# Academic Journal of Research and Scientific Publishing

## International peer-reviewed scientific journal

## The Fifty-first Issue

**Publication date: 05-07-2023**

**ISSN: 2706-6495**

doi.org/10.52132/Ajrsp.en.2023.51

Email: editor@ajrsp.com

## Dedication

It is our pleasure and great privilege to present the fifty-first issue of the Academic Journal of Research and Scientific Publishing to all researchers and doctors who published their research in the issue, and we thanks and appreciate to all contributors and supporters of the academic journal and those involved in the production of this scientific knowledge edifice.

Academic Journal of Research and Scientific Publishing

# Editorial Board

## Table of Content:

Academic Journal of Research and Scientific Publishing | Vol 5 | Issue 51
Publication Date: 05-07-2023 ISSN: 2706-6495

# Women's Career Challenges and Opportunities (A Study of Career and Job Satisfaction among Bangladeshi Women)

**Dr. Md Nurul Raihen**
Visiting Assistant Professor, Department of Mathematics and Statistics, Stephen F. Austin State University, Nacogdoches, 75962, TX, USA
Email: fy4233@wayne.edu
ORCID: https://orcid.org/0000-0003-2680-0658

**Sultana Akter**
Teaching Assistant, MS in Statistics, Department of Statistics, Western Michigan University, Kalamazoo, 49002, MI, USA
Email: sbg2612@wmich.edu

**Md Nazmul Sardar**
Senior Officer, Product Development at Radiant Nutraceuticals Ltd (F. Hoffmann-La Roche Ltd), Dhaka, 1000, Bangladesh
Email: nazmulsardar91@gmail.com

## Abstract

The purpose of this research is to learn more about women in Bangladesh and their perceptions of career options and job satisfaction. Women's labor force participation has increased dramatically in Bangladesh, as it has in many other developing countries. But despite these improvements, women still face several roadblocks in the workplace. Women's professional development and job happiness can be aided by policies and environments that take into account the unique obstacles they confront. The study uses a Univariate, Bivariate, and multivariate method, collecting information through both quantitative surveys and qualitative interviews. Participants are professional women from a wide range of fields in Bangladesh. Quantitative surveys analyze issues including work-life balance, gender bias, education status, women's violence in the job sector, support from family members, promotion prospects, and job satisfaction.

The qualitative interviews dive more deeply into the women's lived experiences, shedding light on the difficulties they face and the strategies they use to overcome them. The study has both theoretical and practical significance. For practical purposes, this research will improve our understanding of the most significant obstacles to women's careers and participation in development processes and the most effective ways to overcome them. This paper will also be useful as a source of information for feminist groups and other organizations with the goal to advance women's rights and equality.

**Keywords:** Women's career, Job satisfaction, Career challenges, Work-life balance, Gender bias, Hypothesis, Regression Analysis, Chi-square Test.

## 1. Introduction

Due to its impact on both professional and personal life, the issue of women career and job satisfaction in Bangladesh has captured the attention of researchers and academics in the modern world of competition because of the fact that it has the capacity to bring beneficial results for people on their own, within their families, and within their organizations. The career of women has been characterized by education, occupation, discussed family planning with partners, household decision making, freedom movement, age at marriage, political representation, and legal rights (Tasnim et al., 2006).

In recent years, the percentage of working-age women in Bangladesh has risen dramatically. Women, meanwhile, are stereotyped as having fewer doors opened to them in the workplace. Increasing the participation of women in the development process is often cited as a way to improve the prospects for progress in countries like Bangladesh, where women make up over half the population. It is still the case in Bangladesh that women and men are treated differently. Despite the fact that a substantial number of women labor in the informal sector, their contribution is not recognized in society. They must overcome a number of challenges in order to improve their talents and increase their production. These include a lack of company start-up money, a lack of education, employee-related issues, and limited mobility, which leads to poor access to the market, information, technology, and finance.

The research shows that women in Bangladesh confront a number of barriers in the workplace, such as societal expectations, a lack of access to education and training, gender-based discrimination, an imbalance between work and personal life, and little chances to grow in their careers. Reduced job satisfaction and stunted professional development are common outcomes of these difficulties. However, the research also reveals areas where advancement is possible, such as expanding access to education, enacting rules to combat gender bias in the workplace, encouraging work-life balance, and establishing support networks for women in a variety of fields.

This study is useful for governments, companies, and organizations that want to establish more inclusive work environments and empower women in their careers because it sheds light on the specific obstacles and opportunities experienced by women in Bangladesh. Working to overcome these obstacles and seize these openings will help women professionals as a whole advance in their careers, which in turn will benefit society at large.

## 2. Objectives of the Study

The overarching goal of this research is to examine how women's self-power influences their engagement with Bangladesh's development efforts. Those precise goals are:

- To investigate the various opportunities for women's career that are currently available in Bangladesh.
- To analyze how women have been educated in various ways.
- In order to determine the many ways in which women have gained economic independence.
- To find out what kind of jobs and careers Bangladeshi women have and how much they take part in the growth process.

## 3. Literature Review

The way a person feels about their work can be largely predicted by how satisfied they are with their position. Happock et al., 1935 was the first to define job satisfaction as the "state of mind" that results from a confluence of "I am satisfied with my job" triggers in the worker's immediate physical surroundings, interpersonal interactions, and organizational culture. Low levels of employee contentment are an important warning indicator that things are becoming worse in an organization. It contributes to discontent, low output, disciplinary issues, and other types of workplace strife (Farzana, 2012).

The issue of gender becomes more prominent after the problems of property and violence, especially in emerging countries. At this point in human history, the 21st century, men and women are each making an equal contribution to the total progress. Both of them work in industry, academia, bank, public and non-government organizations and so on. Still, it has been determined that there is a significant problem with the variation in the percentages of different types of jobs that are available in developing countries for instance Bangladesh (Farzana Sultana, 2012; Alam 2005). Self-empower according to Sen and Batiliwala, 2000 is not just having more success to resources (human, financial, intellectual), but also having more faith in one's own abilities and undergoing a transformation of one's consciousness (Paul et al., 2016).

In developing countries, and particularly in Bangladesh, the number of women working in virtually any field is significantly lower than the global average. The lack of employment opportunities available to women in Bangladesh is a significant barrier to the country's continued economic and social growth. One of the primary factors that contributes to the low employability of women in this day and age is dissatisfaction with their current jobs. According to the statistics, discrimination on the workplace and many elements connected to the job, such as income, advancement, working conditions, social status security, recognition, and so on, are a major determining factor in overall job satisfaction (Raihen et al., 2023). Because the results of the interaction between psychological elements and the work outcome of persons are the most critical parts of human existence, it is vital to consider the situation of female job satisfaction (Afza, 2008).

Job satisfaction has been extensively investigated in organizational research over the past four decades (Currivan, 1999; Lund, 2003). Both its global construct and its notion with numerous dimensions have been described and measured (Locke, 1969, 1976; Price 1997). According to Bullock et al., 1952, a person's level of contentment on the job is based on how well they strike a balance between the positive and negative aspects of their work. According to Smith (1955), it is the degree to which an individual feels his or her employment satisfies his or her numerous needs. The term was coined by Blum and Naylor (1968) to describe an individual's way of thinking that has developed due to their experiences in the workplace, their personality, and their personal relationships.

It is imperative that action be taken as early as possible in the educational process in order to ensure that women and men have equal possibilities in the digital world and in the development of technology. Young female students around the world are leaving fields of study related to science, technology, engineering, and mathematics (STEM) as they progress in their education and careers. Despite economic freedom and gender equality, this tendency persists in the world's countries and societies. Collen, 2018 indicates that the gender gap in academic ability mostly depends on the women age and current level of proficiency. We could assume that women's job security has a small effect in Bangladesh due to the country's strong patriarchal heritage (Amin, 1995; Cain et al., 1979). Recent research, however, suggests that women's earning a living can result in positive changes, including: better bargaining position within the household (Kabeer, 1997a); increased access to information and support networks (Amin et al., 1997); and increased feelings of self-worth (Sarah Salway, Sonia Jesmin, and Shahana Rahman, 2005). However, there are also negative repercussions, such as an increased likelihood of violence (Paul-Majumder & Begum, 2000).

Women in Bangladesh now have much greater access to higher education than they did a few decades ago, especially in urban areas. Women now make up the largest pool of employment applicants for several fields as they pursue higher education. In order to attract and keep talented women, employers must solve the women career challenge. Administrators should not focus on women career as a women's issue since it's critical to the success of their organizations (MD Ali Aklas, 2015, Oslen, 1995).

## 4. Women in Bangladesh's Workforce: Where They Stand Today

Equality for women in jobs is a major component of gender equality. From prehistoric times onward, women performed a wide range of roles, including those related to the home, farming, the wedding, and the harvest. Broadus et al., the GDP was $16 trillion in 1993, according to the government's statistics. Between 10% and 35% of their total income was generated by women. According to a study done in 1990, the global GDP would have increased by 20%-30% if all national income had been accounted for, including the contributions made by women in the workplace (Nuruzzaman, 2004).

In addition to that, it's distressing that fewer woman than man complete postsecondary education at the national level. This inequality emerges in elementary school and grows in colleges and

universities. In 1999, males outnumbered females at admitted to universities by a margin of 77.20% to 22.80%. Some programs made the completion of primary school mandatory, and others prioritized educating girls to narrow the gender gap. Despite this, in 1995 it was observed that male students comprised 63% of the total while female students comprised 37%. It's worth noting that now 95% of children who are school age are enrolled in elementary school, yet 38% of those children will not continue their education through the basic level.

## 5. Data Source and Methodology

The National Institute of Population Research and training (NIPORT) of the Ministry of Health and Family Welfare of Bangladesh oversaw the 2018 Bangladesh Demographic and Health survey (BDHS) data used in this analysis. There has been usage of both univariate, bivariate and multivariate analysis. To determine what factors contribute to women's career and job satisfaction, researchers utilized multiple linear regression analyses and constructed a women career and job satisfaction related index.

### 5.1 Univariate Analysis

The purpose of univariate analysis is to examine and summarize data using only one independent variable. Without taking into account any correlations between other variables, it analyzes the data's distribution, central tendency, and variability. Univariate analysis focuses on the description and understanding of a single categorical or continuous variable (Park, 2015), (Charro, Fernando, Alaa Haj Ali, Nurul Raihen, Monica Torres, and Peiyong Wang, 2023).

**Table 1:** The frequency and the percentage of the respondent's age

| | **Frequency** | **Percentage** | **Valid Percentage** | **Cumulative Percentage** |
|---|---|---|---|---|
| **Valid** | | | | |
| 15-25 | 172 | 27.1 | 27.1 | 27.1 |
| 25-35 | 123 | 37.9 | 37.9 | 65.0 |
| 35-50 | 133 | 29.3 | 29.3 | 94.3 |
| 50-65 | 24 | 5.3 | 5.3 | 99.6 |
| 65+ | 2 | 0.4 | 0.4 | 100 |
| **Total** | 454 | 100 | 100 | |

Comments: Most of the participants belong to the age group 15-50, and the total percentages of them is 94.3% between the interval of 15-50 age.

**Table 2:** The frequency and the percentage of the women's marital status

| | Frequency | Percentage | Valid Percentage | Cumulative Percentage |
|---|---|---|---|---|
| **Valid** | | | | |
| **Single** | 134 | 29.4 | 29.5 | 29.5 |
| **Married** | 304 | 67.0 | 67.0 | 96.5 |
| **Divorced** | 5 | 1.1 | 1.1 | 97.6 |
| **Widowed** | 9 | 2.0 | 2.0 | 99.6 |
| **Separated** | 2 | 0.4 | 0.4 | 100 |
| **Total** | 454 | 100 | 100 | |

Comments: Most of the participants women are married and the percentage is 67.0%, and the single women's percentage is 29.5%.

**Table 3:** Bangladeshi female entrepreneurs' work-life balance

| | No. of respondents | Percentage | Valid Percentage | Cumulative Perce |
|---|---|---|---|---|
| **Valid** | | | | |
| **Modular working hours** | 15 | 3.3 | 3.3 | 3.3 |
| **Transport facility** | 53 | 11.7 | 11.8 | 15.1 |
| **Assisted living facility** | 9 | 2.0 | 2.0 | 17.1 |
| **Child Care facility** | 228 | 50.2 | 50.2 | 67.3 |
| **Flexible work arrangements** | 146 | 32.2 | 32.2 | 99.5 |

| | | | | |
|---|---|---|---|---|
| **Reduced labor hours and burden** | 3 | .5 | .5 | 100 |
| **Total** | 454 | 100 | 100 | |

Comments: The percentage of respondents for the factor of childcare facility is highest, and it is 50.2%. From this above result, most of the women are concern about their childcare facility and suitable work management.

**Table 4:** The frequency and percentage of the participant women's educational level

| | **No of respondents** | **Percentage** | **Valid Percentage** | **Cumulative Percentage** |
|---|---|---|---|---|
| **Valid** | | | | |
| **Under class 8** | 5 | 1.1 | 1.1 | 1.1 |
| **Secondary school certificate (S.S.C)** | 68 | 13.9 | 13.9 | 15.0 |
| **Higher secondary school certificate (H.S.C)** | 93 | 20.5 | 20.5 | 35.5 |
| **Undergraduate** | 158 | 34.8 | 34.8 | 70.3 |
| **Postgraduate** | 112 | 24.7 | 24.7 | 95 |
| **More than university education** | 18 | 5.0 | 5.0 | 100 |
| **Total** | 454 | 100 | 100 | |

Comments: The percentage of undergraduate educational level among the participant women in our survey is highly performed, and it is 34.8%.

**Table 5:** Frequency table of the best job for women in terms of safety

| | Frequency | Percentage | Valid Percentage | Cumulative Percentage |
|---|---|---|---|---|
| **Valid** | | | | |
| **Doctor** | 37 | 8.5 | 8.5 | 8.5 |
| **Teacher** | 263 | 60.5 | 60.5 | 69 |
| **Artist** | 13 | 3 | 3 | 72 |
| **NGO** | 2 | .5 | .5 | 72.5 |
| **Business** | 12 | 2.8 | 2.8 | 75.3 |
| **Journalist** | 1 | .2 | .2 | 75.5 |
| **Lawyer** | 2 | 5.6 | 5.6 | 81.1 |
| **Engineer** | 3 | .7 | .7 | 81.8 |
| **Bank** | 49 | 10.6 | 10.6 | 92.4 |
| **Other** | 45 | 7.6 | 7.6 | 100 |
| **Total** | 427 | 100 | | |

Comments: Most of the participants to this survey are preferring to do the Teaching profession, and their percentage of choosing teaching job is 60.5. Teaching job is selected most secure job among the Bangladeshi women.

### 5.2 Bivariate Analysis

When it comes to statistics, bivariate analysis means looking at the correlation or causation between two independent variables. The variables in this sort of study are often numerical or quantitative in character. The primary goal of bivariate analysis is to identify any associations or correlations between the two variables under consideration.

### 5.2 .1. Association between job status and type of school (public or private)

**Hypothesis:**

$H_0$: There exists no association between job status and type of school.

$H_1$: There exists an association between job status and type of school.

**Table 6:** Association between job status and type of school

| Chi-square test | | | |
|---|---|---|---|
| | **Value** | **df** | **Assymp.sig (2-sided)** |
| **Pearson Chi-Square** | 43.865[a] | 4 | 0.000 |
| **Likelihood** | 45.515 | 4 | 0.000 |
| **Linear-by-Linear Association** | 42.270 | 1 | 0.000 |
| **N of valid cases** | 449 | | |

Comments: From the Chi-square table we see that the Pearson Chi-Square p-value is 0.000 which is less than the level of significance 0.05, so we may reject the null hypothesis at 5% level of significance. So can conclude that there exists an association between the job and status and the type of school (public or private). The women from public universities are receiving higher position than the women come from private universities (Raihen et al., 2023).

### 5.2.2 Association between women's opinion in personal satisfaction according to their job position in their own sector

**Hypothesis:**

$H_0$: There exists no association between the job position and women's satisfaction.

$H_a$: There exists an association between the job position and women's satisfaction.

**Table 7:** Association between women's job satisfaction and job position

| Chi-square test | | | |
|---|---|---|---|
| | **Value** | **df** | **Assymp.sig (2-sided)** |
| **Pearson Chi-Square** | 11.071[a] | 4 | 0.024 |
| **Likelihood** | 14.557 | 4 | 0.000 |
| **Linear-by-Linear Association** | .132[b] | 1 | 0.036 |
| **N of valid cases** | 443 | | |

Comment: From the Chi-square table we can see that the p-value is 0.024 which is less than 0.05 (level of significance). So, we can reject the null hypothesis at 5% level of significance. So, we can conclude that there exists a significant relationship between the women's satisfaction from their own perspective and their job status.

### 5.2.3 Association between women's violence and type of job sector (government and private sector)

**Hypothesis:**

$H_0$: There is no association between women's violence and the types of job sector.

$H_a$: There is an association between women's violence and the types of job sector.

**Table 8:** Association between women's violence and types of job sector

| Chi-square test | | | |
|---|---|---|---|
| | **Value** | **df** | **Assymp.sig (2-sided)** |
| **Pearson Chi-Square** | 10.081[a] | 1 | 0.001 |
| **Likelihood** | 10.482 | 4 | 0.001 |
| **Linear-by-Linear Association** | .132[b] | 1 | 0.002 |
| **N of valid cases** | 372 | | |

Comments: From the chi-square table we see that the p-value is .001 which is less than level of significance .05. So, we may reject the null hypothesis at 5% level of significance. Therefore, we may conclude that there is a strong association between any violence in the job sector and the type of job (government and private).

### 5.2.4. Association between good position of women in their job and support from family members

**Hypothesis:**

$H_0$: There is no association between position in the job and the support from family.

$H_a$: There is an association between them.

**Table 9:** Association between the job and the family support

| Chi-square test | | | |
|---|---|---|---|
| | **Value** | **df** | **Assymp.sig (2-sided)** |
| **Pearson Chi-Square** | 21.208[a] | 16 | 0.171 |
| **Likelihood** | 25.467 | 16 | 0.062 |
| **Linear-by-Linear Association** | 4.381[b] | 1 | 0.036 |
| **N of valid cases** | 446 | | |

Comments: From the chi–square table p-value is .171 which is greater than level of significance .05, so we may not reject the null hypothesis at 5% level of significance. So, there is no significant link between the women job position and the support from their family members.

### 5.2.5 Association between women's job satisfaction with their position according to their gender.

**Hypothesis:**

$H_0$: There is no association between women's position and gender.

$H_a$: There is an association between women's position and gender.

**Table 10:** Association between women's position and gender

| Chi-square test | | | |
|---|---|---|---|
| | **Value** | **df** | **Assymp.sig (2-sided)** |
| **Pearson Chi-Square** | 27.054[a] | 1 | 0.000 |
| **Likelihood** | 25.910 | 4 | 0.000 |
| **Linear-by-Linear Association** | 16.905 | 1 | 0.000 |
| **N of valid cases** | 128 | | |

Comment: From the chi-square table, p-value is .000 which is less than level of significance .05, So we may reject the null hypothesis at 5% level of significance. We conclude that there is an association between women's position in the workplace and gender.

### 5.3 Multivariate Analysis

We wish to know the dependency of women's job satisfaction in this part by utilizing multiple linear regression and Binary Logistic regression.

Using the chi-square test, it is possible to analyze the relationship between women's job satisfaction and each associated variable and to determine the strength of each relationship. Nonetheless, the dependent variable may be influenced by multiple factors concurrently (Raihen et al., 2017). Multiple regression analysis can be utilized to investigate the relationship between a dependent variable and a set of independent variables. Both dependent variables in this case are continuous. Consequently, we will attempt to fit two multiple linear regression models (Raihen and Stein et al., 2023).

In our multiple regression Analysis, we use women's job satisfaction as a dependent variable, and the explanatory variables are age, education level, gender, and family support.

**Table 11:** Analysis of variance

| Source | SS | df | MS | F-value | P-value |
|---|---|---|---|---|---|
| **Model** | 12.5817197 | 21 | 0.599129509 | | |
| **Residual** | 50.7261982 | 319 | 0.159016295 | 3.77 | 0.0000 |
| **Total** | 63.3079179 | 340 | | | |

R-squared = 0.1987 Adj R-squared = 0.1460 Root MSE = .39877

Comments: Since, the p-value < 0.05, so we can conclude that at 5% level of significance, mean of the women's job satisfaction are not equal for all predictors. Model fit explains just 19.87% of the total variation in female job satisfaction ($R^2$=.1987), indicating the model is inadequate (Raihen et al., 2022).

### 5.4 Binary Logistic model

Both the probit and the logit models can be applied because the dependent variable, Y, can take on the values 1 (if the woman is content with her employment) and 0 (if she is not). These two models both make a probability forecast. However, a logistic regression model is utilized here since it is more straightforward and employs a tried-and-true method of analysis (Chauhan 2016, Cramer 1999).

#### 5.4.1 Model of logit regression

Calculation of WJSI (WOMEN JOB SATISFCATION INDEX): Here, our response predictor is

WJSI = mean of the recoded variables.

And Women Job Satisfaction (WJS) =1; if WJSI 0.5

0; otherwise

Here we want to know the dependency of Women job satisfaction with respect to age, educational status, gender, family support as independent variables (LaValley, 2008).

#### 5.4.2 Logistic regression

Log likelihood = -156.06736 Number of observations = 330 Prob > chi2 = 0.0000

Pseudo R2 = 0.1514 LR chi2(18) = 55.67

#### 5.4.3 Interpretation

From the above result, Prob > chi2 = 0.0000 < 0.05. There is significant effect of age, educational status, gender, family support on the dependent variable at 5% level of significance.

## 6. Result and Conclusion

With the help of this study, an attempt was made to investigate the current situation regarding women career, job, and other factors that contribute to the professional advancement of women in a variety of industries and service sectors in Bangladesh. It is envisaged that the research information that will be offered by this study will prove to be valuable to policy makers in various organizations.

The results of this research have uncovered a few of the contributing components that are responsible for the formation of women self-power effects. In addition to this, it shed light on a few elements that assist women in furthering their professional development.

Women have to play many roles at home and at work, which can lead to fatigue, stress, and dissatisfaction. Though Bangladesh has made significant work-life improvements in recent years, there is still much to do. According to the poll, 34.8% of female employees were satisfied that their jobs interfered with their studies. 50.2% of respondents said their personal or household life (childcare facilities) interfered with their work. Bangladeshi female teachers' job satisfaction is 60.3%, according to this report. Only when the organization provides modular working hours (roistered days off and family-friendly starting and finishing times), transport facility, assisted living facility, childcare facility, Flexible work arrangements, reduced labor hours and burden for female employees will they be able to contribute to both family and organization. Women employees must care for their families both physically and financially in order to meet their families' demands. Work for the achievement of corporate goals as well as individual advancement to meet career needs. Since the Prob > chi2 = 0.0000, we conclude that demographic factors such as age, education level, gender, and family support have a significant impact on women's job satisfaction in Bangladesh.

Gender parity and women's professional empowerment are not merely an issue of social fairness; they are crucial to Bangladesh's long-term economic success. If discrimination is eliminated and women are given an equal opportunity in the workplace, they will be more productive and happier as a result.

**Funding:** This research received no external funding.

**Conflicts of Interest:** The authors declare no conflict of interest.

## 7. References

Tasnim, S. (2006). *Job Satisfaction among Female Teachers: A study on primary schools in Bangladesh* (Master's thesis, The University of Bergen).

Hoppock, R. (1935). Job satisfaction.

Sultana, F., & Begum, B. (2012). Measuring the job satisfaction of female library professionals working in the health libraries in Dhaka city. *Eastern Librarian*, *23*(1), 37-50.

Alam, S. S., Talha, M., Sivanand, C. N., & Ahsan, M. N. (2005). Job satisfaction of university woman teachers in Bangladesh. *Journal of Social sciences*, *1*(2), 88-91.

Presser, H., & Sen, G. (2000). *Women's empowerment and demographic processes: Moving beyond Cairo*. Oxford University Press.

Paul, G. K., Sarkar, D. C., & Naznin, S. (2016). Present situation of women empowerment in Bangladesh. *Int J Math Sta Invention*, *4*(8), 31-38.

Raihen, M. N., Akter, S., & Sardar, M. N. (2023). Food Satisfaction among Students: A Study of Present Public University Students in Bangladesh. *Journal of Mathematics and Statistics Studies*, *4*(1), 01-18.

Afza, S. R., & Newaz, M. K. (2008). Factors determining the presence of glass ceiling and influencing women career advancement in Bangladesh.

Currivan, D. B. (1999). The causal order of job satisfaction and organizational commitment in models of employee turnover. *Human resource management review*, *9*(4), 495-524.

Lund, D. B. (2003). Organizational culture and job satisfaction. *Journal of business & industrial marketing*.

Locke, E. A. (1969). What is job satisfaction?. *Organizational behavior and human performance*, *4*(4), 309-336.

Price, J. L. (1997). Handbook of organizational measurement. *International journal of manpower*, *18*(4/5/6), 305-558.

Bullock, R. P. (1952). *Social factors related to job satisfaction: A technique for the measurement of job satisfaction* (No. 70). Bureau of Business Research, College of Commerce and Administration, Ohio State University.

Lawrence, L. C., & Smith, P. C. (1955). Group decision and employee participation. *Journal of Applied Psychology*, *39*(5), 334.

Blum, M. L., Naylor, J. C., & Naylor, J. C. (1968). *Industrial psychology; Its theoretical and social foundations*. Harper & Row.

Ganley, C. (2018). Are boys better than girls at math. *Scientific American*.

Amin, S. (1995). *The rise of dowry in Bangladesh*. National Centre for Epidemiology and Population Health, Australian National University.

Cain, M., Khanam, S. R., & Nahar, S. (1979). Class, patriarchy, and women's work in Bangladesh. *Population and Development review*, 405-438.

Kabeer, N. (1997). Women, wages and intra-household power relations in urban Bangladesh. *Development and change*, *28*(2), 261-302.

Salway, S., Jesmin, S., & Rahman, S. (2005). Women's employment in urban Bangladesh: A challenge to gender identity?. *Development and Change*, *36*(2), 317-349.

Paul-Majumder, P., & Begum, A. (2000). *The gender imbalances in the export oriented garment industry in Bangladesh*. Washington, DC: World Bank, Development Research Group/Poverty Reduction and Economic Management Network.

Olsen, D., Maple, S. A., & Stage, F. K. (1995). Women and minority faculty job satisfaction: Professional role interests, professional satisfactions, and institutional fit. *The Journal of higher education*, *66*(3), 267-293.

Broadus, J. M. (1993). Possible impacts of, and adjustments to, sea-level rise: the case of Bangladesh and Egypt. *Warrick, RA, Barrow, EM, & Wigley, TML (eds.)*, 263-275.

Nuruzzaman, M. (2004). Neoliberal economic reforms, the rich and the poor in Bangladesh. *Journal of Contemporary Asia*, *34*(1), 33-54.

Park, H. M. (2015). Univariate analysis and normality test using SAS, Stata, and SPSS.

Charro, F., Ali, A. H., Raihen, N., Torres, M., & Wang, P. (2023). A bifurcation phenomenon in a singularly perturbed two-phase free boundary problem of phase transition. *Nonlinear Analysis: Real World Applications*, *73*, 103911.

Raihen, M. N., & Akter, S. (2023). Forecasting Breast Cancer: A Study of Classifying Patients' Post-Surgical Survival Rates with Breast Cancer. *Journal of Mathematics and Statistics Studies*, *4*(2), 70-78.

Raihen, N. (2017). *Convergence Rates for Hestenes' Gram-Schmidt Conjugate Direction Method without Derivatives in Numerical Optimization* (Doctoral dissertation, University of Toledo).

Stein Jr, I., & Raihen, M. N. (2023). Convergence Rates for Hestenes' Gram–Schmidt Conjugate Direction Method without Derivatives in Numerical Optimization. *AppliedMath*, *3*(2), 268-285.

Raihen, M. N. I. (2022). *A Bifurcation Phenomenon of Regularized Free Boundary Problems of Two-Phase Elliptic-Parabolic Type* (Doctoral dissertation, Wayne State University).

Chauhan, V., Suman, H. K., & Bolia, N. B. (2016). Binary logistic model for estimation of mode shift into Delhi Metro. *The Open Transportation Journal*, *10*(1).

Cramer, J. S. (1999). Predictive performance of the binary logit model in unbalanced samples. *Journal of the Royal Statistical Society: Series D (The Statistician)*, *48*(1), 85-94.

LaValley, M. P. (2008). Logistic regression. *Circulation*, *117*(18), 2395-2399.



**Doi:** https://doi.org/10.52132/Ajrsp.en.2023.51.1

Academic Journal of Research and Scientific Publishing | Vol 5 | Issue 51
Publication Date: 05-07-2023 ISSN: 2706-6495

# Examining the Impact of Financial Inclusion on Unemployment in Africa (A Panel Data Analysis)

**Yanlin Sun**

School of Economics, Huazhong University of Science and Technology, Wuhan, Hubei, P.R.China

**Nagasha Scola***

PhD student, School of Economics, Huazhong University of Science and Technology, Wuhan, Hubei, P.R.China

*Corresponding author. Email: nagsco@yahoo.co.uk

## Abstract:

Financial inclusion improves the accessibility of the poor and other marginalized groups to basic financial services such as savings, investments, credits, and insurance which directly influences income. This study uses panel data analysis and the two-step Generalized Method of Moments (GMM) estimation to empirically assess the relationship between financial inclusion and unemployment in 49 African countries from 2009 to 2020. The results show that financial inclusion has a negative and significant effect on unemployment. This supports the idea that financial inclusion can help African countries in job creation by reducing unemployment thus it suggests an increase in access and use of financial services. The study also finds that the effect of financial inclusion on unemployment is stronger in countries with higher levels of education. This suggests that education is an important factor in the relationship between financial inclusion and unemployment. The results of the study have important policy implications for African countries that want to reach the Sustainable Development Goals (SDGs). Especially, SDG-8 which promotes inclusive and sustained economic growth with full employment and productivity. Governments should introduce policies regarding the usage of mobile money and microfinance in rural areas to enhance financial inclusion. Moreover, sustaining of economic growth through encouraging foreign direct investment and new business creation may help bring down the unemployment rate.

**Keywords:** Financial inclusion, unemployment rate, Okun's law, Generalized Method of Moments, SDGs

## 1. Introduction

It is very important for economic growth, poverty reduction, and sustainable development that poor people can access financial services (Sharma 2016, Demirgüç-Kunt, Klapper et al.). Financial inclusion improves accessibility of the poor and other marginalized groups to basic financial services such as savings, investments, credits and insurance which directly influences income. For these reasons, World Bank is promoting financial inclusion to achieve SDGs (Demirgüç-Kunt, Klapper et al.). Approximately 60% of Africa's total population is under the age of 25 which is an evidence of Africa's youngest and fastest-growing population. According to the findings of the International Labor Organization (2020), almost half of the world's youth will be African by 2100. Africa's growing young population made it difficult for governments to offer enough stable employment opportunities.

On the other hand, according to the International Labor Organization's most current figures (2020), young unemployment in Africa is the lowest it has ever been. The young unemployment rate in Africa has been falling steadily over the last decade, reaching 11.7%. Families and small business owners can generate income, manage irregular cash flow, invest in opportunities, and work their way out of poverty with the assistance of quality financial services that are both affordable and accessible to them. Inclusion in the financial system can give individuals and communities the ability to meet fundamental requirements, such as having access to nourishing food, clean water, shelter, education, and medical care. Inclusion in the financial sector also plays an important part in the efforts to assist people in preparing for, responding to, and recovering from crises such as the COVID-19 pandemic, inflation, economic shocks, and climate change.

According to (Rani, Kumar Dhir et al. 2021), COVID-19 had negative impacts on employment rate around the globe. A report of World Bank (2020) states that almost one-third of working youth became unemployed during epidemic in 15 African nations. As a result, pandemic enhanced income inequalities in the developing world (WHO, 2021). All the economies around the globe are confronting an increase of unemployment rate in recent times. It is anticipated that the global unemployment rate will be 5.7% in 2022 with an estimate of 205 million unemployed individuals (higher than the pre-COVID unemployed workers). Unemployment is harmful for economy because of having long term impacts on financial and social stability.

Therefore, enhancement of employment opportunities for youth is need of modern time to achieve SDG-8 and financial inclusion can play a vital role in reducing unemployment and income inequalities. Keeping this agenda in concern, impact of financial inclusion on unemployment in African nations is analyzed in this particular study. The findings of the study could help researchers to understand the connection between financial inclusion and the dynamics of developing nations' labor markets. Furthermore, outcomes of this specific study will help policymakers to understand the amalgamation of financial inclusion in the employment system in order to reduce the unemployment rate.

There is ambiguity in describing the linkage between financial inclusion and unemployment because of dissimilar outcomes of some recent studies such as. The aforementioned research shows that the correlation between financial inclusion and unemployment rate has not been well explored, and that the findings are still inconsistent. The claim that greater access to financial services has a crucial role in lowering unemployment is backed up by several empirical studies. However, contrary research has shown no correlation between financial inclusion and joblessness. Many academics agree that having a job is a necessary condition for entering the banking system. A cross-country research is needed to determines the association between financial inclusion and unemployment. This is one of the few studies that attempts to quantify the effect of financial inclusion on the unemployment rate in Africa because introduction of technology in this continent has a potential to enhance accessibility of financial services. The purpose of this study is to build a multidimensional financial inclusion index using Principal Component Analysis (PCA). Second, the impact of financial inclusion on unemployment rates in 49 African Countries for a period of 2009 and 2020 is experimentally investigated using the dynamic two-step Generalized Method of Moments (GMM).

This study continues with following sections: Literature review (including the relevant research works), Methodology (comprised of data, materials and methods employed for analyzing the association), Empirical results and discussion (presents the study's empirical findings and discussion about the outcomes) and Conclusion (provision of conclusions and policy implications on the behalf of outcomes).

## 2. Literature Review

Financial inclusion got considerable attention in late 1990's when policymakers faced issue of social and financial exclusion of individuals (Leyshon and Thrift 1993, Collard and Management 2007). Later,(Kempson and Whyley 1999) (Demirgüç-Kunt, Klapper et al.) explained financial inclusion as improvement in access to conventional banking by suggesting that opening of bank accounts is an essential financial service for the poor. In addition, 2004 Pre-Budget Report (Collard and Management 2007, Demirgüç-Kunt, Klapper et al.) presented ways to improve financial inclusion such as promoting access to financial intermediaries, providing adequate credit services, and providing in-person debt counseling. (Collard and Management 2007)In the late 2000s, research studies tended to focus on the measures of financial inclusion and the relationship between financial inclusion and economic development.

By 2030, the SDGs seek to end global poverty and inequality but any financial crisis could result in significant job losses even in nations with highly established financial sectors (Pagano and Pica 2012). However, (Bruhn and Love 2014, Demirgüç-Kunt, Klapper et al.) discovered that financial access considerably improved labor market outcomes and it has capacity to eliminate poverty. According to (Fonseca, Lopez-Garcia et al. 2001, Demirgüç-Kunt, Klapper et al.), the initial capital is required to create a new employment. However, when start-up expenses (initial capital) are high then business owners become deterred and unemployment rises. Therefore, restricting of financial access to business owners discourages the emergence of new companies that might create employment issues (Acemoglu 2001, Wasmer and Weil 2004). Financial inclusion makes financial access easier which enables entrepreneurs to launch and expand their own businesses. As a result, it eventually leads to a decline in unemployment by creating job opportunities.

Moreover, (Cull, Ehrbeck et al. 2014) (Demirgüç-Kunt, Klapper et al.) assessed the macro and micro level effects of financial inclusion on disadvantaged families throughout the world. They found that job and financial inclusion are positively connected. Additionally, World Bank (2014)(Group 2013) claimed that access of small business to financial services is linked with growth, innovation and the creation of new jobs. Additionally, (Mol and TP 2014) found that financial inclusion improves control on finance, empowers people and breaks the cycle of poverty and unemployment. Financial inclusion and job development have a favorable association (Zulfiqar, Chaudhary et al. 2016).

The fundamental finding of these research is that financial inclusion improves accessibility of poor individuals to financial services which increases self-employment opportunities as a result.

Some researchers suggested that financial inclusion programs have positive effects on the labor market in both short and long term. By expanding people's access to financial services and enabling them for proper usage of these services can help in job creation (Sykes, Elder et al. 2016). So, the inclusion of the financial sector is essential in increases the number of people that are employed. In case of Kenya's poverty and joblessness, (Mugo and Kilonzo 2017) discovered that low-income and marginalized communities received benefits from financial inclusion by initiating businesses, building resources and enhancing incomes. Additionally, the study revealed that financial inclusion caused a significant reduction in unemployment by having two-way causal relation. (El Bourainy, Salah et al. 2021)Moreover, Kondo's (2007) disclosed that micro-credit had a prominent effect on both the start-up of new small businesses and the creation of jobs in Philippines. Individuals initiated more than 20% small business by using micro-credit which resulted in more than 17% enhancement in job creation.

The World Bank looked at how it could improve financial inclusion and found that it had a positive effect on employment, new businesses, and GDP. For every 1% increase in financial inclusion, employment goes up by 0.7%, the number of new businesses goes up by 0.5%, and GDP goes up by 0.3% (Bruhn and Love 2014, Demirgüç-Kunt, Klapper et al.). According to (Fonseca, Lopez-Garcia et al. 2001, Demirgüç-Kunt, Klapper et al.) Fonseca et al. (2001), investing in the foundation of a new occupation is crucial. But when it's difficult to get a business off the ground due to hefty initial capital requirements, more people choose to enter the workforce. The economy is unable to generate new jobs, and the unemployment rate drops. Therefore, financing restrictions for entrepreneurs lead to a decline in new business formation, which in turn worsens the job situation(Acemoglu 2001, Wasmer and Weil 2004)Thus, financial inclusion that eases the acquisition of financial services, particularly credit, may encourage the launch and expansion of new businesses, thus reducing unemployment when existing ones close down. This results in more people who are jobless being hired and finding work.

In addition, (Molefhi 2019) investigated the effect of financial inclusion on job creation in Botswana from 2004 to 2016. The findings of the study indicated that opening of bank account, the availability of bank branches and borrowing money from a commercial bank all had a positive

impact on the level of employment both in the short run and in the long run. On the other hand, researchers discovered that the number of depositors at commercial banks had a negative impact on employment in both short and long run. Furthermore, (Yorulmaz 2018)also discovered that employment and financial inclusion have a positive correlation. they concluded that unemployed and irregularly employed populations are less likely to participate in the financial system.

In order to let the unbanked and poor participate in mainstream economic life, it is essential to provide them continued access to low-cost financial services, as defined by the United Nations (International Telecommunication Union, 2016). The IMF defines financial inclusion as "systematic initiatives to expand access to financial services for all people, particularly the financially excluded and the poor." Financial inclusion is defined by the World Bank as "the provision of appropriate, inclusive, and sustainable financial products and services to all members of society in order to enable them to meet their financial needs (credit, payments, insurance, and savings) and to participate effectively in the economic system" (World Bank, 2018).

## 3. Data and Econometric Strategy

### 3.1. Data

For our empirical analysis, we collected data from two main sources, namely; the International Monetary fund (IMF) for financial inclusion variables; and the World Development Indicators Database for the dependent variable and control variables. The data was collected from 2009 to 2020 for 49 African countries which is purely based on the availability of data.

### 3.2. Dependent Variable

The unemployment rate, is measured as a percentage of the total labor force the empirical regularity that can be observed between real output growth and the change in unemployment rate is referred to as Okun's Law. This law is used in the estimation of the relationship that exists between financial inclusion and unemployment by relying on the empirical regularity that exists between the two variables (Okun 1962, Demirgüç-Kunt, Klapper et al.).

### 3.3. Main Variable of Interest

According to (A. Asongu, Nwachukwu et al. 2018) and (Asongu, Odhiambo et al. 2018), financial inclusion can only be measured by generating an index. Consequently, we generated a PCA index

using some indicators comprised of outstanding loans from commercial banks (% of GDP), outstanding deposits with commercial banks (% of GDP), number of insurance corporations per 100, 000 adults, number of deposit accounts with commercial banks per 1,000 adults, number of commercial bank branches per 100,000 adults, geographical outreach and number of ATMs per 100,000 adults and mobile and internet bill payment that take into account three dimensions of access, usage and penetration.(Sarma 2008, Sarma and Pais , Pagano and Pica 2012, Demirgüç-Kunt, Klapper et al. , Yorulmaz)(Prachowny and Statistics) The detail of variables is provided in Table 1.

### 3.4. Control Variables

We use the annual percentage change in per capita GDP as a proxy for growth; the consumer price index as a proxy for inflation; the secondary school enrollment rate as a proxy for education; and population growth as a proxy for growth. Instead of using contemporaneous values of the control variables, we employ lagged values to deal with endogeneity issues. Unemployment can be mitigated by a rise in GDP per capita, in regards to new innovations that lead to job creation. However, it can rise if joblessness and number of education is low (Gosavi). The detail of variables is provided in Table 1.

### 3.5. Model

The empirical regularity that can be observed between real output growth and the change in unemployment rate is referred as Okun's Law. This law is used in the estimation of the relationship that exists between financial inclusion and unemployment by relying on the empirical regularity that exists between the two variables (Okun 1962, Demirgüç-Kunt, Klapper et al.). We rely on this paradigm since it has been shown to be accurate via empirical research, not just for the United States but also for other groups of countries ((Nourzad and Almaghrbi 1995); (Gordon and Clark 1984, Knoester 1986); (Kaufman 1988, Prachowny and Statistics 1993) and (Weber 1995)). The research conducted by (Abou Hamia 2016)and (Alshyab, Sandri et al. , Demirgüç-Kunt, Klapper et al.) has also recommended the validity of this law throughout the Middle East and North African Countries.

Okun's law posits a negative relationship between change of unemployment ($\Delta \boldsymbol{U_t}$) and real economic growth ($\boldsymbol{GDPgr_t}$) as illustrated in the equation where $\varepsilon_t$the error term and t is the time.

$$\Delta U_t = \alpha_0 + \alpha_1 GDPgr_t + \varepsilon_t \qquad (1)$$

We build the following model in order to estimate the impact of financial inclusion on the level of unemployment in Africa by including the financial inclusion index (Findex) and some control variables (inflation, population growth, FDI, government policy expenditure on education, education, Number of days required to start a business) as shown in equation (1):

$$\Delta U_{it} = \alpha_0 + \alpha_1 GDPgr_{it} + \alpha_2 Findex_{it} + \alpha_3 X_{it} + \varepsilon_t \qquad (2)$$

Where financial inclusion index is denoted by (***Findex***) and the control variables are denoted by (***X***). Control variables are comprised of inflation (Beck, Demirgüç-Kunt et al. 2007, Hermes 2014, Aslan, Deléchat et al. 2017, Neaime and Gaysset 2018, Park and Mercado Jr 2018, Lacalle-Calderon, Larrú et al. 2019)**,** education (Beck, Demirgüç-Kunt et al. 2007, Jaumotte, Lall et al. 2013, Hermes 2014, Park and Mercado Jr 2018, Lacalle-Calderon, Larrú et al. 2019), population growth (Beck, Demirgüç-Kunt et al. 2007, Hermes 2014, Lacalle-Calderon, Larrú et al. 2019), number of days required to start a business (Startbiz), the government policy expenditure on education (Govpolicyedu) and Foreign Direct Investment (FDI). Here, $\varepsilon_t$ *is* the error term, which is also assumed to have mean 0 and variance equal to one.(El Bourainy, Salah et al.)

***Table 1, Description of the variables.***

| Variables | Source | Definition |
|---|---|---|
| Unemployment Rate | International Labour Organization, database. | Unemployment refers to the share of the labor force that is without work but available for and seeking employment. |
| Findex | IMF financial Access Survey dataset<br><br>Index calculated by author (PCA) | Outstanding loans from commercial banks (% of GDP), Outstanding deposits with commercial banks (% of GDP), value of mobile and internet banking transactions, Number of insurance corporations per 100, 000 adults, Number of deposit accounts with commercial banks per 1,000 |

| | | |
|---|---|---|
| | | adults, Number of commercial bank branches per 100,000 adults, Geographical Outreach and Number of ATMs per 100,000 adults |
| GovPolicyEdu | World Development Indicators 2021 | Government expenditure on education, total (% of GDP) |
| Startbiz | World Development Indicators 2021 | Time required to start a business (days) |
| Education | World Development Indicators 2021 | School enrollment, secondary (% gross) |
| Population Growth | World Development Indicators 2021 | Annual population growth rate for a year. |
| FDI | United Nations Conference on Trade and Development (UNCTAD) | Log of inward FDI stock per capita |
| Inflation | World Development Indicators 2021 | GDP deflator (Annual %) |

Note: *This table presents the variables used in the paper, their definitions and/or measurement, and the sources of raw data.*

## 4. Results and Discussion

**Table 2: Principal Component Analysis (PCA) For Composite Financial Inclusion Index**

| PCA | Deposits | Loans | Mobile pay/ internet | Bank Branches | ATMS | Insurance | Deposits A/C | Borrower | Proportions | Cumulative Proportio | Eigen Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **First PC (UDI)** | 0.705 | 0.705 | -0.071 | | | | | | 0.666 | 0.666 | 1.997 |
| **Second PC** | 0.051 | 0.050 | 0.997 | | | | | | 0.332 | 0.997 | 0.995 |
| **Third PC** | -0.707 | 0.707 | 0.000 | | | | | | 0.003 | 1.000 | 0.008 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| First PC **(ADI)** | | | | 0.605 | 0.618 | 0.503 | | | 0.705 | 0.705 | 2.114 |
| **Second PC** | | | | -0.412 | -0.298 | 0.861 | | | 0.209 | 0.913 | 0.626 |
| **Third PC** | | | | 0.682 | -0.728 | 0.074 | | | 0.087 | 1.000 | 0.261 |
| First PC **(PDI)** | | | | | | | 0.707 | 0.707 | 0.641 | 0.641 | 1.282 |
| **Second** | | | | | | | 0.707 | -0.707 | 0.359 | 1.000 | 0.718 |
| First PC **(Findex)** | -0.061 | -0.062 | -0.019 | 0.500 | 0.548 | 0.373 | 0.509 | 0.208 | 0.353 | 0.353 | 2.821 |
| **Second PC** | 0.700 | 0.701 | -0.073 | 0.048 | 0.035 | 0.062 | 0.057 | -0.051 | 0.250 | 0.602 | 1.998 |
| **Third PC** | 0.020 | 0.026 | 0.899 | 0.110 | 0.031 | 0.058 | 0.026 | -0.417 | 0.126 | 0.729 | 1.010 |

*Notes:* PC= principal component, Findex=Financial inclusion Index ,loans = Outstanding loans from commercial banks (% of GDP),Deposits = Outstanding deposits with commercial banks (% of GDP), Mobile pay/ internet = mobile and internet bill payment, Insurance =Number of insurance corporations per 100, 000 adults, Deposit A/C=Number of deposit accounts with commercial banks per 1,000 adults, Bank Branches=Number of commercial bank branches per 100,000 adults, ATMS=Geographical Outreach and Number of ATMs per 100,000 adults. AFI=access dimension index, UFI=usage dimension index and PFI= penetration dimension index.

The PCA for the financial inclusion I dimensions and the financial inclusion index are shown in Table 2. Kaiser (1974) and Jolliffe (2002)'s criterion for preserving common factors is applied to the problem of preserving eigenvalues. The requirement for the typical component is that no eigenvalue less than one be kept. Therefore, the eigenvalues (71.83%, 70.46%, and 66.56%) for the penetration (PDI), availability (ADI), and usage (UDI) dimensions are 1.99677, 2.11375, and 1.28166, respectively. With an eigenvalue of 2.8213 for the first principal component, 1.99752 for the second, and 1.00988 for the third, the Financial Inclusion Index (Findex) explains over 72.86 percent of the information present across the eight financial inclusion indicators.

**Table 3: Descriptive Statistics**

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Unemployment | 490 | 8.586 | 6.968 | .32 | 28.025 |
| Findex(PCA) | 490 | .48 | 1.655 | -1.714 | 8.83 |
| GDPgr | 490 | 4.147 | 7.603 | -62.076 | 123.14 |
| Education | 490 | 49.669 | 23.518 | 9.689 | 109.444 |
| Startbiz | 490 | 29.164 | 26.736 | 4 | 216.5 |
| Govpolicyedu | 490 | 4.08 | 2.01 | 0 | 10.639 |
| Population | 490 | 2.371 | .924 | -2.629 | 4.626 |
| FDI | 490 | 69.001 | 28.216 | 22.24 | 160.21 |
| Inflation | 490 | 6.383 | 9.898 | -29.691 | 95.409 |

Annotations: This table provides a quick glance at the estimates' key variables and their associated summary statistics. The value of Observations is denoted by Obs. The standard deviations are presented for a group of African countries over the period 2009–2018. Each variable's mean value is calculated by taking its arithmetic mean, minimum value, and maximum value from the sample, respectively. Unemployment is the percentage of the labor force that is unemployed but actively looking for work. Findex(Outstanding loans from commercial banks (% of GDP),Outstanding deposits with commercial banks (% of GDP),Number of insurance corporations per 100, 000 adults, Number of deposit accounts with commercial banks per 1,000 adults, Number of commercial bank branches per 100,000 adults, Geographical Outreach and Number of ATMs per 100,000 adults). As a surrogate for human capital, "education" refers to a person's rate of secondary school attendance. The rate of inflation is defined as the percentage increase or decrease in the CPI over a given time period. Population is shorthand for the annual percentage increase in the world's human population. Gross Domestic Product Growth Rate (GDPgr).number of days required to start a business (Startbiz) and the government policy expenditure on education Govpolicyedu) and Foreign direct investments (FDI) .The term "Findex" refers to a financial inclusion index.

**Table 4: Matrix of correlations**

| Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| (1) Unemployment | 1.000 | | | | | | | | |
| (2) Findex | 0.050 | 1.000 | | | | | | | |
| (3) GDPgr | -0.020 | 0.007 | 1.000 | | | | | | |
| (4) Population | 0.124 | -0.216 | 0.044 | 1.000 | | | | | |
| (5) Inflation | -0.059 | -0.047 | 0.066 | 0.031 | 1.000 | | | | |
| (6) FDI | 0.047 | 0.024 | -0.025 | -0.050 | -0.074 | 1.000 | | | |
| (7) Education | 0.147 | 0.006 | 0.017 | -0.031 | -0.080 | 0.020 | 1.000 | | |
| (8) Startbiz | -0.038 | -0.104 | 0.017 | -0.029 | 0.051 | -0.071 | 0.000 | 1.000 | |
| (9) Govpolicyedu | 0.012 | 0.325 | -0.009 | -0.326 | -0.049 | -0.027 | 0.102 | 0.105 | 1.000 |

**Table 5: Fisher ADF panel unit root test**

| Variable | Inverse chi squard | Inverse normal | Inverse logit | Modified inv. chi-squared | Decision |
|---|---|---|---|---|---|
| Unemployment | 418.9187*** | -7.6643*** | -13.5297*** | 22.9228*** | Reject Ho |
| Findex | 168.7970*** | 1.1429** | -0.7017** | 5.0569*** | Reject Ho |
| GDPgr | 264.4989*** | -5.2453*** | -7.8571*** | 11.8928*** | Reject Ho |
| Education | 101.1237* | 1.4568* | 0.9489* | 0.2231* | Reject Ho |
| Startbiz | 246.9755*** | -0.0668** | -4.8876*** | 10.6411*** | Reject Ho |
| Govpolicyedu | 312.3433*** | -3.8118*** | -8.1394*** | 15.3102*** | Reject Ho |
| Population | 1857.6633*** | -33.7841*** | -72.6817*** | 125.6902*** | Reject Ho |
| Inflation | 147.3125*** | -1.3589* | -1.6559** | 3.5223*** | Reject Ho |
| FDI | 255.5668*** | -2.0318* | -5.2813*** | 11.2548*** | Reject Ho |

*Notes:* Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The descriptive statistics for each variable that was analyzed are presented in Table 3, which can be found below. The average unemployment rate during the decade spanning 2009-2018 was 8.586%, while the standard deviation was 6.968.

The average score on the Findex was 0.48, which suggests that the level of financial inclusion in African countries is still relatively low. There was a wide range of values, with the mean GDP growth rate coming in at 4.147%. These values ranged from -62.076% to 123.14%. The mean score for education was 49.669, which indicates that there is a significant range of education levels across the African countries. The average score for a start-up was 29.164, which indicates that there is room for improvement in terms of both entrepreneurship and innovation in African nations. The average score for government education policy was 4.08, which indicates that education policy is still prioritized less by African governments than it should be. The mean population score was 2.371, indicating that population growth in African countries is still relatively high. This is evidenced by the fact that the continent as a whole received this score. There was a wide range of values, with the mean inflation rate coming in at 6.383%. These values ranged from -29.691% to 95.409%.

The correlation matrix in table 4, shows that few variables have strong correlations. GDP growth correlates positively with population and negatively with inflation. Financial inclusion (measured by the Findex) is positively correlated with government education policy and negatively correlated with population. The correlation matrix shows low to moderate correlations between independent variables, indicating no multicollinearity.

The findings of the Unit Root test indicate in table 5 that According to the findings of the tests, the alternative hypothesis of a unit root should not be accepted for any of the variables at the 1% level of significance. This indicates that there is no discernible trend in any of the variables, nor is there a unit root that could influence the statistical properties of any of the variables.

Comparisons are made between a Pooled Regression model, a Fixed Effect (FEM) model, and a Random Effect (REM) model in order to ascertain which one is the most suitable for estimating the value of equation (2). The outcomes of the Hausman specification test are listed in Table 6. The test compares the coefficients from the fixed effects model and the random effects model to determine which best fits the data. The random effects model is correct if and only if the coefficients from the two models are comparable. However, the fixed effects model is preferred if there is a large discrepancy between the coefficients.

The chi-square value is 6.63 and p-value is.577 as shown in the table 6. Failure to reject the null hypothesis (p-value >.05) leads us to believe that the random effects model is suitable for the data.

Since our model's dependent variable and independent variables are random, we can use the random effects model to estimate their relationship. As a consequence of this, the findings of REM will be taken into consideration as shown in Table 8. Additionally, the likelihood ratio test is utilized to examine for the presence of a heteroscedasticity issue. Since the probability value is less than 0.05 which discloses that heteroscedasticity is present in this study's model as shown in Table 7.

The Wooldridge test is additionally employed to check for autocorrelation. Table 7 shows that the Wooldridge test has a probability value of less than 0.05, indicating the existence of autocorrelation. Finally, the Davidson-MacKinnon exogeneity test is used to check endogeneity issue. As the P-value is less than 0.05, the results indicate the presence of endogeneity.

**Table 6: Hausman (1978) specification test**

| | Coef. |
|---|---|
| Chi-square test value | 6.63 |
| P-value | .577 |

**Table 7: Heteroscedasticity, autocorrelation, and endogeneity tests**

| **Likelihood ratio test** | | **Wooldridge test** | | **Davidson-MacKinnon test of exogeneity** |
|---|---|---|---|---|
| **LR Chi-square** | **Prob > Chi-square** | **F** | **Prob >F** | **P-value** |
| 423.07 | 0.000 | 54.946 | 0.000 | 0.018 |

Notes: Calculated by the author

**Table 8: Regression results Random Effect Model**

| **Variables** | **REM** |
|---|---|
| unemployment | 1.63*** |
| | (0.019) |
| Findex | -0.034*** |
| | (0.001) |

| | |
|---|---|
| GDPgr | -0.0045*** |
| | (0.017) |
| FDI | 0.002*** |
| | (0.001) |
| population | 0.006 |
| | (0.836) |
| Education | 0.76 |
| | (.017) |
| Starbiz | -0.075*** |
| | (0.064) |
| Inflation | 0.005 |
| | (0.652) |
| Govt.policyEdu | 0.013 |
| | (0.245) |
| Observations | 490 |
| R-squared | .058 |

*Notes: standard errors are in parentheses*** p<.01, ** p<.05, * p<.1*

The findings of the regression analysis in table 8 indicate that the inclusion of finance, as represented by the findex variable, has a highly significant and deleterious influence on the rate of unemployment in African countries. This is made clear by the negative coefficient (which is calculated to be -0.034 at the 1% level of significance). The fact that the coefficient has a negative sign indicates that one percent increase in financial inclusion causes 3.4 percent decrease in unemployment in the African countries. This finding is consistent with the existing literature on the relationship between financial inclusion and unemployment, which suggests that financial inclusion can provide access to credit and financial services and enables individuals and firms to create job opportunities. This finding is consistent with the existing literature on the relationship between financial inclusion and unemployment (De Koker and Jentzsch 2013) (Beck, Demirgüç-Kunt et al. 2007).

The findings also indicate that a significant negative relation exists between GDP and unemployment. This is made abundantly clear by the negative coefficient (-0.0045591) which is statistically significant at the 1% level.

This finding reveals that one percent rise in economic growth will reduce unemployment by 0.4459 percent. This result is consistent with Okun's law, which proposes that there is an inverse relationship between economic growth and unemployment. The population coefficient is positive, but it is not statistically significant. This suggests that population does not have a significant effect on unemployment in the African nations.

Unemployment in Africa does not react to inflation in a statistically significant way. This result is in line with previous research on the topic, which has shown that the Phillips curve relationship between inflation and unemployment may not hold in the long run. An increase in FDI is associated with a rise in unemployment, as indicated by the positive and statistically significant (0.002 at the 1% level) coefficient of FDI. While it's commonly accepted that freer trade results in a flourishing economy and more job opportunities. While, it is true that FDI reduces unemployment, many other factors, such as FDI's composition, economic development, and its effect on income distribution, may also play a role in this phenomenon. There is no statistically significant relationship between education level or new business formation and employment rates. This finding endorces that reducing unemployment in Africa may not be as simple as boosting education and encouraging entrepreneurship. Furthermore, the economic and social benefits of education and entrepreneurship extend far beyond mere job creation (Osikena and Uğur 2016). Finally, the coefficient of government policy on education is positive but not statistically significant, suggesting that education policies implemented by African governments have little but insignificant impact on the continent's unemployment rate.

VIF was used to test for multicollinearity. Table 9 shows that FII, primary school enrolment, inflation rate, and economic growth have VIFs <5. This indicates no multicollinearity between the model's independent variables.

**Table 9. Variance inflation factor test for multicollinearity**

| Variables | VIF |
|---|---|
| GDPgr | 1.206 |
| Findex | 1.055 |
| FDI | 1.067 |
| population | 1.15 |
| Education | 1.036 |

| | |
|---|---|
| Starbiz | 1.126 |
| Inflation | 1.154 |
| Govt.policyEdu | 1.166 |
| Mean VIF | 1.132 |

*Notes:* Log of all variables taken before analysis

**Table 10 Robustness test Results of Financial Inclusion impact on Un-employment Rate.**

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Unemployment Rate is the Dependent variable | GMM (Findex) | FE (Findex) | UFI (usage Dimension) | AFI (Access Dimension) | PFI (Penetration Dimension) |
| lnUnemployment | 1.046*** | | | | |
| | (.016) | | | | |
| Findex | -.023** | -.405*** | | | |
| | (.009) | (.128) | | | |
| GDPgr | -.043** | -.005** | -.005** | -.006** | -.005** |
| | (.007) | (.006) | (.006) | (.006) | (.006) |
| POPULATION | -.025** | -.168 | -.179 | -.183 | -.166 |
| | (.0012) | (.159) | (.164) | (.158) | (.162) |
| INFLATION | .006** | .002 | .003 | .002 | .003 |
| | (.004) | (.005) | (.005) | (.005) | (.005) |
| EDUCATION | -.012*** | -.008*** | -.008*** | -.01*** | -.009*** |
| | (.008) | (.003) | (.003) | (.003) | (.003) |
| FDI | -.033* | -.486* | -.486* | -.486* | -.486* |
| | (.002) | (.260) | (.260) | (.260) | (.260) |
| STARTBIZ | -.009** | -.002** | -.001** | -.002** | -.001** |
| | (.006) | (.002) | (.002) | (.002) | (.002) |
| GOVPOLICYEDU | -.049*** | .107* | .118** | .092 | .119** |
| | (.0013) | (.058) | (.059) | (.058) | (.059) |
| UFI | | | -.029* | | |
| | | | (.118) | | |

| | | | | | |
|---|---|---|---|---|---|
| AFI | | | | -.664*** | |
| | | | | (.13) | |
| PFI | | | | | -.112* |
| | | | | | (.101) |
| constant | 1.412 | 8.992*** | 8.935*** | 9.151*** | 8.91*** |
| | (6.636) | (1.135) | (.478) | (.464) | (.475) |
| Observations | 490 | 490 | 490 | 490 | 490 |
| AR1 | -1.818(0.009) | | | | |
| AR2 | 1.082(0.279) | | | | |
| Instruments/ j.stat | 40 | | | | |
| Chi2/Wald test | 504,898(0.0000) | | | | |
| Sargan test | 23.46(0.754) | | | | |
| Hansen test | 8.768(0.198) | | | | |
| Countries | 49 | 49 | 49 | 49 | 49 |
| Year Effect (i.year) | yes | yes | yes | yes | yes |

*Notes: Robust standard errors are in parentheses*** p<.01, ** p<.05, * p<.1*

We employed Two-step system Generalized Method of Moments (GMM) to compare the results with the Random Effects Model as shown in Table 10. It is found that financial inclusion has a significant negative effect on unemployment with a coefficient of -0.023 (p-value of 0.5). Similar outcomes were also found by (Demirgüç-Kunt, Klapper et al. 2020). According to the findings of the financial inclusion index dimension, having access to financial services appears to have a significant influence on lowering the unemployment rate. In particular, the usage dimension of financial inclusion (UFI) has a negative coefficient (-0.029) at a significance level of 10 percent which indicates that one percent increase in the use of financial services and products lowers unemployment rates by 2.9 percent. This is because UFI is a measure of the extent to which a population participates in the financial system. On the other hand, the access dimension of financial inclusion (AFI) has a much stronger negative impact on unemployment (-0.664, p0.01), indicating that better access to financial services is more critical in reducing unemployment rates. In a similar manner, the penetration dimension of financial inclusion (PFI) also has a significant negative impact on unemployment (-0.112, p0.1), which indicates that higher levels of financial service penetration in the economy significantly lowers the level of unemployment.

Supporting previous research works of (Andersen and Tarp 2003, Sharma 2016, Ibrahim and Alagidede 2018) this study adds weight to the argument that the provision of financial services stimulates economic expansion and creation of employment opportunities.

The negative effect of GDP growth on unemployment is also consistent with regression results (Sharma 2016);(Sethi and Sethy 2018). This suggests that policies that promote economic growth may be an effective way to reduce unemployment in the long run. The negative relationship between FDI and unemployment is also endorsed by robust testing. This is likely due to the fact that FDI can create jobs directly by increasing demand for labour and indirectly by stimulating economic growth. The negative relationship between number of days to start-up businesses and unemployment is unexpected, as one might expect that more competition for jobs would lead to higher unemployment. However, it is possible that start-up businesses may be creating new job opportunities that offset any negative effects on employment caused by competition for existing jobs. The positive relationship between inflation and unemployment is also indorsed by robust checking. This is because high inflation rates can lead to uncertainty and instability in the economy, which can discourage investment and job creation(El Bourainy, Salah et al. 2021). he negative association between government policies on education and unemployment indicates that these policies are not effective in improving education outcomes or they have unintended negative consequences on the labour market. Overall, the results of the system GMM analysis provide further support for the idea that financial inclusion, economic growth, FDI, start-up businesses, and inflation are all important factors that affect unemployment rates. However, the results also suggest that government policies aimed to improve education may not be as effective at reducing unemployment.

**Table 11 Robustness test Results of individual measures of financial inclusion on their impact on Un-employment Rate.**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Dependent variable | Unemployment rate | Unemployment rate | Unemployment rate | Unemployment rate | Unemployment rate | Unemployment rate | Unemployment rate | Unemployment rate |
| | Usage Dimension | | | | Access Dimension | | | Penetration Dimension |

| | Deposits | LOANS | Mobile and internet | Bank branches | ATMS | Insurance | Depositac | Borrowers |
|---|---|---|---|---|---|---|---|---|
| FI | -.043*** | -.020** | -.001* | -.042** | -.016* | -.262*** | -.013* | -.029*** |
| | (.009) | (.008) | (.060) | (.031) | (.031) | (.023) | (0.008) | (0.010) |
| GDPgr | -.005* | -.005* | -.005** | -.005** | -.005* | -.004** | -.005** | -.005* |
| | (.004) | (.004) | (.004) | (.004) | (.004) | (.004) | (.004) | (.004) |
| POPULATION | -.148 | -.152 | -.15 | -.159 | -.151 | -.16 | -.148 | -.143 |
| | (.204) | (.204) | (.2) | (.2) | (.204) | (.194) | (.2) | (.206) |
| INFLATION | .003 | .003 | .003 | .003 | .003 | .002 | .003 | .003 |
| | (.006) | (.006) | (.006) | (.006) | (.006) | (.006) | (.006) | (.006) |
| EDUCATION | -.008* | -.008* | -.008* | -.008* | -.009* | -.012** | -.008* | -.009* |
| | (.007) | (.007) | (.007) | (.007) | (.006) | (.005) | (.007) | (.007) |
| FDI | -.012 | -.012 | -.012 | -.012 | -.012 | -.012 | -.012 | -.012 |
| | (.008) | (.008) | (.008) | (.008) | (.008) | (.008) | (.008) | (.008) |
| STARTBIZ | -.001 | -.001 | -.001 | -.002 | -.001 | -.001 | -.001 | -.001 |
| | (.002) | (.002) | (.002) | (.002) | (.002) | (.002) | (.002) | (.002) |
| GOVPOLICYEDU | .117 | .117 | .121 | .115 | .117 | .084 | .117 | .118 |
| | (.08) | (.08) | (.08) | (.08) | (.076) | (.084) | (.08) | (.079) |
| _cons | 8.856*** | 8.874*** | 8.835*** | 9.205*** | 8.671*** | 9.432*** | 8.825*** | 8.775*** |
| | (1.403) | (1.407) | (1.387) | (1.423) | (1.525) | (1.316) | (1.459) | (1.457) |
| Observations | 490 | 490 | 490 | 490 | 490 | 490 | 490 | 490 |
| $R^2$ | 0.091 | 0.037 | 0.014 | 0.049 | 0.057 | 0.097 | 0.027 | 0.045 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| COUNTRY | 49 | 49 | 49 | 49 | 49 | 49 | 49 | 49 |
| YEAR EFFECT | YES | YES | YES | YES | YES | YES | YES | YES |

*Robust standard errors are in parentheses *** p<.01, ** p<.05, * p<.1*

In the final step, the individual financial inclusion indicators are put through an evaluation to determine how much of an impact they have on the unemployment rate in Africa. This provides us with information that can be used to inform further policy implications and recommendations. The findings from the GMM analysis of the system are detailed in Table 11. However, in order to determine whether or not the GMM is valid for the system, we look at the diagnostic information. To begin, the Arellano and Bond test finds that the second order autocorrelation (AR (2)) with the null hypothesis of there being no autocorrelation is not rejected for any of the estimations. Second, the Hansen over identification restrictions test demonstrates that the instruments being used are reliable. In addition, the rule of thumb requirement for each specification helps to ensure that the concerns regarding instrument proliferation are addressed. In conclusion, the fisher test is significant for the specifications because it is used to evaluate the joint validity of the estimated coefficients.

After ascertaining the validity of the GMM estimate, the following findings can be established from table 10: first the usage dimension that is outstanding deposits with commercial banks as a percentage of GDP (Deposits), outstanding loans from commercial Banks as a percentage of GDP (Loans) and value of mobile and internet banking transactions as individual indicators have significant negative impact on unemployment rates, which means that a percentage increase in the use of the financial inclusion indicators of the usage dimension reduce the level of unemployment rate. Which is consistent with findings by (Osikena and Uğur 2016, Sharma 2016). The Schumpeterian model of expansion accounted for the multiplicative impact of loanable funds on economic activity. Micro, small, and medium-sized enterprises (MSME) in Africa do not use bank credit, as evidenced by the negligible effect of outstanding loans on economic growth. MSME are hesitant to take out bank loans due to the perceived high default risk and the influence of banks' wide-ranging collateral demands.

People still worry about using their mobile phones and the internet to access formal banking services (Chatterjee 2020), despite the fact that mobile money has helped reduce transaction costs in informal markets, strengthened risk sharing networks, and improved households' ability to respond to shocks(Jack and Suri 2014). This might be due to worries about identity theft, cybercrime, the sharing of private information, or invasion of privacy(De Koker and Jentzsch 2013) . Economic growth is negatively impacted because people are less likely to invest, save, and spend due to their worries about losing money(Abor, Amidu et al. 2018).

The bank branches, automated teller machines, and insurance products that make up the access dimension. According to the findings, it appears that there is a correlation between an increase in the availability of these services and a decrease in the unemployment rate. This finding is also consistent with previous research that found a positive relationship between financial access and employment growth (Claessens, Demirgüç-Kunt et al. 2001).

Thirdly the individual indicators of penetration dimension that is number of deposit Accounts with commercial banks per 1000Adults (DepositAC) and number of borrowers with commercial banks. According to the findings, there may be a correlation between an increase in the number of deposit accounts and a decrease in the unemployment rate that have significant effect on the outcome. Previous research (Demirgüç-Kunt and Klapper 2013) has found that there is a positive relationship between financial inclusion and employment growth. This finding confirms those findings and is consistent with those findings.

Consequently, this research shows that financial inclusion is an effective method to fight unemployment in Africa. Expanding mobile money services, establishing microfinance institutions, and fostering a culture of financial literacy can enhance financial inclusion in African region. The unemployment rate in Africa can be lowered by adopting growth-promoting policies like investing in education, reduce the days to start business, infrastructure, innovation, and human capital. Therefore, financial inclusion is both a driver and an enabler of broad-based economic growth and resilience, as well as improved financial health, job creation, and development. Every nation needs to have an inclusive financial system as a necessary piece of infrastructure.

## 5. Conclusion

Using panel data analysis that is REM and system GMM, the study analyzes and interpret the correlation between financial inclusion and unemployment in 49 African countries between 2009 and 2020. The findings provide support for the hypothesis that enhancement in access to financial services can promote economic growth and reduce unemployment, suggesting that financial inclusion has a negative and significant effect on unemployment in the African countries. Unemployment is found to be significantly influenced by GDP growth, FDI, startup businesses, inflation, and government policy regarding education, population, and education. Also, the negative significant effect of the financial inclusion dimensions on an unemployment adds weight to the argument that the provision of financial services stimulates economic expansion and creation of employment opportunities.

On behalf of outcomes, it is suggested that encouraging citizens to participate in the financial system is one way to combat unemployment and boost economic growth. Furthermore, governments should introduce policies regarding usage of mobile money and microfinance in rural areas to enhance financial inclusion. Moreover, sustaining of economic growth through encouraging foreign direct investment and new business creation may help bring down the unemployment rate.

It is found that financial inclusion has less influence on unemployment in countries with low levels of education and high levels of corruption. Therefore, in order to increase the efficiency of financial inclusion policies in decreasing unemployment, policymakers must address these factors. Incorporating financial inclusion into national development strategies with the assistance of regulations and institutions can help in reduction of unemployment in developing world. Meanwhile, global alliance and financial organization should play a vital role to provide a platform where developing nations could enhance their financial inclusion in order to achieve SDG-8 & 10 Expanding mobile money services, establishing microfinance institutions, and fostering a culture of financial literacy can enhance financial inclusion in African region. The unemployment rate in Africa can be lowered by adopting growth-promoting policies like investing in education, reduce the days to start business, infrastructure, innovation, and human capital.

Therefore, financial inclusion is both a driver and an enabler of broad-based economic growth and resilience, as well as improved financial health, job creation, and development. Every nation needs to have an inclusive financial system as a necessary piece of infrastructure.

For better addressing of these SDGs, researchers and policy makers can explore other dimensions of economy which are influenced by financial inclusion such as agriculture and manufacturing. Improving people's financial literacy is a crucial first step toward financial inclusion because it encourages them to use and benefit from financial services and products. According to(Bhatt 2017), "financial literacy" refers to "a high level of awareness, knowledge, and upgraded skills to make financial decisions about borrowing, saving, investing, and spending." It's seen as a tool for increasing the number of people who have access to the financial system Since financial inclusion is meaningless and counterproductive without a base level of financial literacy, governments should prioritize this issue.

## 6. Acknowledgment

I would like to express my heartfelt appreciation to my family for emotional support in the completion of this journal article. I am deeply grateful to my supervisor for their guidance. appreciation to the reviewers and editors for their valuable feedback., my colleagues for their assistance, and my friends and family for their unwavering support. I also acknowledge the financial support from Chinese Government Scholarship.

## 7. Reference

A. Asongu, S., J. C. J. I. T. Nwachukwu and People (2018). "Comparative human development thresholds for absolute and relative pro-poor mobile banking in developing countries." 31(1): 63-83.

Abor, J. Y., M. Amidu and H. Issahaku (2018). "Mobile telephony, financial inclusion and inclusive growth." Journal of African Business 19(3): 430-453.

Abou Hamia, M. A. J. J. f. L. M. R. (2016). "Jobless growth: empirical evidences from the Middle East and North Africa region." 49(3): 239-251.

Acemoglu, D. J. E. E. R. (2001). "Credit market imperfections and persistent unemployment." 45(4-6): 665-679.

Alshyab, N., S. Sandri and D. Daradkah "Financial inclusion in the Middle East and North Africa and its Effect on Unemployment."

Andersen, T. B. and F. J. J. o. I. D. T. J. o. t. D. S. A. Tarp (2003). "Financial liberalization, financial development and economic growth in LDCs." 15(2): 189-209.

Aslan, G., C. Deléchat, M. M. Newiak and M. F. Yang (2017). Inequality in financial inclusion and income inequality, International Monetary Fund.

Asongu, S. A., N. M. J. A. J. o. S. Odhiambo, Technology, Innovation and Development (2018). "Human development thresholds for inclusive mobile banking in developing countries." 10(6): 735-744.

Beck, T., A. Demirgüç-Kunt and R. J. J. o. e. g. Levine (2007). "Finance, inequality and the poor." 12: 27-49.

Bhatt, S. (2017). "Financial literacy: A holistic perspective." Asian Journal of Research in Banking and Finance 7(6): 127-139.

Bruhn, M. and I. J. T. J. o. F. Love (2014). "The real impact of improved access to finance: Evidence from Mexico." 69(3): 1347-1376.

Chatterjee, A. (2020). "Financial inclusion, information and communication technology diffusion, and economic growth: a panel data analysis." Information Technology for Development 26(3): 607-635.

Claessens, S., A. Demirgüç-Kunt and H. Huizinga (2001). "How does foreign entry affect domestic banking markets?" Journal of banking & finance 25(5): 891-911.

Collard, S. J. P. M. and Management (2007). "Toward financial inclusion in the UK: Progress and challenges." 27(1): 13-20.

Cull, R., T. Ehrbeck and N. J. W. B. G. Holle, nota de enfoque CGAP (2014). "Financial inclusion and development: recent impact evidence, Washington, DC." 92.

De Koker, L. and N. Jentzsch (2013). "Financial inclusion and financial integrity: Aligned incentives?" World development 44: 267-280.

Demirgüç-Kunt, A. and L. Klapper (2013). "Measuring financial inclusion: Explaining variation in use of financial services across and within countries." Brookings papers on economic activity 2013(1): 279-340.

Demirgüç-Kunt, A., L. Klapper, D. Singer, S. Ansar and J. J. T. W. B. E. R. Hess (2020). "The Global Findex Database 2017: Measuring financial inclusion and opportunities to expand access to and use of financial services." 34(Supplement_1): S2-S8.

Demirgüç-Kunt, A., L. Klapper, D. Singer, S. Ansar and J. J. W. B. G. R. d. h. o. w. o. b. h. o. p. Hess (2017). "La base de datos Global Findex."

El Bourainy, M., A. Salah and M. El Sherif (2021). "Assessing the impact of financial inclusion on inflation rate in developing countries." Open Journal of Social Sciences 9(1): 397-424.

El Bourainy, M., A. Salah and M. J. O. J. o. S. S. El Sherif (2021). "Assessing the impact of financial inclusion on inflation rate in developing countries." 9(1): 397-424.

Fonseca, R., P. Lopez-Garcia and C. A. J. E. E. R. Pissarides (2001). "Entrepreneurship, start-up costs and employment." 45(4-6): 692-705.

Gordon, R. J. and P. K. J. B. P. o. E. A. Clark (1984). "Unemployment and Potential Output in the 1980s." 1984(2): 537-568.

Gosavi, A. J. J. o. A. B. (2018). "Can mobile money help firms mitigate the problem of access to finance in Eastern sub-Saharan Africa?" 19(3): 343-360.

Group, W. B. (2013). Global financial development report 2014: Financial inclusion, World Bank Publications.

Hermes, N. J. A. E. (2014). "Does microfinance affect income inequality?" 46(9): 1021-1034.

Ibrahim, M. and P. J. J. o. P. M. Alagidede (2018). "Effect of financial development on economic growth in sub-Saharan Africa." 40(6): 1104-1125.

Jack, W. and T. Suri (2014). "Risk sharing and transactions costs: Evidence from Kenya's mobile money revolution." American Economic Review 104(1): 183-223.

Jaumotte, F., S. Lall and C. J. I. e. r. Papageorgiou (2013). "Rising income inequality: technology, or trade and financial globalization?" 61(2): 271-309.

Kaufman, R. T. J. J. o. C. E. (1988). "An international comparison of Okun's laws." 12(2): 182-203.

Kempson, E. and C. J. U. a. Whyley (1999). "Kept out or opted out."

Knoester, A. J. W. A. (1986). "Okun's law revisited." 122(4): 657-666.

Lacalle-Calderon, M., J. M. Larrú, S. R. Garrido and M. J. R. o. D. E. Perez-Trujillo (2019). "Microfinance and income inequality: New macrolevel evidence." 23(2): 860-876.

Leyshon, A. and N. J. J. o. R. S. Thrift (1993). "The restructuring of the UK financial services industry in the 1990s: a reversal of fortune?" 9(3): 223-241.

Mol, S. T. and S. J. A. I. M. R. J. o. R. i. M. a. TP (2014). "Financial inclusion: Concepts and overview in Indian context." 3(6): 28-35.

Molefhi, K. (2019). "Financial Inclusion and its Impact on Employment Creation in Botswana."

Mugo, M. and E. J. C. B. o. K. Kilonzo (2017). "Community–level impacts of financial inclusion in Kenya with particular focus on poverty eradication and employment creation." 13.

Neaime, S. and I. J. F. R. L. Gaysset (2018). "Financial inclusion and stability in MENA: Evidence from poverty and inequality." 24: 230-237.

Nourzad, F. and Y. J. J. o. P. K. E. Almaghrbi (1995). "Okun's law and the fulfillment of wage and price expectations." 18(2): 293-308.

Okun, A. M. J. T. A. E. R. (1962). "The predictive value of surveys of business intentions." 52(2): 218-225.

Osikena, J. and K. Uğur (2016). "Enterprising Africa What role can financial inclusion play in driving employment-led growth." The Foreign Policy Centre, London, United Kingdom.

Pagano, M. and G. J. E. P. Pica (2012). "Finance and employment." 27(69): 5-55.

Park, C.-Y. and R. J. T. S. E. R. Mercado Jr (2018). "Financial inclusion, poverty, and income inequality." 63(01): 185-206.

Prachowny, M. F. J. T. r. o. E. and Statistics (1993). "Okun's law: theoretical foundations and revised estimates." 331-336.

Rani, U., R. Kumar Dhir, M. Furrer, N. Gőbel, A. Moraiti and S. J. G. I. L. O. Cooney (2021). "World employment and social outlook: the role of digital labour platforms in transforming the world of work."

Sarma, M. (2008). Index of financial inclusion, Working paper.

Sarma, M. and J. J. J. o. i. d. Pais (2011). "Financial inclusion and development." 23(5): 613-628.

Sethi, D. and S. K. Sethy (2018). "Financial inclusion matters for economic growth in India: Some evidence from cointegration analysis." International Journal of Social Economics.

Sharma, D. J. J. o. f. e. p. (2016). "Nexus between financial inclusion and economic growth: Evidence from the emerging Indian economy." 8(1): 13-36.

Sykes, J., S. Elder, Y. Gurbuzer and M. J. W. Y. P. S. Principi (2016). "Exploring the linkages between youth financial inclusion and job creation: evidence from the ILO school-to-work transition surveys." 42.

Wasmer, E. and P. J. A. E. R. Weil (2004). "The macroeconomics of labor and credit market imperfections." 94(4): 944-963.

Weber, C. E. J. J. o. a. e. (1995). "Cyclical output, cyclical unemployment, and Okun's coefficient: A new approach." 10(4): 433-445.

Yorulmaz, R. J. B. I. R. (2018). "An analysis of constructing global financial inclusion indices." 18(3): 248-258.

Zulfiqar, K., M. A. Chaudhary, A. J. P. E. Aslam and S. Review (2016). "Financial inclusion and its implications for inclusive growth in Pakistan." 54(2): 297-325.



**Doi:** https://doi.org/10.52132/Ajrsp.en.2023.51.2

Academic Journal of Research and Scientific Publishing | Vol 5 | Issue 51
Publication Date: 05-07-2023 ISSN: 2706-6495

# Optimizing Wind Farm Layouts with Genetic Algorithms (Enhancing Efficiency in Wind Energy Planning and Utilization in Bosnia and Herzegovina)

**Author: Jure Zorić**

Bachelor of Electrical Engineering, Faculty of Technical Engineering, University of Bihać, Bosnia and Herzegovina

Email: jure091@gmail.com

## Abstract:

This paper proposes a genetic algorithm-based approach to optimize wind farm layouts in Bosnia and Herzegovina, a country with a high potential for wind energy production. The primary objective is to maximize the total power output derived from the wind farm while concurrently minimizing the wake effects resulting from turbine interactions. This balance is pivotal in ensuring the optimal utilization of wind energy resources. In this study, three different wind data scenarios are considered: a single wind direction with overall average velocity, the most prevalent wind direction with overall average velocity, and an all-encompassing wind direction analysis incorporating a weighted objective function. The results of the study suggest that the genetic algorithm is highly effective in identifying optimal solutions across each scenario. This serves as a testament to the algorithm's accuracy, robustness, and applicability in tackling real-world problems, thereby marking a significant step forward in the realm of wind farm optimization. The limitations of this research include the use of a simplified wake model and a fixed turbine type. The implications of this research include the potential for increasing the efficiency and profitability of wind farms in Bosnia and Herzegovina, as well as informing future research on more complex and realistic optimization problems.

**Keywords:** Wind Farm Layout Optimization, Genetic Algorithm, Wake Effects, Bosnia & Herzegovina, Wind Energy Utilization

## 1. Introduction

Wind farm layout optimization (WFLO) is a critical aspect of harnessing wind energy more efficiently, as it focuses on maximizing the energy production from wind farms. One of the main challenges in designing wind farms is the turbine interactions, which can cause energy losses between 10-20% and in some instances, as high as 40% (Stanley & Ning, 2019). These interactions are primarily due to the wake effects created by turbines, which disrupt the wind flow and consequently reduce the power generation of downstream turbines.

To address this issue, minimizing wake effects becomes crucial in order to enhance energy production and increase profitability for wind farm operators. This is where genetic algorithms come into play as an effective optimization method. These algorithms, inspired by natural evolution processes, help identify the optimal layout for wind turbines by using independent variables and an objective function, which usually targets maximizing energy output while minimizing wake losses.

Previous research in the field of wind farm layout optimization using a genetic algorithm has shown significant progress and the potential of this method in improving efficiency and harnessing wind energy. Some key studies include the research by Grady et al. (2005), who used a genetic algorithm to study the optimal layout of wind turbines under different wind direction cases.

Chen et al. (2013) focused on optimizing wind farm layouts using a genetic algorithm with different wind turbine heights, revealing that the use of wind turbines of different heights can increase total energy production and reduce costs per unit of power.

Asfour et al. (2022) developed a genetic algorithm-based optimization approach for determining the most suitable locations for wind turbines that maximizes net energy production while minimizing energy costs.

In addition to these key studies, there are many others that have studied various aspects of wind farm layout optimization, including the Monte Carlo model by Marmidis et al. (2008), the ant colony algorithm by Eroğlu and Seçkiner (2012), particle swarm optimization by Chowdhury et al. (2012), and a combination of genetic and Definite Point Selection (DPS) algorithms by Shakoor et al. (2014).

Furthermore, researchers such as Elkinton et al. (2006) have focused on reducing wake effects, Chen et al. (2015) have used more realistic wind models, and Graf et al. (2016) have utilized multiple types of wind turbines. Also, there are standard software for wind farm layout optimization, such as WindPRO and WAsP (Shakoor et al., 2016).

Although previous research has provided valuable insights into various aspects of wind farm layout optimization, it is clear that there are still areas that require further research and improvement.

### 1.1. Objectives of the Article

The primary objective of this article is to optimize wind farm layouts in Bosnia and Herzegovina using genetic algorithms. To achieve this, I focus on three main aspects: maximizing the power output, minimizing wake effects, and reducing overall costs associated with wind farm layouts.

My research assesses three distinct wind data scenarios: a single wind direction with an overall average velocity, the most prevalent wind direction with an overall average velocity, and an all-inclusive wind direction analysis that incorporates a weighted objective function. The exploration of these scenarios is designed to reveal the unique challenges and opportunities inherent to each, guiding the development of strategies for wind farm layout optimization.

### 1.2. Significance of the Article

This article has importance within the field of renewable energy, specifically in relation to wind farm layout optimization. It reiterates the application of genetic algorithms to enhance the efficiency of wind farm layouts, an area of untapped wind energy potential. By examining various wind data scenarios, this study aims to summarize current research, offering comprehensive insights into effective wind farm planning and utilization. Furthermore, the research underscores the role of genetic algorithms in optimizing complex energy systems, reiterating their potential beyond current applications. The insights derived can serve to support other renewable energy initiatives globally, contributing to the broader transition towards sustainable energy sources.

## 2. Methods of Mathematical Modelling and Optimization

This section details the methods for calculating costs and modeling wakes, which are used to construct the wind farm model proposed in this study.

### 2.1. Jensen's Wake Model…..

The Jensen's wake model, an analytical wake model, is utilized to determine the actual wind velocity experienced by each wind turbine. This model is based on the law of conservation of momentum within the wake. For a single wake scenario, the near field behind the wind turbine is disregarded, allowing the wake to be modeled as turbulent. The wake's radius, when originating from the wind turbine, is equal to the turbine's radius. As a result, the wake's radius, $r_1$, grows linearly based on the downstream distance, $x$, as it moves further downstream, as illustrated in Figure 1.

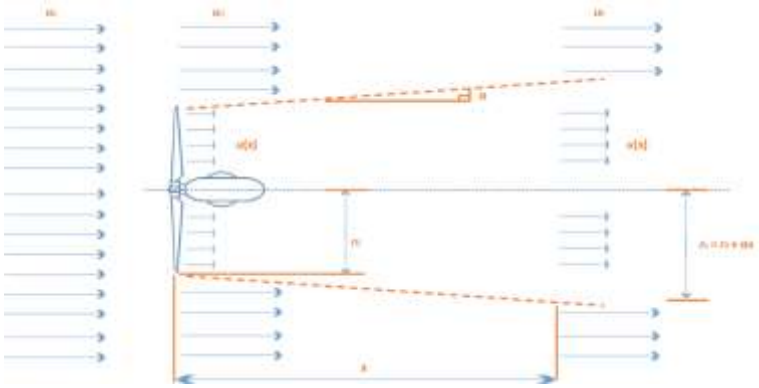

**Figure 1.** Schematic of Jensen's Wake Model

The wind speed at downstream, influenced by the wake created by an upstream wind turbine, can be determined using the subsequent formula.

$$u = u_0 \left[ 1 - \frac{2a}{\left[ 1 + \frac{\alpha x}{r_1} \right]^2} \right] \quad (1)$$

where:

- $u_0$ free stream velocity,
- $r_1$ radius of wake behind the turbine at distance, x.

$$r_1 = r_d + \alpha x \quad (2)$$

where:

- $r_d$ radius of wind turbine,
- $a$ axial induction factor.

The axial induction factor, denoted as "$a$", can be determined using the wind turbine's thrust coefficient, known as $c_T$.

$$c_T = 4a(1-a) \tag{3}$$

$$\alpha = \frac{0{,}5}{ln\left(\frac{z}{z_0}\right)} \tag{4}$$

where:

- $\alpha$ decay factor,
- $z$ hub height,
- $z_0$ surface roughness.

The decay factor, $\alpha$, outlines the breakdown of the wake by defining the expansion of the wake width for every meter traveled downstream. Determining the decay factor depends on factors such as ambient turbulence, turbine-induced turbulence, and atmospheric stability. The parameter, $z_0$, plays a vital role in calculating the decay coefficient.

In cases where a wind turbine experiences multiple wake effects from upstream turbines, the resulting velocity, $u_i$, can be determined by equating the combined kinetic energy deficits of each wake to the kinetic energy deficit of the mixed wake at that specific point, as demonstrated in the given formula.

$$u_i = u_0\left[1 - \sqrt{\sum_{i=1}^{N}\left(1-\frac{u}{u_0}\right)^2}\right] \tag{5}$$

The power of the wind turbine is directly proportional to the cube of wind speed. Therefore, to maximize the output power of the wind farm, the wind speed deficit in the previous equation needs to be minimized, as shown in the following expression.

$$Max(P_{total}) \sim Min \sqrt{\sum_{i=1}^{N} \left(1 - \frac{u_i}{u_0}\right)^2} \quad (6)$$

The cost function, as shown in equation 7 and developed by Mosetti, is based on the number of wind turbines installed. The model is designed to depend solely on the total installed wind turbines in a wind farm (Mosetti et al., 1994).

$$cost = N\left[\frac{2}{3} + \frac{1}{3}e^{-0,00174N^2}\right] \quad (7)$$

where:

- $N$ the number of wind turbines.

The relationship between the cost function and the number of wind turbines can be seen in Figure 2. The visualization shows how the cost function is affected by different numbers of wind turbines within the wind farm, demonstrating the impact on total costs as the size of the installation changes. For smaller wind farms, the cost function is nonlinear, which has a greater impact on the objective function. It is assumed that the cost of individual wind turbines will decrease as more wind turbines are purchased, maintained, or installed.

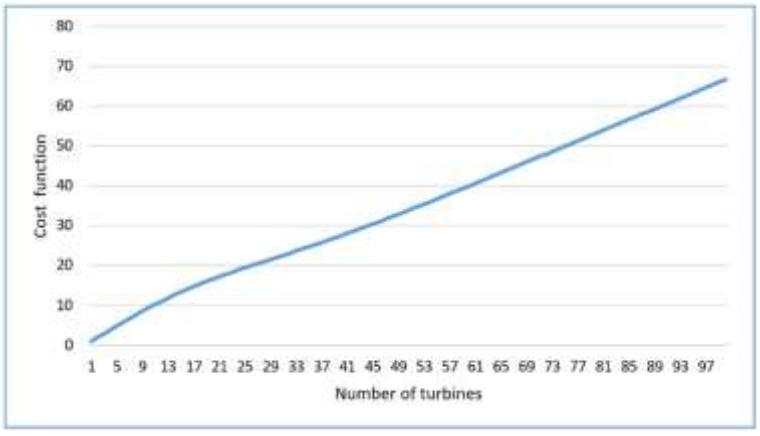


**Figure 2.** Mosetti's Wind Turbine Cost Model Plot

In general, the objective function for wind farm layout optimization is quite similar across various models. Typically, the objective function involves either maximizing or minimizing a problem, with cost and power or energy as the numerator or denominator.

When the goal is to maximize, the function considers the power over cost ratio, whereas in minimization problems, the focus is on the cost over power ratio. Two widely used maximization objective functions can be found in wind farm layout optimization, referred to as equation 8 and 9.

$$objective = \max\left(\frac{P_{total}}{cost}\right) \quad (8)$$

$$objective = \max\sum_{i=1}^{n}\left(\frac{P_{i_{total}}}{cost}\cdot f_i\right) \quad (9)$$

where:

- $f_i$ value of the wind speed distribution function $i$,
- $n$ number of directions of wind speeds

The actual total power generated in a wind farm, taking into account the wake effect, can be determined using the following equation.

$$P_{total} = \sum_{i=0}^{N}(0{,}3\ \cdot\ u_i^3) \quad (10)$$

## 3. Optimization via Genetic Algorithm

In this paper, the author uses genetic algorithm in MATLAB to search the optimal layout of a given wind farm. Drawing inspiration from the principles of natural selection, genetic algorithms employ a population-based approach where a diverse set of candidate solutions is allowed to evolve over multiple iterations or generations. Each candidate solution, represented as a chromosome, is composed of genes that encode the problem-specific variables. The fitness of each chromosome is evaluated using a fitness function, which quantifies how well the candidate solution satisfies the problem's objectives and constraints.

Central to the functioning of genetic algorithms are the genetic operators, which mimic the processes of selection, crossover, and mutation. Selection simulates the survival of the fittest, where fitter chromosomes are more likely to be chosen as parents for the next generation.

Crossover, inspired by genetic recombination, combines the genetic material of two parent chromosomes to create offspring, thereby promoting the exchange of beneficial traits among the solutions. Mutation, analogous to random genetic mutations in nature, introduces small perturbations in the chromosomes, ensuring diversity and exploration of the solution space.

In addition to the aforementioned genetic algorithm processes, other crucial steps such as initialization and termination play significant roles. The initialization phase is a fundamental step in the genetic algorithm process, laying the foundation for the subsequent evolution of candidate solutions. This critical stage is responsible for generating an initial population, which serves as the starting point for the exploration and exploitation of the solution space. A well-defined termination strategy is essential for the success of a genetic algorithm, as it determines when the algorithm should cease its search for optimal solutions. The flowchart of a simple genetic algorithm is given in Figure 3.

Further application-specific details of the genetic algorithm, including the definition of genes and chromosomes within the context of this wind farm layout problem, the specification of the fitness function, and the particular parameters or settings used, will be discussed in detail in the following chapter, where the results of this optimization approach are presented.


**Figure 3.** Flowchart of a Simple Genetic Algorithm

## 4. Results and Discussion

In this study, as previously mentioned, the author explores three distinct wind data scenarios to optimize the wind farm layout using the genetic algorithm. The scenarios are as follows:

- Case 1: The layout is optimized for a single wind direction. In this case, the wind is assumed to approach perpendicular to the turbine face, and we consider the overall average wind velocity.

- Case 2: The layout is optimized considering only the most prevalent wind direction, along with the overall average wind velocity.
- Case 3: The layout is optimized for all wind directions, calculated using the average wind velocity in each direction. This scenario incorporates a weighted objective function to provide a balanced solution.

Each of these cases is visually represented in Figure 4, which demonstrates the wind directions used in the genetic algorithm for each scenario.

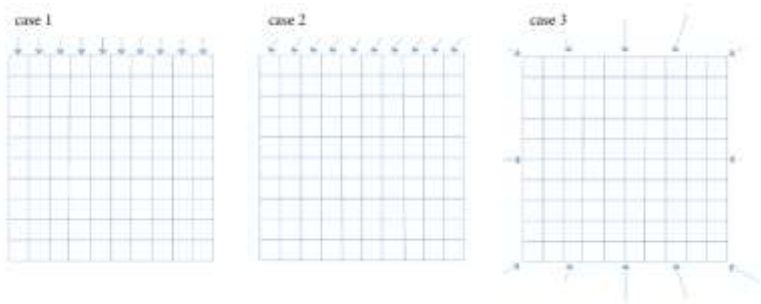


**Figure 4.** Visualization of Wind Directions Used in the Genetic Algorithm for Each Case

Various recommendations have been made for wind turbine spacing, with a minimum of 3 and up to 5 times the rotor diameter perpendicular to the wind direction, and 6 to 10 diameters along the wind direction (Porté-Agel et al., 2020). In this particular study, the grid optimization method will be executed using square grid sizes equal to 5 times the rotor diameter.

In setting up the genetic algorithm several tuning parameters must be carefully considered. These include the number of individuals, the maximum number of generations, the generation gap, sub-population size, migration, and migration generation. These parameters play a critical role in the effective operation of the genetic algorithm. In particular, the number of individuals and the maximum generations are crucial for achieving convergence in the solution. Increasing either or both of these parameters may enhance the efficiency of convergence. Specifically, increasing the number of individuals may reduce the number of generations required for convergence, thus speeding up the attainment of optimized solutions.

Table 1 presents the tuning parameters of genetic algorithm used for the first two cases. Table 2 outlines the wind turbine properties selected for the first two cases.

**Table 1.** Genetic Algorithm Tuning Parameters

| Genetic algorithm tuning parameters | Value |
|---|---|
| **Number of individuals** | 30 |
| **Maximum generation wanted** | 10000 |
| **Random starts** | 50 |
| **Generation gap** | 2 |
| **Probability of mutation** | 0.2 |

**Table 2.** Wind Turbine Properties

| Wind turbine dependent variables | Value |
|---|---|
| **Power coefficient** | 0.4 |
| **Free stream velocity** | 12 m/s |
| **Rotor diameter** | 108 m |
| **Rotor radius** | 54 m |
| **Swept area** | 9 160 $m^2$ |
| **Hub height** | 80 m |
| **Surface roughness** | 0.03 m |
| **Decay factor** | 0.146 |
| **Axial induction factor** | 0.324 |
| **Wind angle** | 0° (case 1); -30° (case 2) |

Utilizing the grid optimization method, the wind farm's accessible area for optimization, in conjunction with the aforementioned tuning parameters and turbine properties, must be supplied to produce turbine coordinates. The genetic algorithm, however, employs binary strings rather than "real values" to manipulate data. Consequently, these binary strings need to be transformed into real values or coordinates assigned to the wind turbines in the objective function segment.

In case 1, an area of 5.4 km x 5.4 km is considered for the wind farm. This total area is further divided into 100 cells of equal size (540 m x 540 m) which correspond to square cells equal to 5 times the rotor diameter in both directions, ensuring the recommended safety distance that will help avoid interference between wind turbines.

This means that there are 100 potential positions for wind turbines, hence, 100 independent variables. For the first case, a fixed number of wind turbines (30) are chosen to be placed at the most optimal locations relative to each other, and the following chromosome is obtained as shown in Figure 5.

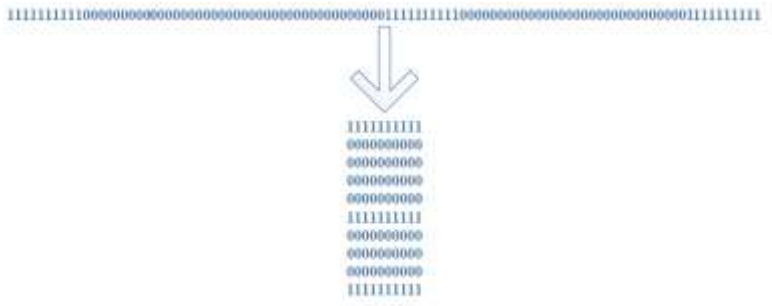

**Figure 5.** Binary Wind Farm Layout Representation for Case 1

The resulting chromosome, as illustrated in Figure 6, has full rows of ones in the first, sixth, and tenth row, representing the optimized layout of wind turbines achieved through the genetic algorithm. This layout is considered the optimal solution primarily because it minimizes losses due to the effects of wake. Interference occurs when wind turbines are placed too close to each other, causing downstream wind turbines to experience reduced wind speed and, consequently, lower output power. Directly behind the first row of wind turbines, the speed deficit is the greatest, so fewer wind turbines are placed there.

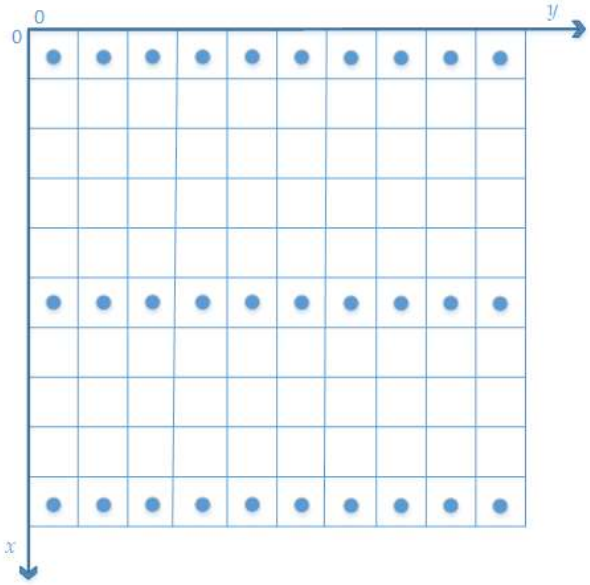


**Figure 6.** Example of Wind Turbine Layout Optimization for Case 1

In this configuration, the layout allows sufficient spacing between wind turbines and ensures that the wind flow remains relatively unhindered when reaching downstream wind turbines, allowing them to more efficiently harness wind energy. Additionally, this configuration takes into account the recommended safety distance for spacing wind turbines, further contributing to the reduction of interference losses. The algorithm converges at about 6000 generations and a fitness of 1305.7153, as can be seen in Figure 7.

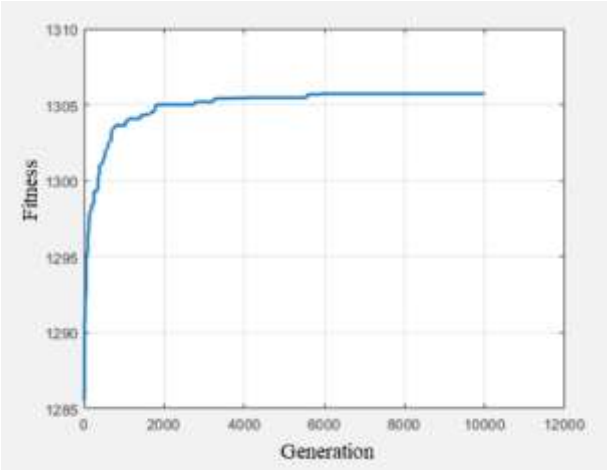


**Figure 7.** Convergence of the Genetic Algorithm for Case 1

The genetic algorithm aims to find the best possible situation where wind turbines produce as much energy as possible while considering the cost function. The total power produced stated in Table 3 makes sense because at an average speed of 12 m/s at wind turbine level, one wind turbine produces about 3.85 MW of power. Such an optimized layout through the grid optimization method does not offer much variation in the layout, forcing wind turbines to be placed in areas where they are exposed to the effects of wake. This wouldn't be a problem with a larger area that would prevent downstream wind turbines from experiencing reduced wind speed and consequently, lower output power or for the wind turbines in the last rows to experience fully recovered wind speed.

**Table 3.** Power Output for Case 1

| Wind direction | Case 1 |
|---|---|
| **Power output** | 115,367 MW |

The plot shown in Figure 8 illustrates the achieved power output of solution (expressed in megawatts) for different random initial conditions, giving us a realistic picture of oscillations between local maxima that the algorithm uncovers and the global maximum. It is significant to note that the difference between the worst and best-found solution is very small, indicating the efficiency of the genetic algorithm in this optimization problem. The worst solution that the algorithm generated is 115.32 MW, while the best solution achieved 115.367 MW. This data confirms the high degree of precision and convergence of the algorithm in finding optimal solutions, which is a result of the simplicity of the problem configuration.

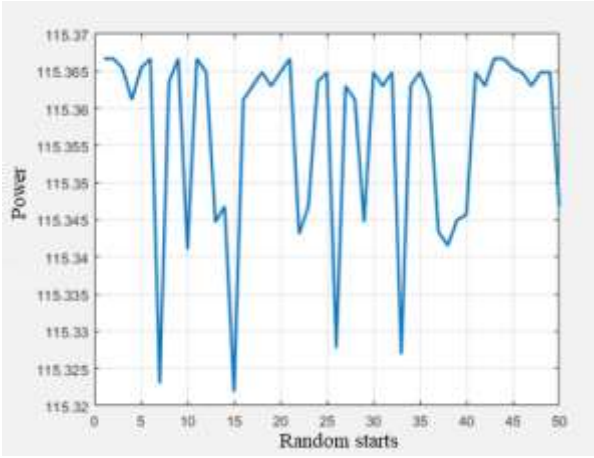


**Figure 8:** Achieved Power Output for Various Random Starts for Case 1

The plot in Figure 9 shows the movement of average quality through generations of the genetic algorithm for a random start for which the best solution was obtained. From the plot, it is evident that the average quality in the population significantly improves after a few initial generations, after which it oscillates. The analysis indicates that the genetic algorithm quickly converges to optimal solutions for this problem.

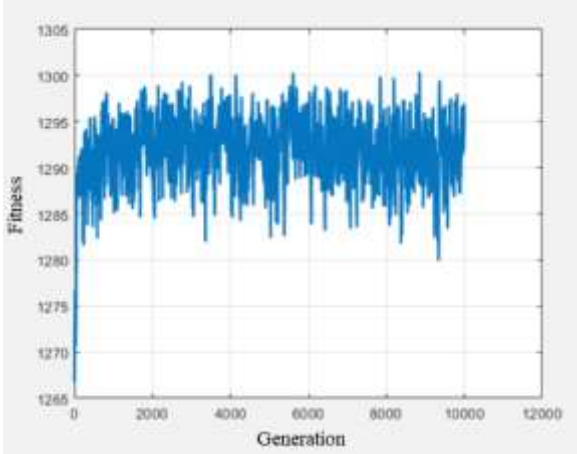


**Figure 9.** Graph of Average Fitness Quality for Case 1

Now the analysis of the obtained results will be carried out for the second case where only the most prevalent wind direction from the real wind data in case 3 is taken into account. Variable values that depend on a specific wind turbine and parameters for setting the genetic algorithm are identical as for case 1 (Tables 1 and 2) except for the value of the wind angle, which has the value of -30° in this case because this angle represents the most dominant wind direction for case 3.

The area, analogous to the first case, is divided into a hundred equal cells of dimensions 540 m x 540 m. This further suggests that there are a hundred possible positions for placing wind turbines, and therefore a hundred independent variables, as in the first case. For the second case, a fixed number of wind turbines (30) is also chosen to be placed in the most optimal locations in relation to each other and the following chromosome shown in Figure 10 is obtained.

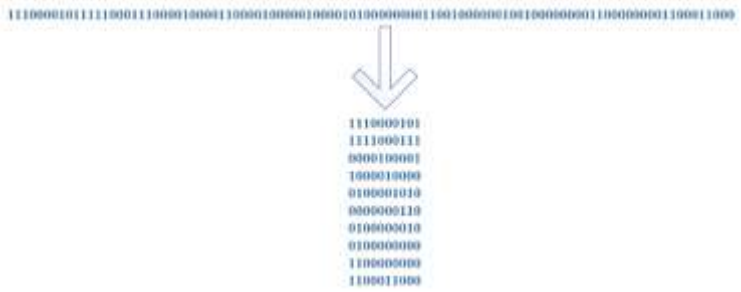

**Figure 10.** Binary Wind Farm Layout Representation for Case 2

The obtained chromosome shows a more complex, but optimized layout of wind turbines achieved through the genetic algorithm. Unlike the first case, where the wind turbines are concentrated in a few rows, in this scenario the wind turbines are spread over several locations, suggesting that this layout form provides better performance for the specific problem. Zeros and ones are transformed into the desired formation of wind turbines as can be seen in Figure 11.

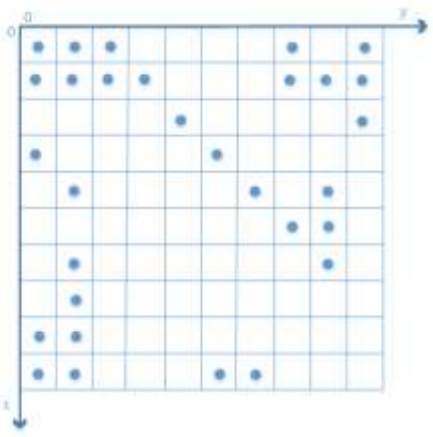

**Figure 11.** Example of Wind Turbine Layout Optimization for Case 2

In this layout, the algorithm converges at about 4000 generations and a fitness of 1316.2625 as can be seen in Figure 12.

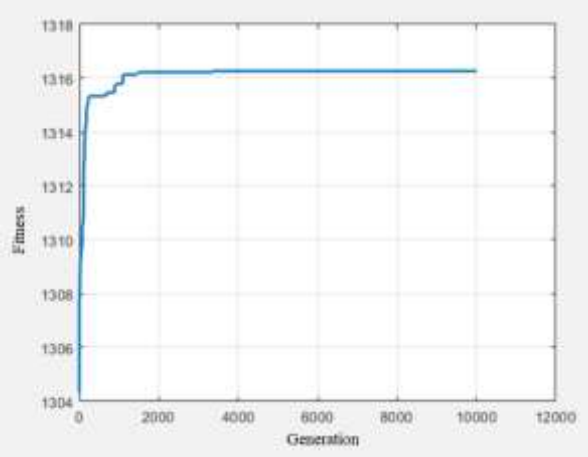


**Figure 12.** Convergence of the Genetic Algorithm for Case 2

The total power produced is stated in Table 4 and according to it, one wind turbine produces around 3.88 MW of power for this case.

**Table 4.** Power Output for Case 2

| Wind direction | Case 2 |
|---|---|
| **Power output** | 116.299 MW |

The chart in Figure 13, illustrating the frequency with which the algorithm successfully finds optimal solutions, allows us to observe the achieved power output of solution (expressed in megawatts) for different random initial conditions, giving us a realistic picture of oscillations between local maxima that the algorithm uncovers and the global maximum, for case 2. We again have a small difference between the worst and best-found solution, indicating the efficiency of the genetic algorithm in this optimization problem. The worst solution that the algorithm generated is 116.245 MW, while the best solution achieved 116.299 MW. This data confirms a high degree of precision and convergence of the algorithm in finding optimal solutions, which is again due to the simplicity of the problem configuration.

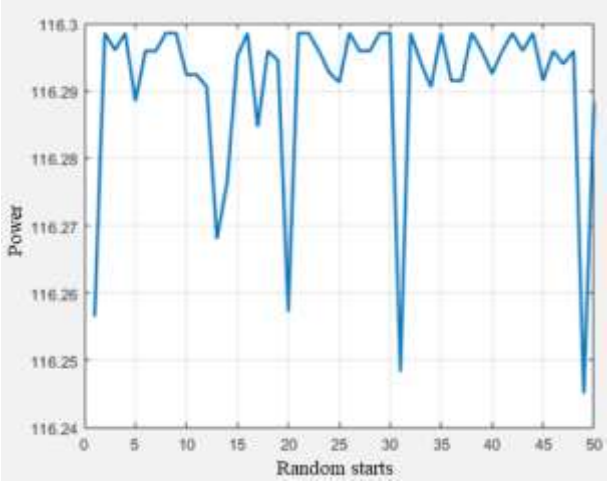


**Figure 13:** Achieved Power Output for Various Random Starts for Case 2

The graph in Figure 14 shows the movement of average quality through generations of the genetic algorithm for a random start for which the best solution was obtained for case 2. As in the first case, it can be seen that the average quality in the population significantly improves after a few initial generations, after which it oscillates. The analysis indicates that the genetic algorithm quickly converges to optimal solutions for this problem.

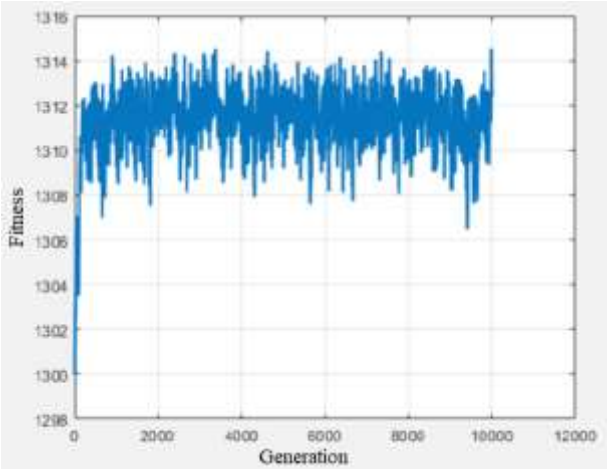


**Figure 14.** Graph of Average Fitness Quality for Case 2

For the third case, wind data will be used that was experimentally obtained for the purposes of setting up the Mesihovina Wind Farm, further processed to correspond to the wind speed at a rotor hub height of 130 m and is given in Table 5. It is expected that the use of real wind data for this research will yield more realistic results.

**Table 5:** Wind Speed, Direction and Frequency Used in Case 3

| Wind Speed | Direction | Frequency | Wind Speed | Direction | Frequency |
|---|---|---|---|---|---|
| **9.10** | 0 | 18 | 8.90 | 180 | 11 |
| **8.57** | 30 | 29 | 5.15 | 210 | 4 |
| **4.14** | 60 | 6 | 5.73 | 240 | 8 |
| **2.82** | 90 | 3 | 4.89 | 270 | 3 |
| **4.84** | 120 | 5 | 2.86 | 300 | 1 |
| **8.39** | 150 | 12 | 2.89 | 330 | 1 |

Table 6 presents the tuning parameters of genetic algorithm used for the last case. Table 7 outlines the wind turbine properties selected for the third case.

**Table 6.** Genetic Algorithm Tuning Parameters

| Genetic algorithm tuning parameters | Value |
|---|---|
| **Number of individuals** | 30 |
| **Maximum generation wanted** | 10000 |
| **Random starts** | 20 |
| **Generation gap** | 2 |
| **Probability of mutation** | 0.2 |

**Table 7.** Wind Turbine Properties

| Wind turbine dependent variables | Value |
|---|---|
| **Rotor diameter** | 130 m |
| **Rotor radius** | 65 m |
| **Swept area** | 13 273 $m^2$ |
| **Hub height** | 110 m |
| **Surface roughness** | 0.03 m |
| **Decay factor** | 0.146 |

| | |
|---|---|
| **Axial induction factor** | 0.258 |
| **Cut-in wind speed** | 4 m/s |
| **Rated wind speed** | 9.8 m/s |
| **Cut-out wind speed** | 25 m/s |

In terms of parameter values for setting the genetic algorithm for this case compared to previous ones, the only difference is now the number of random starts has been reduced to 20 to decrease the necessary computation time. It takes approximately 30 minutes per random start on the computer that was used for executing the algorithm. This ensures the algorithm ends within an acceptable 10 hours timeframe.

Now an area of 6.5 km x 6.5 km is considered for the wind farm. The area is further divided into 100 equal size cells (650 m x 650 m) that correspond to square cells equal to 5 times the rotor diameter in both directions ensuring the recommended safe distance that will assist in avoiding interference between wind turbines. As in previous cases, there are 100 potential positions, therefore, 100 independent variables. Again, a fixed number of wind turbines (30) to be placed in the most optimal locations relative to each other have been selected, and a chromosome is obtained as shown in Figure 15.

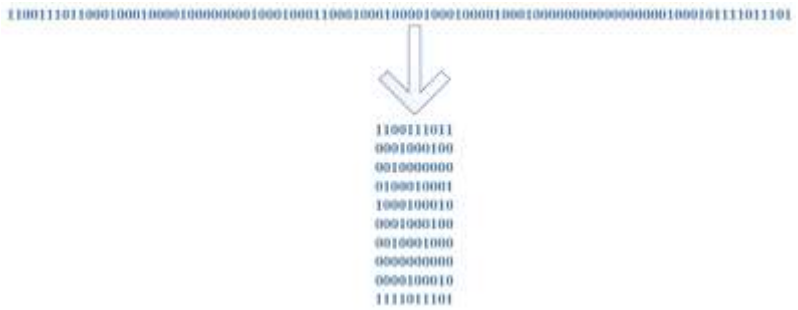

**Figure 15.** Binary Wind Farm Layout Representation for Case 3

The obtained chromosome shows a more complex but optimized layout of wind turbines achieved through a genetic algorithm. Unlike the first case, where the wind turbines are concentrated in several rows, in this scenario, the wind turbines are distributed in multiple locations, suggesting that this form of arrangement provides better performance for the specific problem. Furthermore, it is worth noting that some rows are relatively dense, such as the first and last row, while others are sparse,

which could be a consequence of the objective to minimize wake between wind turbines. Considering that the wind speed deficit can be most pronounced in the rows immediately behind the row with wind turbines, such seemingly irregular arrangement might actually provide optimal output power with regard to wind direction. Zeros and ones are transformed into a desired wind turbine formation as can be seen in Figure 16.

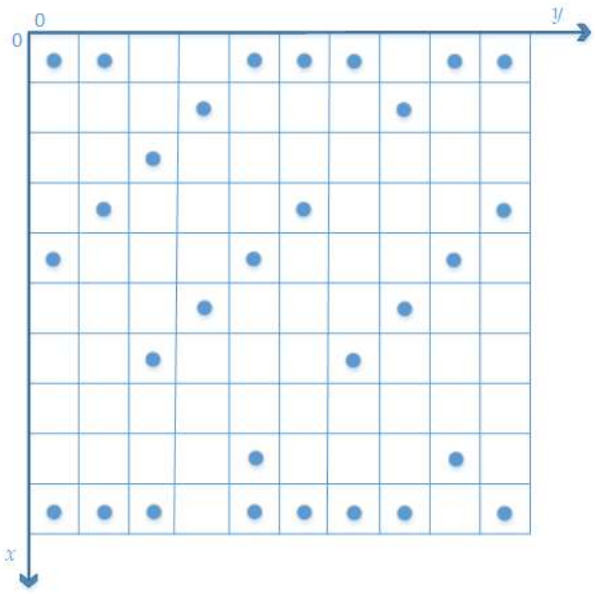


**Figure 16.** Example of Wind Turbine Layout Optimization for Case 3

In this layout configuration, the algorithm converges after about 6000 generations and with a fitness of 604.0969 as can be seen in Figure 17.

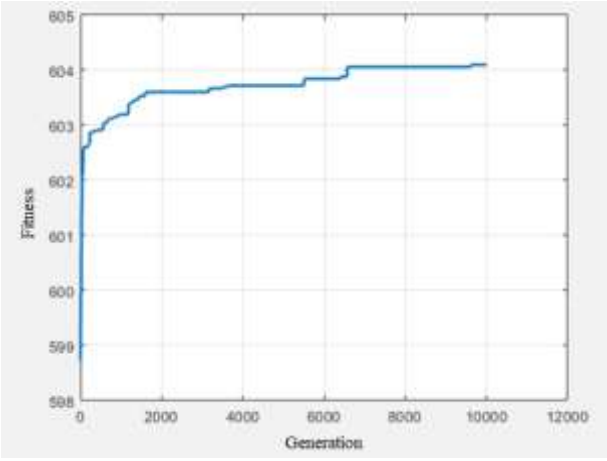


**Figure 17.** Convergence of the Genetic Algorithm for Case 3

As in previous cases, the genetic algorithm aims to find the best possible situation in which the wind turbines produce as much energy as possible taking into account the cost function. The total power output presented in Table 8 is in line with expectations given that a moderate wind speed was utilized for this case. As such, it wasn't anticipated that the power production of a single wind turbine would reach the theoretical maximum of 3.4 MW per unit.

**Table 8.** Power Output for Case 3

| Wind direction | Case 1 |
|---|---|
| **Power output** | 53.375 MW |

In Figure 18, a plot is shown illustrating the frequency with which the algorithm successfully finds optimal solutions. By observing achieved power output of solution (expressed in megawatts) for different random initial conditions, we get a realistic picture of the oscillations between local maxima that the algorithm discovers and the global maximum. Again, as in previous cases, the difference between the worst and best-found solution is small, indicating the efficiency of the genetic algorithm in this optimization problem. The worst solution generated by the algorithm amounts to 53.348 MW, while the best solution reached 53.3751 MW. Again, we have data that confirms the high degree of precision and convergence of the algorithm in finding optimal solutions.

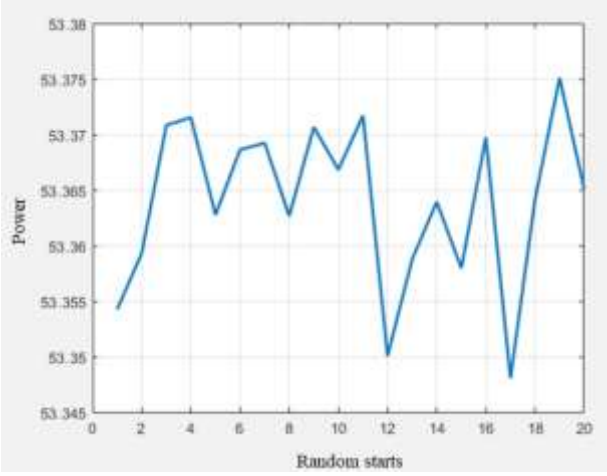


**Figure 18:** Achieved Power Output for Various Random Starts for Case 3

Finally, the plot in Figure 19 shows the movement of the average quality through generations of the genetic algorithm for the random start for which the best solution was obtained for case 3.

From the plot, it is clear how the average quality in the population significantly improves after a few initial generations, after which it oscillates more than it did in previous cases. However, the oscillations are not as pronounced and, as with previous cases, it can be said that the genetic algorithm quickly converges towards optimal solutions for this problem.

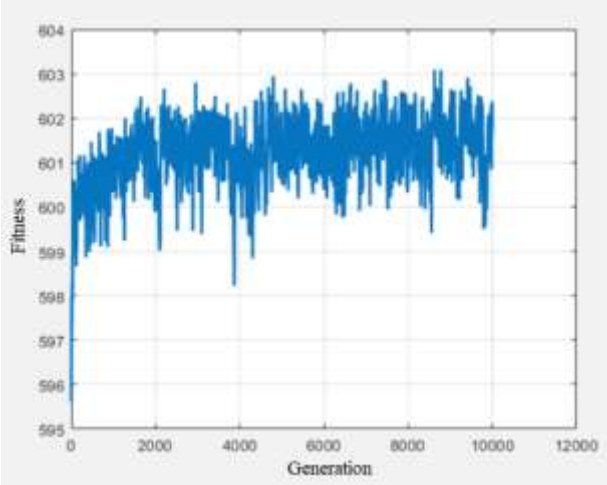


**Figure 19.** Graph of Average Fitness Quality for Case 3

## 5. Conclusion

This research aimed to enhance the efficiency of wind farm layout optimization in Bosnia and Herzegovina using genetic algorithms. By considering three distinct wind data scenarios - representing a single wind direction, the most prevalent wind direction, and a weighted encompassing of all wind directions - insights into effective wind farm planning and utilization were gleaned.

The study confirmed the efficacy of the genetic algorithm in achieving a highly efficient wind farm layout, evident in all three cases. The genetic algorithm was able to converge to optimal solutions effectively, demonstrating precision and resilience to local optima. Even though the complexity of the optimization problem increased in the third case - with the introduction of more realistic, experimentally-obtained wind data - the genetic algorithm consistently performed well, highlighting its robustness and applicability to real-world settings.

Obtained results provide additional evidence to the application of genetic algorithms in optimizing wind farm layouts, contributing to the wider body of knowledge in the field of wind energy.

The research shows that the application of genetic algorithms can successfully address the complex problem of maximizing power output while minimizing wake effects and overall costs associated with the wind farm layout.

Furthermore, the versatility of the genetic algorithm demonstrated in this study underlines its potential in other areas of renewable energy systems optimization. Given the growing importance of renewable energy sources, the findings can inform more efficient utilization and planning of these resources globally. Future work could extend this research to other renewable energy sources or incorporate more complex wake models and varying topographies, further expanding the potential of genetic algorithm-based optimization in the renewable energy sector.

## 6. References

Stanley, A. C., & Ning, A. (2019). Massive simplification of the wind farm layout optimization problem. Wind Energy Science, 4(4), 663–676. https://doi.org/10.5194/wes-4-663-2019

Grady, S. A., Hussaini, M. Y., & Abdullah, M. Z. (2005b). Placement of wind turbines using genetic algorithms. Renewable Energy, 30(2), 259–270. https://doi.org/10.1016/j.renene.2004.05.007

Chen, Y., Li, H., Jin, K., & Song, Q. (2013). Wind farm layout optimization using genetic algorithm with different hub height wind turbines. Energy Conversion and Management, 70, 56–65. https://doi.org/10.1016/j.enconman.2013.02.007

Asfour, R. V., Brahimi, T., & El-Amin, M. (2022). Wind Farm Layout: Modeling and Optimization Using Genetic Algorithm. IOP Conference Series, 1008(1), 012004. https://doi.org/10.1088/1755-1315/1008/1/012004

Marmidis, G. E., Lazarou, S., & Pyrgioti, E. C. (2008). Optimal placement of wind turbines in a wind park using Monte Carlo simulation. Renewable Energy, 33(7), 1455–1460. https://doi.org/10.1016/j.renene.2007.09.004

Eroğlu, Y., & Seçkiner, S. U. (2012). Design of wind farm layout using ant colony algorithm. Renewable Energy, 44, 53–62. https://doi.org/10.1016/j.renene.2011.12.013

Chowdhury, S., Zhang, J., Messac, A., & Castillo, L. (2012). Unrestricted wind farm layout optimization (UWFLO): Investigating key factors influencing the maximum power generation. Renewable Energy, 38(1), 16–30. https://doi.org/10.1016/j.renene.2011.06.033

Shakoor, R., Hassan, M. M., Raheem, A., Rasheed, N., & Nasir, M. N. M. (2014). Wind farm layout optimization by using Definite Point selection and genetic algorithm. https://doi.org/10.1109/pecon.2014.7062439

Elkinton, C. N., Manwell J.F., & McGowan, J.G. (2006). Offshore Wind Farm Layout Optimization (OWFLO) Project: Preliminary Results. 44th AIAA Aerospace Sciences Meeting and Exhibit.

Chen, Y., Li, H., He, B. G., Wang, P., & Jin, K. (2015). Multi-objective genetic algorithm based innovative wind farm layout optimization method. Energy Conversion and Management, 105, 1318–1327. https://doi.org/10.1016/j.enconman.2015.09.011

Graf, P., Dykes, K., Scott, G. H., Fields, J., Lunacek, M., Quick, J., & Réthoré, P. (2016). Wind Farm Turbine Type and Placement Optimization. Journal of Physics, 753, 062004. https://doi.org/10.1088/1742-6596/753/6/062004

Shakoor, R., Hassan, M. M., Raheem, A., & Wu, Y. (2016). Wake effect modeling: A review of wind farm layout optimization using Jensen′s model. Renewable & Sustainable Energy Reviews, 58, 1048–1059. https://doi.org/10.1016/j.rser.2015.12.229

Mosetti, G., Poloni, C., & Diviacco, B. (1994). Optimization of wind turbine positioning in large windfarms by means of a genetic algorithm. Journal of Wind Engineering and Industrial Aerodynamics, 51(1), 105–116. https://doi.org/10.1016/0167-6105(94)90080-9

Porté-Agel, F., Bastankhah, M., & Shamsoddin, S. (2020). Wind-Turbine and Wind-Farm Flows: A Review. Boundary-Layer Meteorology, 174(1), 1–59. https://doi.org/10.1007/s10546-019-00473-0



**Doi:** https://doi.org/10.52132/Ajrsp.en.2023.51.3

Academic Journal of Research and Scientific Publishing | Vol 5 | Issue 51
Publication Date: 05-07-2023 ISSN: 2706-6495

# Petrographic properties and physical-mechanical characteristics of Salang marbles located in Parwan province, Afghanistan

**Mohammad Sadiq Azimi***
Lecturer at Engineering Geology and Mineral Exploration department, Ghazni Technical University, Afghanistan.
Email: sadiqazimi744@gmail.com
**Mohammad Fahim Weyaar,**
Lecturer at Engineering Geology and Mineral Exploration department, Ghazni Technical University, Afghanistan.
Email: fahimweyaar@gmail.com
Asadullah Shakir,
Lecturer at Engineering Geology and Mineral Exploration department, Ghazni Technical University, Afghanistan.
Email: Asadullahshakir228@gmail.com

## Abstract

This research examines Salang marble's petrographic properties and physical-mechanical characteristics in Parwan province, Afghanistan. Situated in the western Hindu Kush zone, these marbles are part of the Afghanistan-North Pamir Folded Region, surrounded by faulted structural units.

Despite the lack of detailed information from the Afghanistan Geological Survey, including maps and reserve estimates, there has yet to be a comprehensive evaluation of the marble's quality, physical-mechanical properties, or material composition. Furthermore, research and exploration efforts in this area have been limited.

The paper aims to discuss and provide conclusions and suggestions regarding petrographic properties, mineral paragenesis, and physical-mechanical characteristics. The marbles predominantly comprise calcite, constituting around 99% of the composition. Spectrometry analysis reveals the presence of elements and oxides such as calcium, aluminum, iron, magnesium, sodium, silicon, and strontium.

The physical-mechanical properties of the Salang marbles, including specific gravity (2.70), bulk density (2.69 g/cm$^3$), marble durability index (98.52 MPa), and resistance to impact value (16.38 GPa) of marble aggregates, are analyzed.

This research involves collecting specimens from the mine area and conducting mechanical tests and petrographic studies following established norms and standards. The findings contribute to a better understanding of the Salang marbles and can inform future exploration and utilization of these valuable resources.

**Keyword**: Marble, petrographic, chemical, composition, spectrometer.

## 1. Introduction

This study focuses on the marble quarry in the Koklami area of Salang district, Parwan province. It aims to discuss the mineralogy, mineral paragenesis, and physical-mechanical properties of these rocks. Marbles are hard metamorphic rocks composed of calcite and dolomite. The formation of these rocks occurs through the crystallization of carbonate volumes under heat and pressure during geological processes (Bucher & Frey, 2002). This results in the formation of marble, characterized by a dense crystal structure and low porosity.

Marble's unique structural characteristics make it highly suitable for architectural and sculptural uses, offering various decorative possibilities (Siegesmund & Török, 2010). Its limited porosity, especially in polished form, makes it less susceptible to water-related damage (Toniolo & Poli, 2002). The transformation of calcium carbonate into marble leaves it vulnerable to various chemical agents such as chloride, nitrite, sulfate, and others (Basu, Orr & Aktas, 2020). Different sharpeners can affect aragonite and marble differently, necessitating attention to their specific characteristics during the production of various marble products.

Marble is generally classified into two types: calcite marble, with calcite as the dominant mineral, and dolomite marble, with dolomite as the primary mineral (Reedy, 2008). Dolomite marble exhibits more excellent resistance to chemical agents compared to calcite marble. The colour variation in marble stones is influenced by elements such as aluminum, magnesium, iron, etc. (Lazzarini, 2004). In the absence of water, iron oxide imparts a red or similar hue, while iron hydroxide results in brown or yellow colouration. Gray, bruised, or black shades are observed in marbles containing charcoal and manganese materials. Some marbles display streaks or foliation, while others are speckled or undulating.

It is essential to consider their mineralogy, mineral paragenesis, and physical-mechanical properties as they contribute to their overall characteristics and potential applications.

## 2. Research Goals:

The main objective of this research is to accurately evaluate the physical-mechanical properties and petrographic composition of the Salang marbles and explore their potential for effective utilization.

## 3. Research Methodology:

A combination of library research, fieldwork, and laboratory analysis was conducted to accomplish the research goals.

The library research involved studying geological information, reports, and archives related to Afghanistan's western Hindu Kush zone. The "Afghanistan Directorate of Survey and Geology" archives and resources available at the Polytechnic University library and private libraries were extensively explored. Unfortunately, no specific reports or documentation regarding the Salang marble mine in Parwan province were found in any of these sources. Therefore, this research represents the first scientific study on the Salang marble mine. Despite potential limitations due to the unavailability of expert teams, sufficient time, and additional security measures, it is hoped that future researchers and engineers will conduct further studies on this mine.

Field research involved on-site inspections of the quarry, studying the marbles and their associated rocks in the study area, and establishing their geological relationships. Various samples were collected during the fieldwork to enable petrographic studies and determination of the physical-mechanical properties of the marbles.

The laboratory component is the leading and crucial part of this research. Samples were carefully labelled and registered in the laboratory, followed by preparing thin sections from each rock sample for petrographic analysis. The study and examination of thin sections were conducted using the LEICA DM750P polarizing microscope from Germany.

Petrographic composition analysis of the rocks employed the spectrometry method, with two samples analyzed to determine their petrographic composition. Additionally, physical-mechanical properties such as specific weight, water absorption, aggregate abrasion, aggregate impact resistance, aggregate crushing value, and durability against sodium sulfate and magnesium sulfate solutions were determined to assess the quality of the marble aggregates.

These tests were conducted in private companies operating building material testing departments in Kabul, following the ASTM standards. The obtained results were compared with standard tables, leading to conclusive findings.

## 4. Research subject:

This research focuses on the "marble mine in the Koklami area of Salang district, Parwan province." Since the Salang marble is located within the Western Hindu Kush zone, the geological characteristics of this mine are examined by the broader geology of the Western Hindu Kush region. The sediments in the Western Hindu Kush zone exhibit variations in age and composition. The oldest sediments belong to the Proterozoic formations, known explicitly as Fulol member, which have a limited distribution. Additionally, there are dry and Sinozoic sediments present in the region.

Field samples were collected and analyzed as slides in the Department of Geological Survey and Mines within the Department of Geological Engineering and Mining Exploration. Due to the similar chemical composition of the mentioned marbles, only one slide was utilized for the study.

### 4.1. Description of Slide Number $M_{1\text{-}1}$:

The observed slide predominantly consists of acceptable to medium-grained calcite minerals, constituting up to 99% of the composition. There is a minimal presence of organic matter in the form of black spots. The particle size of this stone generally ranges from 0.2 to 1.5 mm. The schematic representation of this sample PPL (Plane polarized light) and XPL (Cross polarized light) is presented in Figure 1.

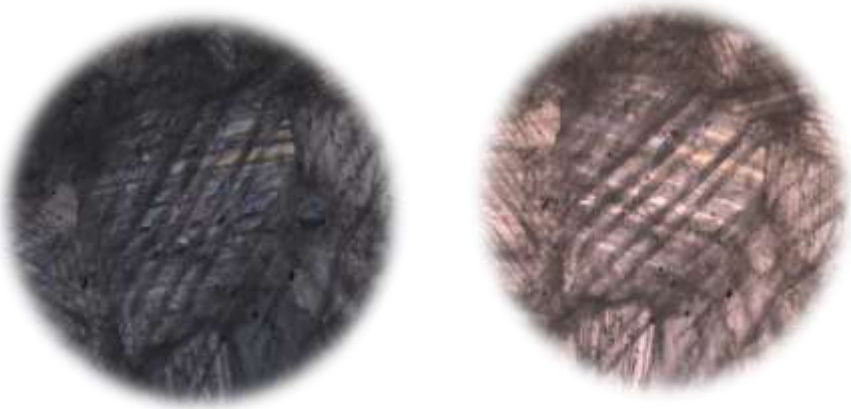

**Fig 1:** Zoom in of 10x10, Ø=2mm, displaying a massive texture, granoblastic structure, and identified as calcite marble.

**Table 1:** The macroscopic properties of the sample Number $M_{1-1}$

| Macroscopic properties | |
|---|---|
| Degree of erosion | Low |
| Porosity | Very low |
| Reaction against acid (HCl) | Severe boils |
| Color | White |

**Table 2:** Geological properties of sample number $M_{1-1}$:

| Geological properties | |
|---|---|
| Sample name | Calcite marble |
| Petrographic class | Metamorphic rock |
| Geological formation | Metamorphic |

### 4.2. Description of Slide Number $M_{3-1}$:

This particular slide exhibits a mineral composition including feldspar, quartz, calcite, muscovite, and biotite as primary constituents. Additionally, hornblende is present as a secondary mineral, and there are accessory minerals of various sizes. The schematic representation of this sample under Plane polarized and cross polarized light is presented in Figure 2.

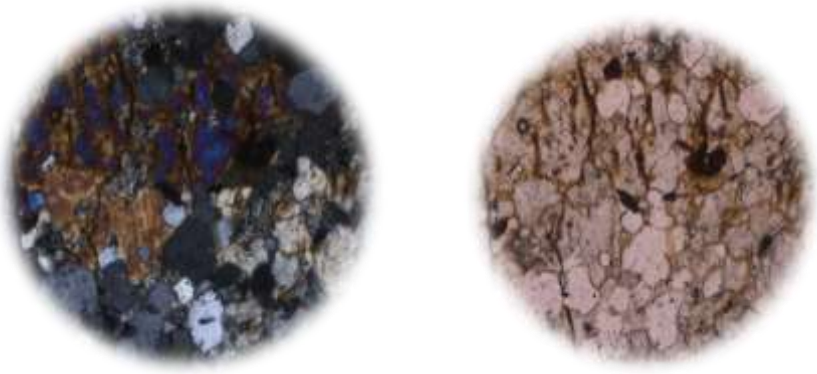

**Fig 2:** Displaying the mineral composition under PPL and XPL.

Zoom in of 10x10, Ø=2mm, displaying a massive texture and granoblastic structure, and identified as calcite marble.

### 4.3. Geochemical Analysis:

Geochemistry is concerned with the distribution, formation, and abundance of chemical elements in the Earth's crust. Various analytical techniques and instruments are employed to determine the elemental composition and percentage in geological samples. Two samples were collected from the marble mine in the Salang district for geochemical analysis using a spectrometer. The results are presented in Table 3.

**Table 3:** Geochemical Analysis Results.

| No | Laboratory No | Field No | oxides | percentage |
|---|---|---|---|---|
| 1 | 56 | $M_{1-3}$ | CaO | 52.54 |
| 1 | 56 | $M_{1-3}$ | $SiO_2$ | 0.86 |
| 1 | 56 | $M_{1-3}$ | $Al_3O_2$ | 0.1 |
| 1 | 56 | $M_{1-3}$ | MgO | 0.89 |
| 1 | 56 | $M_{1-3}$ | $Fe_2O_3$ | 0.08 |
| 1 | 56 | $M_{1-3}$ | $P_2O_5$ | 0.10 |
| 1 | 56 | $M_{1-3}$ | $K_2O$ | 0.003 |
| 1 | 56 | $M_{1-3}$ | $Na_2O$ | 0.54 |
| 2 | 56 | $M_{3-1}$ | CaO | 23.99 |
| 2 | 56 | $M_{3-1}$ | $SiO_2$ | 42.41 |
| 2 | 56 | $M_{3-1}$ | $Al_3O_2$ | 3.14 |
| 2 | 56 | $M_{3-1}$ | MgO | 0.99 |
| 2 | 56 | $M_{3-1}$ | $Fe_2O_3$ | 2.22 |
| 2 | 56 | $M_{3-1}$ | $P_2O_5$ | 0.30 |
| 2 | 56 | $M_{3-1}$ | $K_2O$ | 0.70 |
| 2 | 56 | $M_{3-1}$ | $Na_2O$ | 0.89 |

The analysis and spectrometric examination of the samples indicate that calcium oxides constitute a significant portion of the stone's composition. Additionally, minor amounts of aluminium, iron, magnesium, sodium, silicon, and strontium oxides are present in these marbles.

Therefore, the composition of these marbles can be classified as primary calcite. Aluminium and strontium oxides suggest the occurrence of clay materials in the marbles, although their proportion is negligible.

### 4.4. Physical and Mechanical Tests:

Similar to soil, stones possess pores that can be filled with water under certain conditions, leading to erosion and disintegration. Porosity also affects stones' compressive and tensile strength, directly influencing their mechanical properties and overall quality. To evaluate the physical-mechanical properties and suitability of Salang marbles from Parwan Province for construction materials and infrastructure., a series of mechanical tests were conducted following international and American ASTM standards. The results are presented in Table 4.

**Table 4:** Results of Physical-Mechanical Tests.

| No | Test | description | Percentage (%) |
|---|---|---|---|
| 1 | Specific gravity, bulk density and water absorption according to the (ASTM D 6473) Standard | Water absorption | 0.07 % |
| | | Specific gravity | 2.7 |
| | | Bulk density | 2.69gr/cm$^3$ |
| 2 | Resistance of salang marble agrigates by impact and percussions in Los Angeles device (ASTM C-131) | The average percentage of abrasion material | 49.92 M pa |
| 3 | Durability (ASTM D 4644; Index slake durability) | Average durability | 98.52 M pa |
| 4 | Aggregate impact value of Salang marble (BS-812 Aggregate impact value) | Aggregate resistance to impact | 16.38 G pa |
| 5 | Determining the health of marble aggregates against sodium sulfate and magnesium sulfate | Erosional aggregates | 6.82% |

The durability index tests demonstrate that the marbles from the Salang district mine exhibit exceptionally high durability. According to the global standard table, an index above 98 megapascals falls within the category of extremely high durability. Notably, the durability index of Koklami marble measures 98.52 Megapascals. Therefore, the marbles from the Koklami mine in the Salang district are of outstanding quality from both petrographic and physical-mechanical perspectives, positioning them among the finest marbles worldwide.

## 5. Results and Suggestions:

The research on the marble of the Koklami area of the Salang district yielded the following outcomes:

1. Petrographic analysis and examination of the physical-mechanical characteristics confirmed that Salang marbles consist predominantly of calcite mineral, with negligible amounts of dolomite mineral.
2. Salang marbles exhibit variations in colour, with some being white and suitable for decorative and sculptural purposes, while others display a grey colour due to the presence of foreign minerals and occasional streaks. These marbles can be utilized for diverse construction applications.
3. It is noteworthy that Salang marbles are prone to significant cracking due to the pressures exerted during regional metamorphism, indicating limited suitability for block extraction.
4. The numerous marble mines in the Salang district possess high economic value, primarily due to their proximity to the paved Salang highway.

Suggestions:

1. Given the presence of numerous marble minerals in the Salang Valley, it is recommended to conduct comprehensive studies on these deposits and prepare detailed 1:25,000 scale geological maps for these areas.
2. Considering that all mines, including the marble mines in the Salang Valley, are national assets, it is advisable to implement measures to prevent unauthorized extraction by residents and influential individuals.
3. Marbles with white colour and suitable characteristics for sculpting and decorative purposes should receive significant attention and protection from the government.

## 6. Conclusion:

In conclusion, this study focused on the marble quarry in the Koklami area of Salang district, Parwan province, with the aim of evaluating the mineralogy, mineral paragenesis, and physical-mechanical properties of the marbles. The research findings revealed that the marbles in the Salang district predominantly consist of calcite mineral, with varying colors and characteristics. The marbles exhibited excellent durability, making them suitable for diverse construction applications.

The petrographic analysis and physical-mechanical tests conducted on the Salang marbles provided valuable insights into their composition and quality. The marbles displayed a range of colors, from white to gray, due to the presence of foreign minerals and occasional streaks. However, it was noted that the marbles are prone to cracking, limiting their suitability for block extraction.

The economic value of the marble mines in the Salang district is significant, mainly due to their proximity to the paved Salang highway. To further explore and utilize these deposits, it is recommended to conduct comprehensive studies and prepare detailed geological maps of the area. Additionally, measures should be implemented to prevent unauthorized extraction by residents and influential individuals, as these mines are national assets.

Marbles with white color and favorable characteristics for sculpting and decorative purposes should be given special attention and protection by the government. Overall, the Salang marbles from the Koklami mine demonstrate outstanding quality, both petrographically and in terms of their physical-mechanical properties, positioning them among the finest marbles worldwide.

In light of this research, future studies by researchers and engineers are encouraged to expand the knowledge and understanding of the Salang marble mine and its potential applications. By conducting further investigations, it is possible to unlock the full potential of these marbles and contribute to the development of the marble industry in the Salang district and beyond.

## 7. References:

1. Bucher, K., & Frey, M. (2002). Petrogenesis of metamorphic rocks. Springer Science & Business Media.
2. Siegesmund, S., & Török, Á. (2010). Building stones. In Stone in architecture: properties, durability (pp. 11-95). Berlin, Heidelberg: Springer Berlin Heidelberg.

3. Basu, S., Orr, S. A., & Aktas, Y. D. (2020). A geological perspective on climate change and building stone deterioration in London: Implications for urban stone-built heritage research and management. Atmosphere, 11(8), 788.

4. Reedy, C. L. 2008. "Thin-Section Petrography of Stone and Ceramic Cultural Materials." Archetype Publications, London.

5. Toniolo, L., Poli, T., Castelvetro, V., Manariti, A., Chiantore, O., & Lazzari, M. (2002). Tailoring new fluorinated acrylic copolymers as protective coatings for marble. Journal of cultural Heritage, 3(4), 309-316.

6. Lazzarini, L. (2004). Archaeometric aspects of white and coloured marbles used in antiquity: the state of the art. Periodico di Mineralogia, 73(3), 113-125.

7. Abdullah, S., and Chmyriov, V.M., editors, 2008, Geology and mineral resources of Afghanistan, Book 1, Geology: Ministry of Mines and Industries of the Democratic Republic of Afghanistan, Afghanistan Geological Survey, 15, p. 488. British Geological Survey Occasional Publication.

8. Risen, J. (2010). US identifies vast mineral riches in Afghanistan. New York Times, 13, 17.

9. Hofmann, P., Marschallinger, R., Unterwurzacher, M., & Zobl, F. (2013). Marble provenance designation with object based image analysis: State-of-the-art rock fabric characterization from petrographic micrographs. Earth Sci, 106(2), 73-82.

10. Attanasio, D., Armiento, G., Brilli, M., Emanuele, M. C., Platania, R., & Turi, B. (2000). Multi-method marble provenance determinations: the Carrara marbles as a case study for the combined use of isotopic, electron spin resonance and petrographic data. Archaeometry, 42(2), 257-272.

11. Attanasio, D., Bruno, M., Prochaska, W., & Yavuz, A. B. (2015). A Multi-Method Database of the Black and White Marbles of G öktepe (Aphrodisias), Including Isotopic, EPR, Trace and Petrographic Data. Archaeometry, 57(2), 217-245.

12. Antonelli, F., & Lazzarini, L. (2015). An updated petrographic and isotopic reference database for white marbles used in antiquity. Rendiconti Lincei, 26, 399-413.

13. Wahab, G. M., Gouda, M., & Ibrahim, G. (2019). Study of physical and mechanical properties for some of Eastern Desert dimension marble and granite utilized in building decoration. Ain Shams Engineering Journal, 10(4), 907-915.

14. Siegesmund, S., Weiss, T., Vollbrecht, A., & Ullemeyer, K. (1999). Marble as a natural building stone: rock fabrics, physical and mechanical properties. Zeitschrift der deutschen geologischen Gesellschaft, 237-257.
15. ASTM C503 / C503 M-10 ; Standard Specification for Marble Dimension Stone.
16. ASTM C97 / C97 M Test Methods for Absorption and bulk Specific Gravity of Dimension Stone.
17. ASTM C170 / C170 M Test Methods for Compressive Strength of Dimension Stone.
18. ASTM D3148 / D1348 M. Test Methods for Elastic Moduli of Intact Rocks.
19. ASTM D4644 / C4644 M. Test Methods for Slake – Durability Index.



**Doi:** https://doi.org/10.52132/Ajrsp.en.2023.51.4