.18
5	1487390		126014000	1487390		1.273E+12	Valor añadido del sector manufacturero en proporcion al PIB	0.000117%
6	9.2.2							
7	POmanufact		PO	EPmanufact		EP	Porcentaje de ocupados en industria manufacturera	15.747%
8	9590000		60900000	9300000		1700000	Empleo del sector manufacturero en proporcion del empleo total	547.059%
9	9.5.1							
10	Gi+d			PIB				
11	54559200000			1.273E+12			Gastos de investigacion y desarrollo en proporcion al PIB	4.286%
12	ODS 11: Ciudades y Comunidades Sostenibles							
13	11.6.1						Proporcion de residuos incinerados	3.239%
14	RMincinerados	RM	RMvertidos	RM	RMreciclados	RM	Proporcion de residuos vertidos	48.578%
15	1487.15	45909	22301.7	45909	10546.1	45909	Proporcion de residuos reciclados	22.972%
16	ODS 12:Produccion y Consumo Responsable							
17	12.4.1							
18	RP			P				
19	7500000			126014000			Total de residuos genrados en la economia per capita	0.06
20	12.5.1							
21	RUR			P				
22	1060000			126014000			orcentaje de residuos reciclados respecto del total de residuos tratado	0.0000230
23	ODS 15:Vida de Ecosistemas Terrestres							
24	15.1.1							
25	SBPST							
26	70.6						Superfice de bosque en proporcion a la superficie total	70.60
27	15.1.2							
28	PLIBT							
29	36.48						Proporcion de lugares para la biodiversidad terrestre y de agua dulce	36.48

Figure 4. SDG´s indicators exported to a template in Excel

Source: Own study based on research

Conclusions

This document presents a database designed for the company Minera Tierra Adentro, which through the service provided to the country's mining sector, seeks to adapt its resources to the development and evolution of science and technology. Through this applied technological innovation project, MTA seeks to evaluate Sustainable Development Objectives and legislative parameters contemplated in a scenario channeled by a Sustainable Management Model.

Due to the characteristics of the SMM and the properties of the mining deposits in the extension of the national territory, the design of modules through which the implementation of the model is systematized was established as particular objectives. The programming carried out in both modules also allows MTA to handle the information in an agile and practical way, allowing it to throw calculated and ordered information, for follow-up and subsequent internal and external evaluations. As an added value, it also enables saving information in the cloud as historical data.

The selection of open-source programming languages and appropriate codes promotes the project as a special application in the area of engineering that endorses technological innovation. This assumption allows medium and small companies to conduct their efforts in large corporations since they compete in achieving productive goals. The standardization of processes operating under management schemes in digital formats, information security when embedded in computer clouds and agility are advantages of labor practicality, which MTA takes advantage of in the search for competitive advantages that contribute to the mining sector so that it is effectively evaluated in the operability of its environmental practices.

This study presents as a partial result the database, leaving in progress the implementation in mining units that require it, leaving therefore, the continuity of this project in several ways, for example, the implementation in each mining unit, describing the sustainable findings, legal and policy reactions; improving the database, in terms of practicality, calculations made, presentation of information.

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Authors' Contribution: As an Academic Body (CA), the authors have participated in this particular project since its inception two years ago: Dr. Rosa Elia Martínez Torres has worked since its foundation in 2012 in the company Minera Tierra Adentro, participation exists from the approach of the project with the Manager, to the implementation and future monitoring; member of the CA. Dr. Patricia Rivera Acosta has collaborated in research since the agreement made between MTA and the Academic Body in 2018 and, in this particular project since it began, participates in its execution; member and leader of the CA. Master Juana María Huerta González provides the foundation and organizes ideas in relation

to the theory and execution of the document; member of the CA. The three researchers participated one hundred percent in this particular project with MTA, in the management, liaison with programmers, and implementation.

Engineer Hugo Saavedra Hernández is the programmer of module 1 (Collaborator of the CA), as well as the student Emiliano Osiel Tello Celestino is the programmer of module 2 (participant of the CA), both under the technical advice of Engineer Juan Antonio Alvarado Cano, specialist Developer and member of the CA; participation in the project is predominantly in the programming and implementation part.

Conflict of Interest: There is no conflict of interest, because the information received from the company Minera Tierra Adentro, is not confidential, but for public use, because it is only a database that will be used for internal administration purposes. The information generated from the implementation will be in files of both the analyzed unit and the MTA under collaboration contracts. The participation of Academic Body 7 of the Technological Institute of San Luis Potosí, covers roles of execution, not of information acquisition. The diffusion of the collaboration that takes place is endorsed by Minera Tierra Adentro, as long as it is declared in terms of knowledge management and its application, both for the mining sector and for the education sector.

Acknowledgments and Financial Disclosure: For the company Minera Tierra Adentro, which represented in the person of the General Director, Engineer Rodolfo Martínez Mendoza, has resources and experience so that the projects derived from the agreement that exists with the education sector, represented by the Academic Body 7 of the Technological Institute of San Luis Potosí, are possible, effective and disseminated in search of better opportunities for both sectors: mining and educational.

BAZA DANYCH DO WDROŻENIA SMM W SEKTORZE GÓRNICTWA W MEKSYKU

Streszczenie: Przedstawiono projekt badań stosowanych, wyrażający się w zaprojektowaniu i stworzeniu bazy danych dla firmy Minera Tierra Adentro (MTA), należącej do sektora wydobywczego. Ta baza danych została zaprojektowana w celu wdrożenia modelu zrównoważonego zarządzania (SMM – Sustainable Management Model) w jednostkach operacyjnych sektora. Model daje możliwość obserwacji, pomiaru i oceny czterech celów zrównoważonego rozwoju i 16 parametrów legislacyjnych. Baza danych, podzielona na dwa moduły, opiera się przede wszystkim na algorytmie reprezentującym technikę selekcji jakościowej: porównanie parami, co pozwala nadać priorytet ponad 3000 aktywnych jednostek, dzięki czemu MTA oferuje wdrażanie modelu. Jako drugi moduł baza danych przedstawia zapis wymiernych elementów zebranych celów zrównoważonego rozwoju i para-metrów legislacyjnych, co pozwala, za pomocą algorytmów obliczeniowych, na interpretację i wyrażenie uzyskanych informacji w różnych formatach, ponieważ za pomocą eksportowania danych do programu Excel personel może wykorzystywać, interpretować i włączać je do zapisów, ocen lub oficjalnych dokumentów, takich jak oświadczenie o oddziaływaniu na środowisko (EIA – Environmental Impact Statement) wymagany przez agencje rządowe. Dlatego w niniejszym artykule przedstawiono interfejsy utworzone dla dwóch modułów, które uzupełniają bazę danych, w której MTA będzie zarządzać wdrożeniem SMM.

Słowa kluczowe: sektor wydobywczy, zrównoważony rozwój, innowacje technologiczne