International Journal for Multidisciplinary Research (IJFMR)

E-ISSN: 2582–2160, Volume 4, Issue 4, July-August 2022

# Mine Planning for Sustainable Development- An approach towards Indian Coal Mining Industry using GIS and Remote Sensing

**Sanjay Kumar. Singh [1], Dr Dheeraj Kumar [2]**

[1] Research Scholar, [2] Professor

Department of Mining Engineering, Indian Institute of Technology (ISM), Dhanbad, India

**Abstract**

The economic development and population growth along with the contradiction of the resources and the environment has become a serious concern in mining regions in India. Sustainable mining practices can protect the environment from these hazardous industrial and human interventions. The aspects and prospects of Indian coal mining industry using GIS and remote sensing has helped in designing a framework concerning sustainable development. Hence, the present research aims towards the integration of sustainable development in coal mining operations along with its optimization, measurement and development using GIS and remote sensing techniques. A descriptive research strategy is followed that evolves designing and describing the mindset of the chosen respondents towards the framework of sustainable mining in India by incorporating techniques like GIS and remote sensing. In order to fulfil these objectives, the study adopts a quantitative research approach by using primary data collection method through a survey method using questionnaires as a research tool. The total sample size in this study that has been approached is between 150 to 200 people. The respondents are the stakeholders and the head committee members. Descriptive analysis and comparative correlation analysis with hypothesis testing have been used for analyzing the results in the study. This study has brought a better understanding of the aspects and prospects of designing a framework concerning the sustainable development for the coal mining industry in India. The challenges evolved in this development have addressed sustainability concerns that have supported the development of coal mine sectors in India. The future work should focus on more techniques for monitoring the environmental status for the development and production of coal mine business in India.

**Keywords:** Geographic Information Systems, GIS, Mining, Sustainability Management, Coal Mining, Remote Sensing

## 1. Introduction

Energy accorded from coal accounts for 55% of the country's gross energy need (Qaisar & Ahmad, 2014, p. 1). Its abundance can play a vital role in meeting the incessant demands of secure energy supply. Besides that, it can be aidful for power generation and for functioning several other industrial applications. The common approach of coal excavation is through surface mining; however, there are a lot of complementary environmental risks associated with it. The crucial issues observed through this undertaking are erosion, loss of biodiversity and climate change (Srikanth & Nathan, 2017, p. 2). The

Environmental Performance Index (EPI), put India at 126th rank from a total of 132 countries. In consequence of that, the attributes of sustainability were introduced in the mining industry and hence the terminology of "sustainable mining" emerged in the year 1998 (Whitmore, 2006, p. 309). Sustainable development is defined as the right of the current generation to reserve resources for the future generation (World Commission on Environment and Development, 1987, p. 8). The sustainable development in the Indian coal sector gives leverage to two main agenda which are maintaining social and environmental welfare. Sustainable mining practices can protect the environment from hazardous industrial and human interventions. Several social needs such as healthcare aid, education, employee safety, wages and so on can be uplifted through the means of sustainable mining (Muduli & Barve, 2013, pp. 224-225). Therefore, upthrusting both environmental and social prosperity is the main agenda of CIL.

The sustainability framework proposed by Coal India Limited (CIL), is unilateral; it commences with materiality aspects which then leads to Key Performance Indicators (KPIs) of sustainability. These indicators are substantial in determining objects and targets for each undertaken mining project. As per the reports published by CIL, there are a lot of components that are indicative of sustainability. The CIL reports attest that the number of trees planted as its part for ecological restoration was 19.9 lakhs and the area brought under ecological observation was 821.5 Ha as of the year 2017-18. The other factor undertaken by Corporate Social Responsibility (CSR) was rural development, child education, health and sanitation and skill development. A lump sum of 483.78 crores was used in carrying out these social causes for the year 2017-18. All of these are major promulgators of social sustainability.

Stakeholders play a crucial role in this endeavour too. The main stakeholders of sustainable mining are the Government (Ministry of Coal), employees, owner of the land, local communities, suppliers, NGO, media and customers. All of these stakeholders are responsible for carrying out sustainability mining. The government is the first in line as it usher's new policies and regulations. The media and NGO are willingly appointed as part of the stakeholder's list to report any misconduct on the locales or communities. Materiality assessment is done by the stakeholders of the organization to compute issues that are of concern. It helps the company in mapping out its future plans. Issues such as economic success, environmental and social sustainability are at the top of their materiality list (Sustainability Report 2017-18, p.  23, 24, 28, 30, 31).

Recently, GIS (Geographic Information System) ventured which allows the researcher to know if the area should be free from non-mining activities. This technique, however, requires vast amounts of data to perform analysis. A lot of the factors like a rock formation, slope and so on are taken into consideration while deducing the analysis. Sustainable mining can have positive aftermath if the process is adhered to in India (Anis, Idrus & Amijaya, 2017, p. 358). Hence, this empirical paper will greatly define new methodologies like remote sensing and GIS technology in order to efficaciously improve the mining practices in India.

## 2. Aims and Objectives

The major aim of the empirical paper is to enhance the current framework of sustainable mining in India by incorporating techniques like GIS and remote sensing. The paper also has accompanying objectives which are stated below:

1. Integrating Sustainable Development in Coal Mining Operations.
2. Optimizing Coal Mine Design for Sustainable Development.
3. Development of a Sustainable Mine Closure framework using Geographic Information System (GIS) and Remote Sensing.
4. Measuring Sustainable Development in the Indian Coal Mining Industry.

## 3. Literature Review

### 3.1. The Coal Mining Industry

Coal has been the major source of primary energy contributing to almost half of the total primary energy in the world. The mining industry has undergone a drastic transformation since the last decade and thus there are several challenges that are posing for this industry. Mining is a critical industry with respect to the economic sectors for countries like Australia, South Africa, Zambia and Mongolia. Many of these mining companies have invested in offset initiatives to help the ongoing problems of environmental hazards and to reduce their Greenhouse Gas Emission (GHG). The mining industry is susceptible to many human and social rights violations and so the industry is constantly under scrutiny. The United Nations (UN) is constantly updating its policies and regulations for the same. Social and environmental concerns are at the forefront of any mining project. Mckinsey produced a report in the year 2015, which displayed that the productivity of the mining industry fell by 28% in comparison to the last decade (Lala et al., 2015, p. 2). The faltering situation of the mining industry has caused an advent of a manifesto of Triple Bottom Line (TBL). The three factors are that of environment, social and economic. The TBL environment has undergone a huge surge in all the tiers of organization and government. The TBL structure is used primarily to reinforce policies and to give options to the company which are capable of impacting sustainability in all the three discussed domains (Lederwasch & Mukheibir, 2013, p. 27).

China, Australia and the US constitute the majority of the coal resources and are responsible for 72% of global coal production. Amid the Paris Agreement; China's coal consumption has catapulted. However, the Road and Belt initiative is speculated to curb the unabating coal demand which will give China the status as a global exporter of coal. Additional challenges faced by these countries are that of unfair usage of tax, climate issues and the industry being swarmed by more than the required amount of workers. If we compare the common shortcoming of other countries with India; India faces a consistent issue of slow economic growth due to which many coal mining projects are being shelved and the other provocation being that of power shortage. The government laws are indicative of two factors; the first being to make India the biggest exporter of coal and the other being that the coal industry is the sole proliferator of energy alleviation. This attribute is unlike in many other countries where they are trying to reduce the emission of coal. All four of these countries are trying to improve their economic standards and prospects of job creation in unison with gaining optimal profit from the same. In India, both mandating new policies and practising it is performed by the Ministry of Coal. The principle goal of this department is to increase the production of coal. A lot of political insinuation is also involved in this industry which makes the coal sector in India more susceptible to regulatory capture. Hence the higher authorities should maintain transparency at all levels and all the stakeholders in the hierarchy of coal mining framework should be held accountable (Blondeel & Van de Graaf, 2018, pp. 90-101). If we deduct an analysis between India and Germany the latter country has strongly adhere to the notion of a green economy. Germany has emerged to be an energy-efficient and green economy while simultaneously maintaining its competitive prices and this is possible solely on the criteria of policies proposed by the government of Europe (Goodman, 2016, pp. 184-193). A review of the above-given information is estimating that India's standing in the international arena in context with sustainable mining falls short and hence requires further assistance by the acquisition of new technologies.

### 3.2. Sustainable Coal Mining Operations and Technologies

There are several new technologies that are being incorporated in the field of coal mining in order to emancipate the sustainability quotient. The technique of gasification that is attracting the organization worldwide. Many agricultural and industrial remnants can be used in a sustainable way. The production of hydrogen and ethanol gases from plastics are the budding technologies from an environmental and economic point of view (Pereira et al., 2012, p. 4754). India can greatly benefit by adopting this particular technique as its production of plastic is on a large scale. Besides this, the technique of remote sensing is also greatly manifested. Remote sensing involves procurement, transmission, processing and extraction of geographic information without getting in direct contact with the surface. The aspect of extreme machine learning (EML) is integral in the exploration of the coal mines. Geospatial applications, the one that involves remote sensing and GIS is instrumental in monitoring natural habitat and to check up on the restoration of land that is affected by coal mining. These techniques can help the mining surveyors from selection of mine sites to exploration and extraction till the closure of the project. Mining can have negative complications and thus analysing the disruption by these activities is extremely important (Bauer, 2000, pp. 146-149). Opencast mining includes soil disruption, coal extraction; this particular technique insinuates maximum dust or air pollution which amounts for 69.9 kg of drugs per day. Drilling, blasting and long means of communication of coals are the progenitors of air pollution (Ghose & Majee, 2000, pp. 259-261) which are facilitated through opencast mining. In India, surface mining is extensively undertaken than underground mining. However, in recent times the underground minerals are also being exhausted. The five parameters that are promoted by sustainability are environment, economics, technology, safety acceptance and utilization. Environmental and economic conditions of several countries have been boosted through the onset of sustainability mining. New technologies have been adopted for the course of sustainability. The future of sustainable mining will be built completely on the paradigm of innovative and state of the art technologies. Technologies like identification of a resource, rock excavation, energy proficient and clean technologies that can have minimum adversaries on the environment will be the general norm of the future. Full utilization of resources, association with ICT and the autonomous system will greatly bring about positive changes in the coal mining industries not only in India but across the globe. The mining industry will be immensely beneficial if it is made to work in harmony with the society and environment. So, a consistent exploration and invention of new technologies along with increasing the mining expenditure will help in keeping up with the fast-paced competitiveness and productivity of the world (Ghose, 2009, p. 6).

### Tentative Questionnaire Format

As per the guidelines mentioned we will follow a mixed approach for the questionnaire. For quantitative questionnaire we will follow a 5-Likert scale wherein we will review questions that will quantify the topics main agenda that is remote sensing and GIS will substantially improve the sustainability stance of India. The Likert scale will range answers from strongly agree, agree, neutral, disagree and strongly disagree. The census of the people will be in the range of from 150 to 200 people.

As a qualitative questionnaire, we will take into consideration several stakeholder's insight and then analyse dependent and independent variables that will subsequently determine the main objectives of the empirical paper.

## 4. Research Methodology

### 4.1. Research Approach

The present research study aims to enhance the current framework of sustainable mining in India by incorporating techniques like GIS and remote sensing. The study adopts a quantitative research approach since the researcher collects data through a survey method using questionnaires as a research tool. The developed questionnaire follows a mixed approach. Two main approaches have been developed in this study to achieve the aims and objective of the paper. The first approach involves the evaluation of sustainability reports by having an interaction with the stakeholders. The frequent visits to the offices for meeting with the management of coal mining sectors has been conducted on a definite basis. The interviews with the head committees have been conducted for preparing report analysis on sustainable development. The second approach will involve the conduction of GIS and remote sensing. The present study involves a quantitative questionnaire that requires the analysis of dependent and independent variables by considering several stakeholder's insights.

### 4.2. Research Strategy

The present research study follows a descriptive research strategy. This research strategy has evolved the designing and describing the mindset of the chosen respondents towards the framework of sustainable mining in India by incorporating techniques like GIS and remote sensing.

### 4.3. Data Collection

In this research, primary data collection methods have been used. The data has been collected through a survey method using questionnaires as a research instrument. Various participants have been selected and the questionnaire set has been distributed among those participants. A 5-Likert scale has been used for developing the quantitative questionnaire. The Likert scale analyzes the questions ranging from strongly agree, agree, neutral, disagree and strongly disagree.

### 4.4. Sampling

The sampling techniques that have been used in the present study involve judgemental sampling (non-probability sampling). The total sample size in this study that has been approached is between 150 to 200 people. The respondents are the stakeholders and the head committee members.

### 4.5. Research Tools and Techniques

The present study involves site selection, data collection, and GIS analysis and remote sensing for developing the sustainability framework. The mapping and indexing models have been used for monitoring and validation of the sites and industries. The statistical and comparative correlation analysis have been implemented for analyzing the result of the given study.

**5. Findings and Discussion**

The major finding of the current study has been analyzed from the data analysis o to reach the objective of the study. Descriptive analysis and comparative correlation analysis have been here for analyzing the results in the study. The collected data has been reviewed from the survey conducted by using questionnaires. The collected quantitative data is analyzed by using the SPSS tool. The major findings of the current study have evolved the analysis including descriptive statistics and hypothesis testing which has been elaborated below.

**Descriptive Statistics**

The descriptive statistics has been analyzed from the quantitative data collected from the survey conduction involving the respondents.

The type of coal mines being used have been analyzed (Table 1, Figure 1). It has been observed that almost 70.8% of the respondents have found underground mines. Remaining 29.2% of the respondents have found opencast coal mines.

The gender analysis has also been determined and it has been observed that almost 56.6% of the respondents are males and the remaining 43.4% of them have been found to be females (Table 2, Figure 2).

Also, the age group of the individuals have been analyzed and it has been found that 40.7% respondents belong to the age group consisting 51–60 years. Almost 30.1% respondents belong to the age group consisting 41–50 years. These both age groups of people have been found to be dominant among the respondents (Table 3, Figure 3).

The educational level has also been determined. It has been analyzed that almost 47.8% of the respondents have the bachelor degree as their educational qualification. 15% of the respondents have an educational level of master degree and above. 29.2% of them have intermediate as their educational qualification. Remaining 8% of the respondents have high school or less as qualification level (Table 4, Figure 4).

The annual income of the respondents has been analyzed (Table 5, Figure 5). It has been found that almost 40.7% of the respondents have an annual income ranging between 500,000–700,000. This range of annual income has been considered as the maximum income among most of the respondents.

The marital status has been also determined and it has been found that 86.7% of the respondents are married. The remaining 8.8% of them are single and only 4.4% of the respondents are divorced (Table 6, Figure 6).

Different statements have been also analyzed by descriptive analysis implicating descriptive statistics (Table 7–11). It has been observed that the statement "The produces an environmental report (either as part of a financial report, a sustainability report or as a stand-alone document)" is analyzed for descriptive statistics with estimation of mean value to be high as 3.86 and standard deviation to be 0.46. Another statement "There is a programme of research and development in innovative environmental technologies in the key environmental impact areas in order to improve operational performance" consist of mean value with lower range as 3.5 along with 0.86 as standard deviation.

The statement "Compliance with legislation" has been estimated with mean value of higher range as 3.85 and standard deviation to be 0.63. On the other hand, the statement "Enhanced shareholder value" has been estimated to have mean value to be low as 3.6 with 0.74 to be standard deviation.

The statement "Correlate each impacting factor and each mining environmental component with a weighted value to reflect the level of impact" has been analyzed and it has been observed that the high mean value of this statement is high as 3.82 with a standard deviation to be 0.7. Another statement "Mine closure planning and mine reclamation is the best practice toward sustainability" has been estimated to have a mean value to be low as 3.51 and 0.88 to be standard deviation.

The statement "Apply for mining permits" has been observed to have a high mean value to be high as 3.82 with a standard deviation to be 0.67 and the statement "Improve community education" constitutes a low mean value 3.51 with 0.86 as standard deviation.

The statement "Remote sensing data enables the identification, delineating, and monitoring of pollution sources and affected areas, including derelict land, and changes in surface land use and to water bodies" has been observed to have a mean value to be high as 3.80 and standard deviation to be 0.64. Another statement "Comprehensive, real-time and abundant information source of mine ecological environment can be acquired through processing of remote sensing image" has a mean value to be low as 3.45 with 0.91as standard deviation.

The statement "Factors that have influenced the mining company in adopting business strategies to address Sustainable Development" has been analyzed to have high correlation coefficient and the statement "Sustainable Coal mining operations and technologies" has low correlation coefficients that has been analyzed to be statistically significant.

**Hypothesis Testing**

The hypothesis testing has been done by applying a one-sample T-test using SPSS. Following are the hypotheses that have been formulated and tested for obtaining the major objectives of the study.

**H1:** There is a significant difference in responses regarding sustainable Coal mining operations and technologies.

The hypothesis 1 represents the significant difference in responses regarding sustainable Coal mining operations and technologies. The T value corresponds to the mean difference between the sustainable coal mining operations and technologies and a fixed mean value of 3 was 24.879. The result of the T-test revealed that, the p-value is less than 0.05 which implicated to reject the null hypothesis representing that there is significant difference in responses regarding sustainable Coal mining operations and technologies (Table 13).

**H2:** There is a significant difference in responses regarding factors that have influenced the mining company in adopting business strategies to address Sustainable Development.

In hypothesis 2, T value corresponds to the mean difference between adopting business strategies and a fixed mean value of 3 was 25.767. The result of the T-test revealed that, the p-value has been found less than 0.05 representing to reject the null hypothesis, concluding that there is a significant difference in responses regarding factors that have influenced the mining company in adopting business strategies to address Sustainable Development (Table 14).

**H3:** There is a significant difference in responses regarding Optimizing Coal Mine Design for Sustainable Development.

In hypothesis 3, T value corresponds to the mean difference between the optimizing coal mine design and a fixed mean value of 3 was 18.7. The result of the T-test revealed that, the p-value is less than 0.05 implicating the acceptance of hypothesis and representing that there is a significant difference in responses regarding Optimizing Coal Mine Design for Sustainable Development (Table 15).

**H4:** There is a significant difference in responses regarding Implication of GIS in mining.

In hypothesis 4, T value corresponds to the mean difference between the implications of GIS in mining and a fixed mean value of 3 was 20.369. The result of the T-test revealed that the p-value has been observed to have less value than 0.05 which shows the acceptance of hypothesis and revealing that there is a significant difference in responses regarding implications of GIS in mining (Table 16).

**H5:** There is a significant difference in responses regarding application of remote sensing technology in mining.

In hypothesis 5, T value corresponds to the mean difference between the application of remote sensing technology and a fixed mean value of 3 was 17.569. The result of the T-test revealed that the p-value is found to have less value than 0.05 which represents the acceptance of hypothesis, concluding that there is a significant difference in responses regarding application of remote sensing technology in mining (Table 17).

## 6. Significance of the Study

The present research aims towards the integration of sustainable development in coal mining operations along with its optimization, measurement and development using GIS and remote sensing techniques. This study has brought a better understanding of the aspects and prospects of designing a framework concerning the sustainable development for the coal mining industry in India. The challenges evolved in this development have addressed sustainability concerns that have supported the development of coal mine sectors in India. Also, economic performance of the coal mine industries have paved new ways for more production in the business of coal mining. The implementation of this study has further provided ideas along with the agendas and planning to enhance the production of coal business. This would eventually support the economy of the country and would lead a new goal towards sustainable development.

## 7. Conclusion

The aspects and prospects of Indian coal mining industry using GIS and remote sensing has helped in designing a framework concerning sustainable development. The economic development and population growth along with the contradiction of the resources and the environment has become a serious concern in mining regions in India. Concerning this, evaluation and monitoring of the geographical environment of these regions should be done. The present study has depicted the current scenario of the coal mining industries in India that mainly focus on the industrial outlook and basic approach regarding the coal India limited. The study has analyzed the risks and challenges which have been faced by the coal mining industries. These challenges and risks have led towards the addressing of some sustainable concerns which eventually helped in the development of coal production business in India.

Hence, framework for sustainable development in coal mining industries have been implemented by evaluation criteria constituting different modules. The planning and strategy for development of coal mine business has been operated in the form of sustainable development in three ways including operational mines, closed mines and coal mines projects. The involvement of the stakeholders and other mine management systems has played an important role in coal mining sectors.

Also, the standard practices using remote sensing tools and GIS methods have been also studied for monitoring the mining activities. The remote sensing techniques and GIS assessment has provided important information regarding the geographical areas that have helped in monitoring and evaluating the environmental status of the Indian coal mines. The future work should focus on more techniques for monitoring the environmental status for the development and production of coal mine business in India.

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**Appendix**

**Tables**

Table 1: Type of Coal Mines

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Underground Coal Mines | 80 | 70.8 | 70.8 | 70.8 |
| | Opencast Coal Mines | 33 | 29.2 | 29.2 | 100 |
| | **Total** | **113** | **100** | **100** | |

Table 2: Gender

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Male | 64 | 56.6 | 56.6 | 56.6 |
| | Female | 49 | 43.4 | 43.4 | 100 |
| | **Total** | **113** | **100** | **100** | |

Table 3: Age Group (Which age group are you in?)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | 21 - 30 Years | 7 | 6.2 | 6.2 | 6.2 |
| | 31 - 40 Years | 10 | 8.8 | 8.8 | 15 |
| | 41 - 50 Years | 34 | 30.1 | 30.1 | 45.1 |
| | 51 - 60 Years | 46 | 40.7 | 40.7 | 85.8 |
| | > 60 years | 16 | 14.2 | 14.2 | 100 |
| | **Total** | **113** | **100** | **100** | |

Table 4: Higher Level of Education (Your highest level of education?)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | High School or Less | 9 | 8 | 8 | 8 |
| | Intermediate | 33 | 29.2 | 29.2 | 37.2 |
| | Bachelor Degree | 54 | 47.8 | 47.8 | 85 |
| | Master's Degree and Above | 17 | 15 | 15 | 100 |
| | **Total** | **113** | **100** | **100** | |

Table 5: Income per Year (What is your income per year?)

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | 100,000 and Less | 12 | 10.6 | 10.6 | 10.6 |
| | 100,001 - 300,000 | 6 | 5.3 | 5.3 | 15.9 |
| | 300,001 - 500,000 | 32 | 28.3 | 28.3 | 44.2 |
| | 500,000 - 700,000 | 46 | 40.7 | 40.7 | 85 |
| | 700,001 and Above | 17 | 15 | 15 | 100 |
| | **Total** | **113** | **100** | **100** | |

Table 6: Marital Status

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| **Valid** | Single | 10 | 8.8 | 8.8 | 8.8 |
| | Married | 98 | 86.7 | 86.7 | 95.6 |
| | Divorcee | 5 | 4.4 | 4.4 | 100 |
| | **Total** | **113** | **100** | **100** | |

Table 7: Descriptive Statistics

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| The company has an economic impact on the local communities where it operates. | 113 | 1 | 5 | 3.7522 | 0.76217 |
| Employees are given specific environmental management roles and responsibilities (e.g. environment officer, environment champion, member of the environmental committee) against which their performance is assessed. | 113 | 1 | 5 | 3.7788 | 0.70375 |
| The company sponsors environmental initiatives (e.g., local community forestry programmes). | 113 | 1 | 5 | 3.8407 | 0.62058 |
| There is a programme of research and development in innovative environmental technologies in the key environmental impact areas in order to improve operational performance. | 113 | 1 | 4 | 3.5044 | 0.85695 |
| Environmental impact assessments are required for all significant new developments/installations. | 113 | 1 | 5 | 3.7965 | 0.7216 |

| | | | | | |
|---|---|---|---|---|---|
| All sites have emergency response procedures to mitigate environmental disasters, and these are regularly reviewed. | 113 | 1 | 5 | 3.7788 | 0.6779 |
| There is a programme of regular (e.g., annual) independent audits of environmental management systems, processes and performance. | 113 | 1 | 5 | 3.708 | 0.69026 |
| The produces an environmental report (either as part of a financial report, a sustainability report or as a stand-alone document). | 113 | 2 | 5 | 3.8584 | 0.46034 |
| **Valid N (list wise)** | **113** | | | | |

Table 8: Descriptive Statistics

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Enhanced shareholder value | 113 | 1 | 4 | 3.6018 | 0.73848 |
| Opportunity to enhance reputation/brand | 113 | 1 | 5 | 3.7876 | 0.74942 |
| Exploitation of potential competitive advantage | 113 | 1 | 5 | 3.8142 | 0.64847 |
| Compliance with legislation | 113 | 1 | 5 | 3.8496 | 0.62993 |
| Improved management of risk | 113 | 1 | 4 | 3.5664 | 0.81148 |
| Improved relationships with local communities | 113 | 1 | 5 | 3.7434 | 0.72922 |
| Improvement in employee relations | 113 | 1 | 5 | 3.7965 | 0.67028 |
| Survival of the business in the long term | 113 | 1 | 5 | 3.7257 | 0.65802 |
| Pressure from ethical investors | 113 | 1 | 4 | 3.5841 | 0.75268 |
| Specific condition for attaining project finance | 113 | 1 | 5 | 3.8142 | 0.64847 |
| Cost saving/operational efficiency | 113 | 1 | 5 | 3.7876 | 0.63318 |
| Improved standing with governments and regulators | 113 | 1 | 5 | 3.8142 | 0.66209 |
| **Valid N (list wise)** | **113** | | | | |

Table 9: Descriptive Statistics

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Mine closure planning and mine reclamation is the best practice toward sustainability. | 113 | 1 | 4 | 3.5133 | 0.87745 |
| Mine closure and reclamation plan should be determined in accordance with the sustainability plan of the mining region as much as possible. | 113 | 1 | 5 | 3.7611 | 0.69788 |
| Predicting, management, and preventing early mine closures is one of the main tasks in sustainable mine design. | 113 | 1 | 5 | 3.7345 | 0.74424 |
| Characterize the sustainability context of the region prior to any mining activity and mine design | 113 | 1 | 5 | 3.7611 | 0.71056 |
| Identify the 'impacting factors' associated with mine design that could change the existing environmental social, and economical components. | 113 | 1 | 4 | 3.5398 | 0.8349 |
| Define the possible ranges for the magnitude of the variation caused by each impacting factor. | 113 | 1 | 5 | 3.8142 | 0.68854 |
| Determine those components whose condition could be modified due to mining (these are called mining environment). The mining | 113 | 1 | 5 | 3.8142 | 0.64847 |

| | | | | | |
|---|---|---|---|---|---|
| environment parameters are environmental and socio-economic conditions which have the most significant outcomes. | | | | | |
| Correlate each impacting factor and each mining environmental component with a weighted value to reflect the level of impact. | 113 | 1 | 5 | 3.823 | 0.69732 |
| Estimate the specific magnitude for each impacting factor (using Table 4), and calculate the weighting sum of the impacts on each component. | 113 | 1 | 4 | 3.5133 | 0.85685 |
| **Valid N (list wise)** | **113** | | | | |

Table 10: Descriptive Statistics

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Target mineral exploration | 113 | 1 | 5 | 3.7876 | 0.68727 |
| Evaluate mining conditions | 113 | 1 | 5 | 3.7788 | 0.6779 |
| Model mine construction | 113 | 1 | 5 | 3.7434 | 0.69151 |
| Display geochemical and hydrology data | 113 | 1 | 4 | 3.5664 | 0.78917 |
| Improve facility management and policing | 113 | 1 | 5 | 3.7876 | 0.70014 |
| Apply for mining permits | 113 | 1 | 5 | 3.823 | 0.67122 |
| Assess environmental impact | 113 | 1 | 4 | 3.5487 | 0.84506 |
| Manage land titles | 113 | 1 | 5 | 3.7876 | 0.67416 |
| Process closures | 113 | 1 | 5 | 3.7876 | 0.67416 |
| Plan reclamation activities | 113 | 1 | 5 | 3.7788 | 0.71632 |
| Improve community education | 113 | 1 | 4 | 3.5133 | 0.85685 |
| Valid N (list wise) | **113** | | | | |

Table 11: Descriptive Statistics

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Remote sensing data enables the identification, delineating, and monitoring of pollution sources and affected areas, including derelict land, and changes in surface land use and to water bodies. | 113 | 1 | 5 | 3.7965 | 0.64309 |
| Remote sensing technology is widely used in detection of earth resources, prediction of earthquake and volcanic eruption. | 113 | 1 | 5 | 3.7611 | 0.67181 |
| Remote sensing technology is superior with characteristics of wide range, fast speed and low cost in monitoring. | 113 | 1 | 5 | 3.7965 | 0.69641 |
| Comprehensive, real-time and abundant information source of mine ecological environment can be acquired through processing of remote sensing image. | 113 | 1 | 4 | 3.469 | 0.90702 |
| UAV remote sensing is high in imaging resolution and flexible in data acquisition. | 113 | 1 | 5 | 3.7699 | 0.71973 |
| **Valid N (list wise)** | **113** | | | | |

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Table 12: Correlation

| | | Sustainable Coal mining operations and technologies | Factors that have influenced the mining company in adopting business strategies to address Sustainable Development? | Optimizing Coal Mine Design for Sustainable Development | Implication of GIS in mining | Application of remote sensing technology in mining |
|---|---|---|---|---|---|---|
| Sustainable Coal mining operations and technologies | Pearson Correlation | 1 | .657** | .545** | .564** | .554** |
| | Sig. (2-tailed) | | 0 | 0 | 0 | 0 |
| | **N** | **113** | **113** | **113** | **113** | **113** |
| Factors that have influenced the mining company in adopting business strategies to address Sustainable Development? | Pearson Correlation | .657** | 1 | .762** | .614** | .609** |
| | Sig. (2-tailed) | 0 | | 0 | 0 | 0 |
| | **N** | **113** | **113** | **113** | **113** | **113** |
| Optimizing Coal Mine Design for Sustainable Development | Pearson Correlation | .545** | .762** | 1 | .616** | .652** |
| | Sig. (2-tailed) | 0 | 0 | | 0 | 0 |
| | **N** | **113** | **113** | **113** | **113** | **113** |
| Implication of GIS in mining | Pearson Correlation | .564** | .614** | .616** | 1 | .507** |
| | Sig. (2-tailed) | 0 | 0 | 0 | | 0 |
| | **N** | **113** | **113** | **113** | **113** | **113** |
| Application of remote sensing technology in mining | Pearson Correlation | .554** | .609** | .652** | .507** | 1 |
| | Sig. (2-tailed) | 0 | 0 | 0 | 0 | |
| | **N** | **113** | **113** | **113** | **113** | **113** |
| ** Correlation is significant at the 0.01 level (2-tailed). | | | | | | |

Table 13: One-Sample Test for H1

| | **Test Value = 3** | | | | | |
|---|---|---|---|---|---|---|
| | **t** | **df** | **Sig. (2-tailed)** | **Mean Difference** | **95% Confidence Interval of the Difference** | |
| | | | | | **Lower** | **Upper** |
| Sustainable Coal mining operations and technologies | 24.879 | 112 | 0 | 0.75575 | 0.6956 | 0.8159 |

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Table 14: One-Sample Test for H2

| | Test Value = 3 | | | | | |
|---|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| Factors that have influenced the mining company in adopting business strategies to address Sustainable Development? | 25.767 | 112 | 0.000 | 0.74425 | 0.6870 | 0.8015 |

Table 15: One-Sample Test for H3

| | Test Value = 3 | | | | | |
|---|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| Optimizing Coal Mine Design for Sustainable Development | 18.700 | 112 | 0.000 | 0.69912 | 0.6250 | 0.7732 |

Table 16: One-Sample Test for H4

| | Test Value = 3 | | | | | |
|---|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| Implication of GIS in mining | 20.369 | 112 | 0.000 | 0.71858 | 0.6487 | 0.7885 |

Table 17: One-Sample Test for H5

| | Test Value = 3 | | | | | |
|---|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| Application of remote sensing technology in mining | 17.569 | 112 | 0.000 | 0.71858 | 0.6375 | 0.7996 |

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**Figures**

Figure 1: Types of Coal Mines

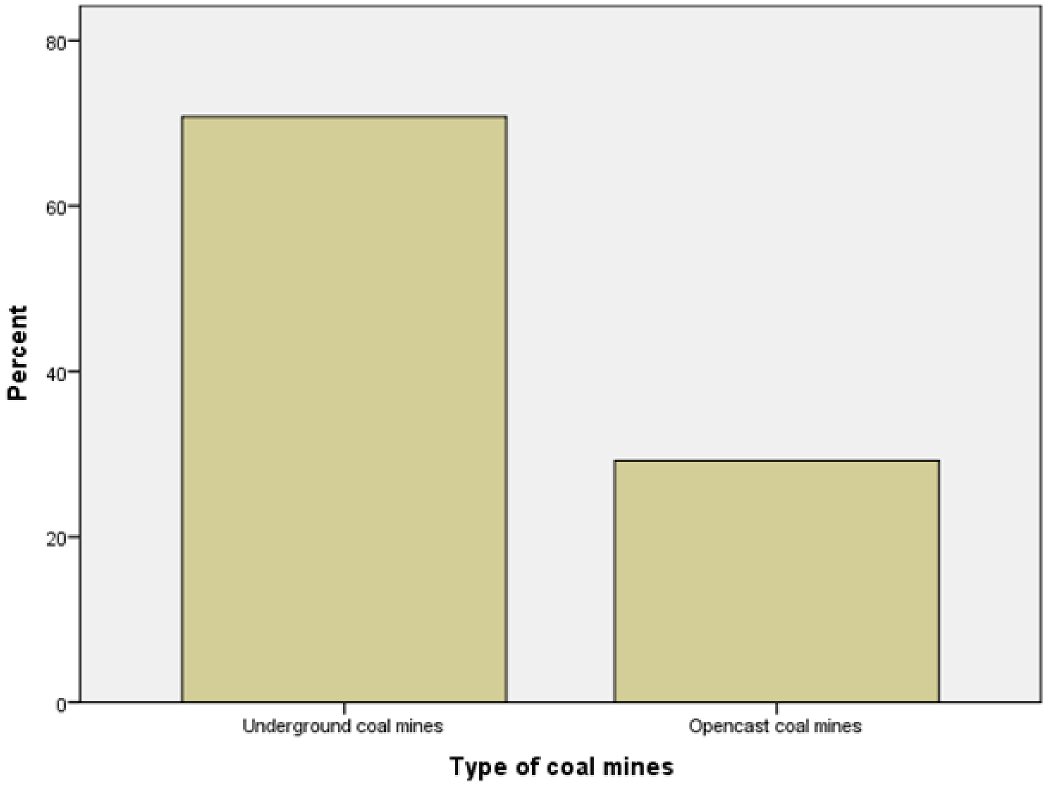


Figure 2: Gender

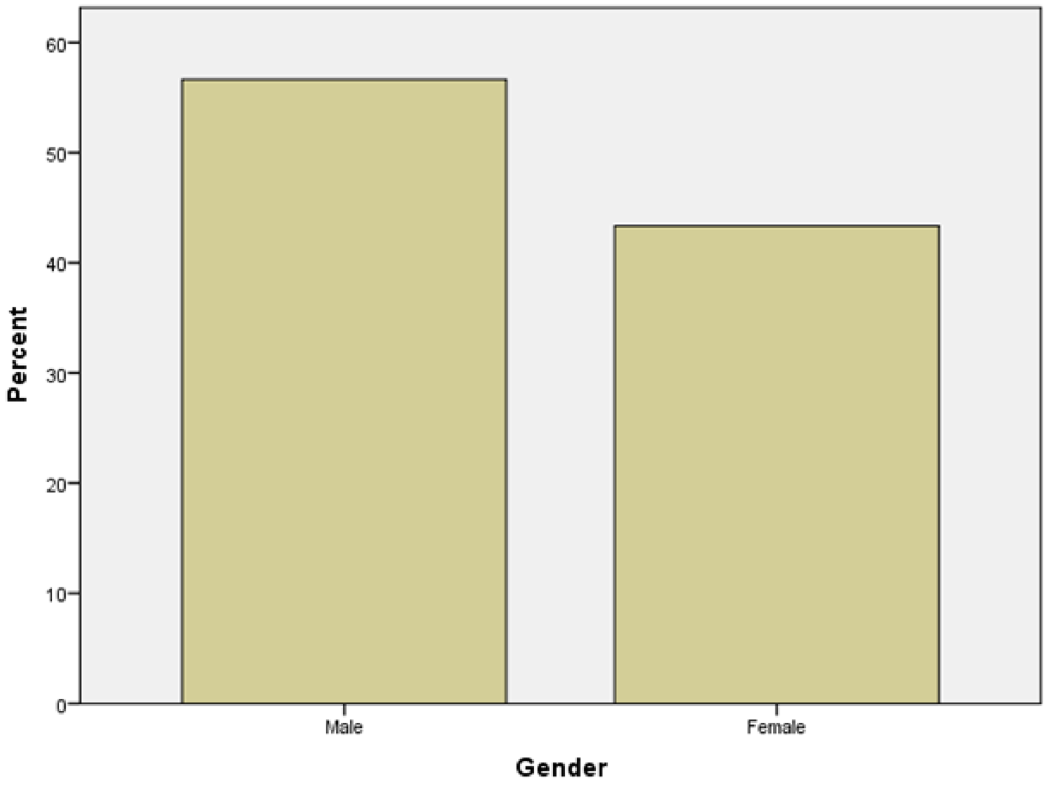

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Figure 3: Age-group (Which age group are you in?)

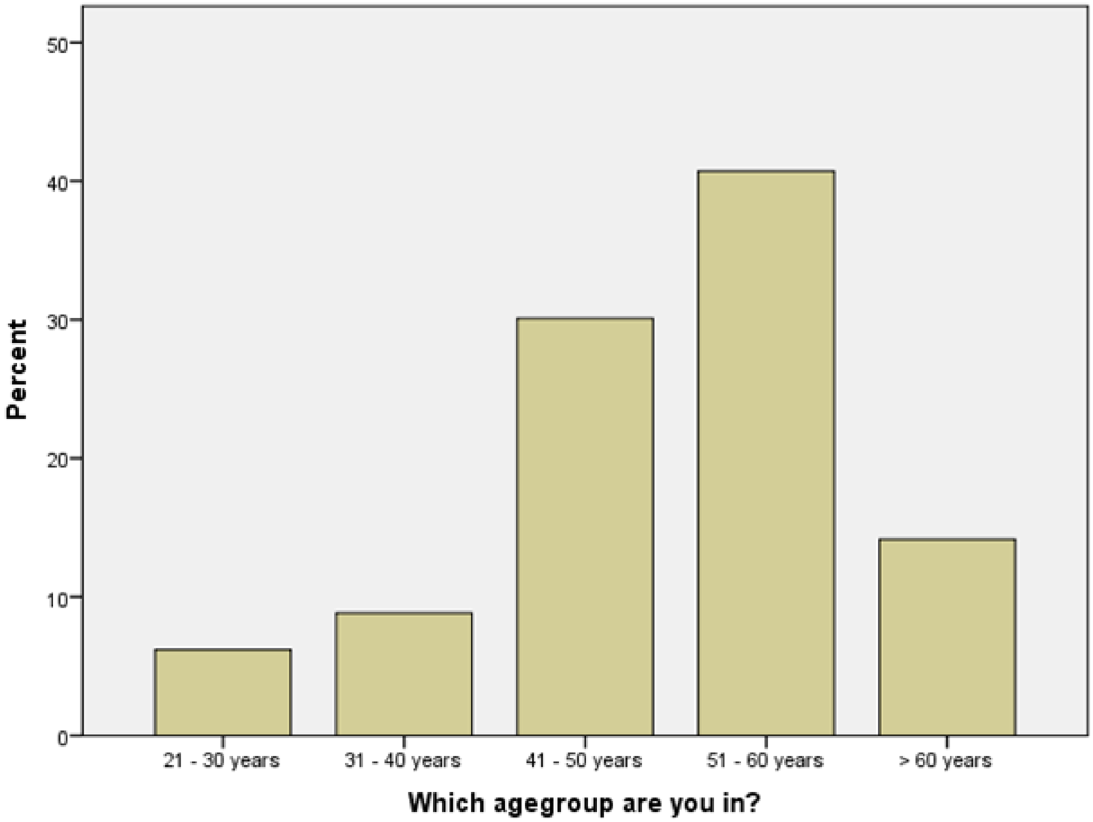


Figure 4: Highest Level Education (Your highest level of education?)

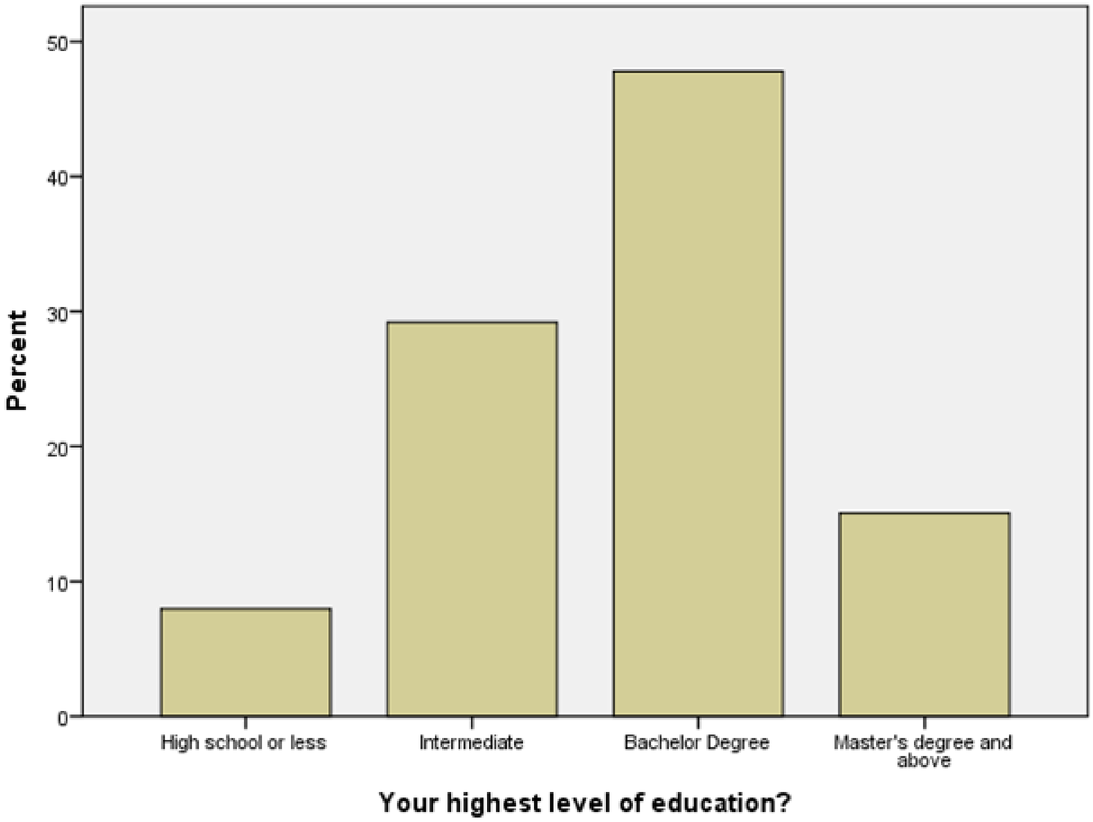

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Figure 5: Income per Year (What is your income per year?)

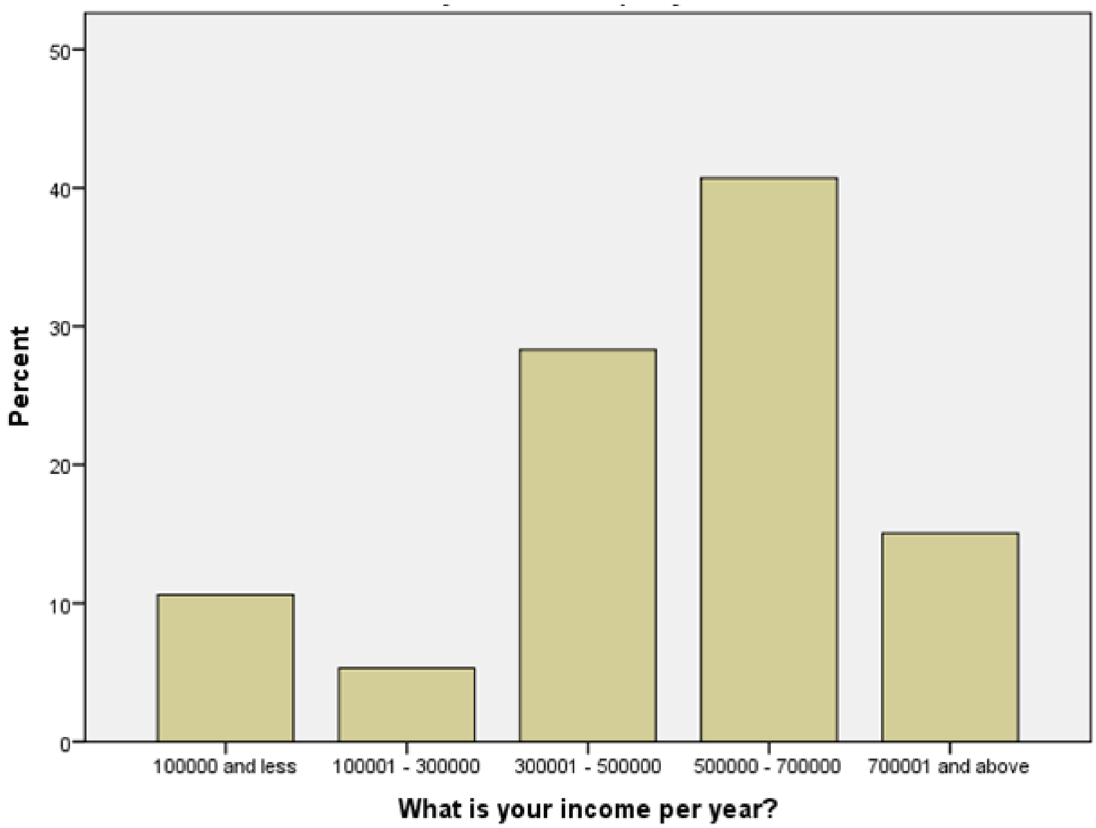


Figure 6: Marital Status