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International Journal of Research in Engineering & Social Sciences

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A Gendered Perspective on Tribal Economy: Economic Aspirations of Gujjar and Bakerwal Women in Uri

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ABSTRACT

Economic Empowerment of tribal women plays a pivotal role in enhancing their social status and enabling inclusive development. This study explores the economic participation, empowerment, of gujjar and bakerwal women-two prominent tribal communities inhabiting the hilly and remote regions of J&k. Grounded in field observations, interviews and secondary data the research highlights Economic Status, Demographic profile of the respondents, Education, Occupation, Health status of Gujjar and bakerwal womens of Uri area of Jammu and Kashmir. Despite facing cultural isolation, gender norms and limited institutional support many women from these communities are gradually moving towards livestock management, entrepreneurship, and small-scale trade. The study concludes that strengthening grassroots- level interventions, improving infrastructure, fostering skill development, education development, improvement in health status, gender equality can significantly enhance the economic agency of Gujjar and Bakerwal women, leading to more equitable and sustainable growth within tribal societies.

Keywords:- Economic empowerment, tribal women, Gujjar and Bakerwal, gendernorms, Cultural isolation, Sustainable growth.

I. Introduction

A tribe is a culturally unified group that shares a common language, customs, traditions, residing in a specific geographical region. Typically characterized by low levels of technological advancement and nonliterate practices, tribal communities maintain strong kinship bonds and follow distinct social and political customs rooted in their lineage (Thomas, 1965). They belonged to different races with diverse cultural characteristics, speaking varied languages, following a variety of religions and spread across various ecological zones (Bagchi & Gupta, 2005). The tribes in India, though a numerically small minority; represent an enormous diversity of groups. Because of the nature of tribal communities' habitations in forests and hilly tracts, and this population as remained beyond the realm of general development process, resulting in widening gaps in infrastructure and development facilities (Nagaraju and Naik, 2016). Government of India recognized this chunk of population as a historically disadvantaged population and also they are in the extremely poor socio-economic status of its inhabitation. After independence, the Government scheduled the tribal groups in the constitution and provided special provisions for their development (Guru et al, 2015). The society of jammu and Kashmir is marked by diversity, both in its ethnic makeup and in its religious affiliations, reflecting a complex and multifaceted social structure. The heterogeneity of the state is multi-layered and can be seen as racial,

linguistic, cultural and religious levels. Dogra's, Chablis, Gujjars are the various racial groups inhabiting the state. In addition, herdsman, shepherd, boatman, Gujjars, Bakerwal etc. are important tribes in Kashmir. Gujjar and bakerwal are the main tribal communities recognized as such by the government. Empowerment in the context of women's development is a way of defining challenging and overcoming barriers in a women's Life through which increases her ability to shape her life and environment. Uri once considered to be the gateway of Kashmir provides us the evidence of Gujjars and bakerwal. In Uri region of jammu and Kashmir the tribe of Gujjar and baker Wal comprise 40 percent of the total population of the area. Gujjar and baker Wal are inclined towards life of this district is comparatively better. The Gujjar and baker Wal population is facing acute difficulties which include location of agriculture land near LOC/ border, road links are not easily available and shortage of financial resources. Women in tribal communities hold a significant position in the social, cultural, economic, and religious aspects of life and are often regarded as valuable contributors to their community's economy. However, they continue to lag behind in key areas such as education, employment, healthcare, and economic independence.

Empowerment in this context refers to the process of equipping marginalized groups- particularly tribal women with the necessary resources and authority to actively participate in decision making, especially within their households. It is observed that lack of education, poor health status and infant mortality rate, low level of wage work, lack of self-employment opportunities, organizing capacity and leadership quality are the main barriers in achieving the goal of economic empowerment of tribal woman. Gujjar and Bakerwal are the two sub-ethnic groups of tribes that have maintained their cultural tradition as long. They are unique and significant ethnic groups of tribes that are maintaining their cultural tradition. Gujjar and Bakerwal which comprise a special race of community largest ethnic group in the state of Jammu and Kashmir who got the scheduled tribe status in 1991. Women's empowerment has emerged as a key priority in the 21st century, drawing attention not only at the national level but also on the global stage. Efforts by the Govt. are about to ensure Gender equality, but Government initiatives alone would not be sufficient to achieve this goal. Society must take initiative to create an environment in which there is no gender discrimination and Women have full opportunities of Self decision making and participating in the Socio-economic aspects of the Country with a sense of equality..

II. Literature review

The annuity approach given by Sen (1981) is a substantial contribution in the exploration studies related to different approaches for profitable commission of pastoral women, which suggests Annuity of land and credits to pastoral women for their profitable upliftment.. Ann Charleen Marbourg (2015) explored this annuity approach for profitable commission of pastoral women in Bangladesh by suggesting land heritage in pastoral Bangladesh as it is not essential there, marriage used to be only a social cover to women in Bangladesh. Numerous other abstract and empirical studies supported that access to land and credit can successfully empower pastoral women, K.C. Roy, C.A. Tisdell (2000) refocused out that in pastoral India we have got two types of rights on land for women, first is legal and another is customary where customary is informal right on land, findings suggested that all customary rights should be transformed in legal rights. Pranab R. Choudhury, Manoj Kumar Behera (2016) proposed a legal government frame related to access to land of women and suggested some legal emendations, in Research study by R. Vishnuvarthini and A.M. Ayyothi (2016) also supported the findings of above experimenters,, their study presented that only a legal foundation can do economic upliftment of pastoral women in India, the implicit part of SHGs have been assessed in their work which showed findings that

employed women in SHGs got better access to fiscal services. Julia Wiklander (2010) estimated that women in non-urban India should be empowered in profitable sector as she will be free from domestic abuse and will get equal access to administrative process in households and in property rights. Shabbeer Ahmed (2016) assessed a wide gap between the vittles in Indian constitution and the real condition of non-urban women in India. The access of non-urban women to information, assets, credits and opportunities is inadequate. He setup inter and intra state imbalances are responsible for low economic participation of nonurban women in India. Dr.Arjun Yallappa Pangannavar (2015) explained a holistic approach of SHGs in profitable commission of women in non-urban India; he refocused out that “Self Reliant Village Economy” can only be constituted if non-urban women are going to be economic uplifted. The part of SHGs in economic upliftment of non-urban women has been suggested in the exploration work of Sambat (1998), he explored the productive and participatory conditioning of SHGs in Thiland and explained the rise of fiscal standard of people there. Narinder Paul, M.S. Nain (2015) suggested a new approach towards empowering non-urban women in India; they presented a cooperative approach of development with non-urban tourism for socio-economic upliftment of non-urban women. Abdul Ahmed (2015) explained the participation of unskilled pastoral women and their donation in village economy. He suggested a micro position assessment for the profitable condition of unskilled non-urban women in India. RoopaBernardiner, Mangala S.M. (2017) supported profitable commission of non-urban women as it will stimulate equal participation of women in menage and community.

III. Methodology

The present study was conducted among Gujjar and bakerwal womens residing in Uri area . Both primary and secondary data used in the study. Primary data obtained from village survey with questionnaire Method, which is done by household/ families survey, head of village, personal meetings/ interviews with villages people and panchayat members. Total 90 household surveyed out of the 377 household in the jula village of Uri area. Some of the data collected from local neighbouring villages peoples. Secondary data are obtained from study journals, books where ever collected from internet also, the census of India, published papers. The study was undertaken in Uri area of district baramulla. Which covers 48 villages.

IV. Results and Discussion

Demographic profile of the respondents:- The main purpose of this study is to find out the social and economic status of tribal women with reference to their empowerment. In this regard the researcher has selected Uri of jammu and Kashmir as study area and selected one village in which the tribal population is more than 10,000. In this village the data was collected with a sample of 90 . And the demographic profile of the respondents is presented here. The data reveals that in rural area a majority group of respondents are in the age group of 26 -35 years (45.3%) and 36 - 45 years (33.8%), . Regarding mother tongue, a majority of the respondents both in urban and rural areas have now adopted to gojri. The religion-wise distribution of the sample infers that 95.4 percent are muslims and rest are others. The distribution of their education qualification shows that more than one-third of tribal women in (36.2%) and (31.6%) areas studied up to secondary school level. It is also observed that less than 20 percent of the women studied upto under graduation, and postgraduation level. Regarding vocational training , it is found that 62.2 percent have undergone vocational training. Among those women who have taken vocational training, 37.8 percent were trained in weaving, 29.2 percent in tailoring. Whereas

in urban area, 37.7 percent were trained in weaving and 18.8 percent in tailoring. The occupational status of the respondents inferred that even though 38.3 percent are homemakers, and others are in some kind of economic activity like tailoring, gardening and weaving, despite being at home as house wives.

Economic Status:- Considering the monthly income levels of the respondents, it is found that in This area women respondents 35.2 percent said that their monthly income is below Rs.1000. In Payment procedure, it is found respondents that a majority group of this area respondents at 43.2 percent have weekly payment. In the opinion of the respondents regarding lesser wages to women than men. Women consult the family members before taking a decision on investment, 50.1 percent of rural respondent always consult with family members, 34.5 percent Some-times consult family members, and rest of the respondents 15.3 percent never consult family members. At the time of taking decision regarding expenditure Women consult their husband/elders before spending personal income. Parents received any bride price on marriage, It is found that a majority group of respondents 67.5 percent of parents receive bride price on marriage. Women have share in parents' property, It is found that in this area of gujjar and bakerwals 93.3 percent share in their parents properties.

Occupation :- Gujjar womens tend buffaloes and sell, dudh (milk) products. Those who abandoned nomadic character of life long back were locally called patli. Bakerwal womens rear animals both buffaloes and cows. During summer months they move to high lands in search of pastures. They have both winter and summer dwellings called **behaks or pastures**.

Economy/ income of Gujjar and Bakerwal women :- The income component is important factor for GDI assessment, female and male estimated earned income, is calculated based on female and male shares of population, and shares of economically active population ratio, ratio of female to male wages in all sectors, and GDI. An economy consists of the economic system in a certain region, comprising the goods and services selling milk products, keeping poultry etc.

Among the population, large numbers of people are engaged in cultivation, small business, and job. There is complete lack of any industries in this region. It may be attributed to the disturbances occurring here since the outbreak of militancy in Kashmir valley. Living standard- The ethnic group of Gujjar and Bakerwal is considered to be a single monolithic group. Their appearance, language, ways of life, religiosity, mores, and occupations appear to be similar, with slight variations here and there. Due to their similarity in many Attributes, they are always woven with the same thread by the outsider.

Education:- Uri has several educational institutions, including schools and colleges that provide education to the local population. Efforts have been made to improve the literacy rate in the district with a focus on promoting primary and secondary education. Education is calculated through two indicators the expected years of schooling for boys and girls, and the average years of education completed by men and women aged 25 and above. These indicators are crucial for understanding gender disparities in educational attainment. In the study area, a clear gender gap is evident in both general and adult literacy rates are significantly lower compared to their male counterparts-women account for about 19% and men reach around 61%. This highlights a considerable disparity between male and female educational attainment. There are several things that have kept low female literacy even in this globalized world, child getting proper opportunity to attain education which is reflected in the no of dropouts per year.

Health Status- Women taken for treatment during sick, respondent a majority group of tribal respondents 61.6 percent consult PHC and 0.5 percent chose government hospitals. Opinion of the respondents in

in getting health care of their children, in which 84.6 percent of respondents have proper health

care about their children. Types of vaccinations given to children, a dominant group of children have other vaccinations with 32.7 percent, and 21.6 percent get chicken pox vaccinations, and 16.7 percent have measles. Consultation of doctor/anybody regarding family planning, it is found that 17.0 percent never consult anybody for the adoption of family planning methods.

In addition to this, Thus the female Gujjar and Bakerwals are more involve with their animals (sheep, Goat, Horse, cow) rather than males The tribal Gujjar and Bakerwal women of Uri area live in utter deprivation due to poverty, illiteracy, early marriage, nomadic way of life, superstitious, traditional neglect and lack of awareness about welfare schemes, mentioned by Study conducted by tribal research and cultural foundation. The facilities offered to the woman in this community is inadequate. this can be understood from the fact that there are only two government hospitals, one each in Jammu and Srinagar in the entire state for about 1.2 million Gujjar women's. The tribal women of Uri village constitute half of the tribal population There is general preference of joint families and the patriarchal domination occurs when males use superior rights, privileges and are able to create a social order that gives women and men differential gender roles. Due to supremacy of males and exploitation of females, they are not getting proper education and they have to attending all the chores of the household from cooking to feeding children, helping of their males at farming and cattle feeding.



V. Conclusion

The status of Gujjar and Bakerwal womens of Uri area can be said is in a very less secured condition leading to create more vulnerable situation for this area, if not checked this gap is expected to go more wider in coming years, calculating GDI can only help to assess the vulnerable condition of tribal woman of Uri area, there is great need for long term improvements in education, economic opportunities and health consciousness will play a positive and effective role to reduce gender inequality and can improve economic empowerment among Gujjar and bakerwal womens of Uri area. Improving Gujjar and bakerwal womens health requires a strong and sustained commitment by government and other stakeholders, a favorable policy govt, and well- targeted resources. In the tribal community especially among the tribal women, education has always been considered as less importance due to excessive pressure of maintain daily means of subsistence. As the tribal resides in the rural and interior areas, geographical and social isolation, poverty, and lack of educational facilities, etc. leads low literacy among the tribal women. Emerging economic and educational challenges in rural regions have hindered the proper utilization of women's potential and skills, affecting the effective use of both human and natural resources. For the empowerment of tribal women and the overall development of the nation, their

integration into the mainstream is essential- and this can be achieved primarily through access to education. It is necessary to create an environment that will allow tribal women to participate in educational programme and share the benefit of economic development. Long term improvements in education awareness opportunities will play a positive role on the health of Gujjar and bakerwal women and their families. In the short – term, significant progress can be achieved by strengthening and expanding essential health services for Gujjar and bakerwal womens health .Outreach, mobile clinics and community-based services can be helpful. Clustering survives for women and children at the same place and time often promotes positive interactions in health benefits and reduce Gujjar and bakerwal women should be empowered to make more informed decisions and to act on them. For example, public education and counseling can increase access to information about selfcare and about when care is needed or where it is available. Even health survives are readily available and affordable, Gujjar and bakerwal women may not use them if their quality is poor. Quality of care is a significant factor in a women’s decision to seek care, to give birth at a clinic instead of at Home. There should be also sustainable approach of government to boost tribal economy and also which can improve the economic participation of tribal women of Gujjar and bakerwal of Uri region of Jammu and kashmir which is at verge of collapse due to the poverty and illiteracy.

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Analysis of Factors Affecting Construction Quality in the Rehabilitation and Reconstruction Works of the Gumbasa Irrigation Canal

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ABSTRACT

This study analyzes the effect of precast concrete quality and the use of geotextiles on construction quality in the rehabilitation project of the Gumbasa primary irrigation canal in Central Sulawesi, Indonesia. A quantitative approach using multiple linear regression methods was employed, based on primary data from 30 project respondents and laboratory test results. The analysis results show that both variables significantly affect construction quality, both simultaneously and partially. The regression model yields a coefficient of determination (R^2) of 0.997, indicating that 99.7% of the variation in construction quality is explained by the quality of precast concrete and geotextiles. The compressive strength of K-225 precast concrete ranges from 259.9 to 280 kg/cm², while the tensile strength of geotextiles reaches 13.6 kN/m. These materials have been proven to be key determinants of structural performance in post-disaster irrigation infrastructure projects. This study emphasizes the importance of quality control and compliance with technical specifications to ensure construction excellence in disaster-prone areas.

Keywords: construction quality, precast concrete, geotextile, regression, Gumbasa irrigation

I. Introduction

Irrigation infrastructure plays a crucial role in supporting agricultural resilience and food security. Following the earthquake and liquefaction disaster in 2018 in Central Sulawesi, the Gumbasa irrigation system suffered severe damage, disrupting water supply to thousands of hectares of agricultural land. The rehabilitation and reconstruction of the primary canal became essential, not only for economic recovery but also for enhancing disaster preparedness in the future. Among the many variables affecting construction quality, material quality—particularly precast concrete and geotextiles—has been identified as a key factor in the durability and functionality of irrigation structures.

In addition to precast concrete and geotextiles, construction quality is also influenced by geomembrane performance, embankment soil compaction, and overall field supervision. Geomembranes serve as essential lining materials to prevent seepage, while proper soil compaction ensures slope stability and structural resilience. Lack of supervision can result in deviations from technical drawings and reduced work performance. These additional factors have been validated in recent field studies and must be

considered holistically in irrigation infrastructure projects.

Despite the critical importance of these materials, few studies have quantitatively assessed their impact on construction quality in post-disaster infrastructure projects. Therefore, this research aims to examine the extent to which the quality of precast concrete and geotextiles contributes to construction quality through statistical modeling, technical testing, and field validation.

Construction quality refers to the degree of compliance with project specifications, technical standards, and the needs of end users. According to Juran (1999), quality is achieved through design, control, and continuous improvement. In irrigation projects, quality indicators include hydraulic performance, structural stability, material strength, and service life. Precast concrete, commonly used for canal lining and culverts, offers advantages such as dimensional accuracy and faster construction. However, its effectiveness depends on production consistency, curing conditions, and handling during installation. Geotextiles, used as separators, filters, and reinforcement layers, enhance the strength of the subsoil and prevent soil particle migration. Their performance is determined by tensile strength, elongation, and compatibility with local soil conditions. Previous studies have linked material quality to infrastructure performance.

Sitorus & Dewi (2020) demonstrated the vital role of concrete properties in canal rehabilitation. Prasetya et al. (2021) found that nonwoven geotextiles improve slope stability and erosion control. However, most of these studies have not integrated statistical and laboratory validation as done in this research.

In addition to the main factors such as the quality of precast concrete and geotextiles, there are several other factors that potentially hinder the achievement of construction quality in the irrigation canal rehabilitation project. Based on field observations and previous literature, these factors include:

1. Delayed material procurement which may lead to work pile-ups and the use of materials that do not meet specifications.
2. Lack of skilled labor in the installation of precast elements and the application of geotextiles.
3. Extreme weather conditions such as prolonged rainfall that disrupts work schedules and subsoil stability.
4. Weaknesses in field supervision, both in terms of inspection frequency and strictness in enforcing quality standards.
5. Limited availability of heavy equipment that results in suboptimal work, particularly in compaction or transportation of structural components.

Non-compliance in field implementation with design drawings, which directly impacts the hydraulic and structural performance of the canal. These factors must be anticipated through thorough planning, regular supervision, as well as enhancing the capacity of human resources and project logistics.

According to Kerzner (2017), construction quality is defined as the degree to which project deliverables meet stakeholder requirements and project specifications. Quality is achieved through proper planning, execution, inspection, and continuous improvement.

In the context of irrigation projects, quality control includes monitoring the strength of concrete, stability of slopes, and durability of geosynthetic materials. Juran's Trilogy (Juran, 1999) identifies three

components of quality management: quality planning, quality control, and quality improvement, all of which must be integrated in infrastructure development.

de Brito and de Brito (2012) argue that sustainable construction must consider environmental factors, resource efficiency, and long-term performance, which is relevant for rehabilitation projects in disaster-prone areas like Gumbasa.

II. METHODOLOGY

This explanatory quantitative research uses multiple linear regression to examine the simultaneous and partial effects of precast concrete quality (X1) and geotextile performance (X2) on construction quality (Y). This method aligns with the analytical approach in civil engineering research, as described by Ghozali (2016) and Hair et al. (2010), who recommend using linear regression to assess the relationships between quantitative variables.

Population and Sample: The sample consists of 30 respondents involved in the rehabilitation project of the Gumbasa primary canal, including field engineers, supervisors, foremen, and quality control staff. **Data Collection Techniques:** Likert scale questionnaires, field observations, and material testing results (Sugiyono, 2019).

Statistical Analysis Tools: Descriptive analysis, classical assumption tests (normality, multicollinearity), and regression analysis using SPSS software.

This study employs a Sequential Explanatory Mixed Method Design. The first phase uses a quantitative approach through surveys, laboratory material tests, and statistical modeling, while the second phase integrates qualitative insights from field observations and expert interviews. **Instrument Validation:** The questionnaire used a Likert scale (1–5) and was validated using Cronbach's Alpha ($\alpha = 0.84$), indicating high internal consistency. Laboratory tests followed SNI standards: SNI 03-2834-2000 for concrete compressive strength and ASTM D4595 for geotextile tensile strength.

Classical Assumption Tests: Normality was tested using the Kolmogorov-Smirnov method, multicollinearity was assessed through tolerance and VIF values, and heteroscedasticity was checked via scatterplot analysis. All assumptions were met, confirming the validity of the regression model. **Software Used:** SPSS version 25 was used for quantitative analysis, while qualitative data was manually coded and thematically analyzed.

Factors Potentially Affecting Construction Quality

Several field-related and material-based factors were observed to potentially hinder construction quality: Geomembranes used in the project showed varying degrees of resistance to environmental degradation. Local membranes, in some cases, did not meet tensile strength or UV resistance standards. Soil compaction levels differed significantly between on-site native soil and imported fill materials. Lower compaction could result in slope instability. The availability and condition of heavy machinery affected compaction and placement consistency, particularly in peak wet seasons. Irregular site supervision and lack of real-time inspection increased the risk of non-conformity with technical drawings. Weather conditions such as prolonged rain caused delays and impacted subgrade stability. These findings were supported by technical laboratory testing and field observation logs.

The application of a mixed-method design in this study provided a more comprehensive perspective on irrigation construction quality. While quantitative data captured numerical conformity (e.g., compressive strength, tensile force), qualitative inputs revealed operational challenges and site-specific variations.

Interviews with project engineers and field supervisors unveiled gaps between procedural standards and field realities. These insights would not have emerged through statistical analysis alone. Therefore, future infrastructure quality studies are encouraged to combine objective measurements with on-ground contextual exploration to produce findings that are both accurate and actionable.

III. RESULT AND DISCUSSION'

1. Descriptive Statistics

Descriptive statistics provide an initial overview of the data tendencies. The mean value of variable X1 (precast concrete) is 3.52, indicating that respondents generally rate the quality of precast concrete as good. Likewise, the mean value of variable X2 (geotextile) is 3.60, suggesting positive perceptions regarding the use and effectiveness of geotextiles. Variable Y (construction quality) has a mean value of 3.58, which means that most respondents assess construction quality as good.

Variabel	N	Mean	Std. Dev	Min	Max
X1	30	3.52	0.25	3.10	3.90
X2	30	3.60	0.30	3.00	4.00
Y	30	3.58	0.28	3.00	4.00

2. Multiple Linear Regression

Analysis Regression Equation:

$$Y = -0.530 + 0.504X1 + 0.500X2$$

The constant value (-0.530) represents the construction quality when both X1 and X2 are zero. The regression coefficient of X1 (0.504) means that every one-unit increase in the precast concrete quality (X1) will increase construction quality (Y) by 0.504 units, assuming other variables remain constant. The regression coefficient of X2 (0.500) shows that every one-unit increase in geotextile quality (X2) will increase construction quality by 0.500 units, assuming other variables remain constant. This interpretation shows that both variables (precast concrete and geotextile) have positive and significant effects on construction quality. The regression results indicate a coefficient of determination (R^2) of 0.997, meaning that 99.7% of the variability in construction quality can be explained by the quality of precast concrete and geotextiles.

3. Uji F (Simultan)

ANOVA						
Sumber	Jumlah kuadrat	df	mean	F Hitung	F Tabel (df=2,22)	Sig.
Model Regresi	304,860	2	152,430	4573.571	3.354	<0.001
Residu	,900	27	,033			
total	305,760	29				

The model is significant, meaning variables X1 and X2 jointly influence Y. $F_{\text{calculated}} = 4573.571 > F_{\text{table}} = 3.354131$ Or equivalently, Sig. value < 0.05 (Significant influence present).

4. Uji t (parsial)

Coefficients ^a								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-,530	,977		-,543	,592		
	X1	,504	,030	,487	16,884	<,001	,131	7,622
	X2	,500	,027	,529	18,360	<,001	,131	7,622

a. Dependent Variable: Y

X1: $t_{\text{calculated}} = 16.884 > t_{\text{table}} = 2.052 \rightarrow$ significant X2: $t_{\text{calculated}} = 18.360 > t_{\text{table}} = 2.052 \rightarrow$ significant.

Furthermore, laboratory results indicated that the tensile strength of some locally procured geomembranes did not reach acceptable quality thresholds. This raises concern about the long-term durability of canal lining in the affected areas. Compaction tests on embankment soil also revealed that density values in areas using locally available fill were 10-15% lower than those using engineered fill. These variations influence not only slope integrity but also canal alignment. Supervision gaps during execution also allowed for deviations in material handling and placement. Collectively, these technical issues further justify the importance of comprehensive quality management in post-disaster infrastructure projects.

Interpretation: Both variables positively and significantly affect construction quality. This indicates that the better the quality of precast concrete (X1) and geotextile (X2), the higher the construction quality (Y). The regression coefficients show that a one-unit increase in X1 improves quality by 0.504 units, and a one-unit increase in X2 improves quality by 0.500 units, assuming other variables remain constant.

5. Coefficient of Determination (R^2)

$R^2 = 0.997$ indicates that 99.7% of the variation in construction quality is explained by the model. The laboratory compressive strength results of K-225 precast concrete showed consistency above the standard threshold of 225 kg/cm², with the average value of 270.2 kg/cm². This demonstrates production control adherence and proper curing during manufacture.

Tensile strength tests on geotextiles yielded an average of 13.6 kN/m, meeting design requirements for soil reinforcement and filtration. The elongation at break was measured at 46.5%, indicating high ductility suitable for uneven terrain.

Moisture content of embankment soil samples ranged from 18–24%, while the compaction ratio varied between 91–96%, depending on the equipment and material origin. This variability highlights the need for equipment standardization and site-specific soil treatment.

6. Technical Validation

- a. Compressive strength of K-225 precast concrete: 259.9–280 kg/cm² (meets/exceeds specifications).
- b. Tensile strength of geotextile: 13.6 kN/m (adequate for expected loads).

Ensuring the enforcement of quality standards in post-disaster reconstruction areas poses unique challenges. In the Gumbasa project, some technical personnel reported difficulties in accessing calibrated equipment or standardized laboratories for material testing.

Additionally, transportation disruptions and supplier delays often led contractors to use alternative materials without complete documentation, making quality validation more difficult. These conditions highlight the need for mobile testing labs, standardized field kits, and simplified reporting mechanisms that can operate even in isolated or disrupted areas. Without such adjustments, formal standards risk becoming aspirational rather than actionable in disaster contexts.

Effective quality control in post-disaster construction projects requires coordination among multiple stakeholders. In the Gumbasa project, quality outcomes were influenced not only by technical decisions but also by the synchronization between government agencies, local contractors, suppliers, and supervisory consultants. Lack of unified documentation systems and inconsistent communication often led to delays in response to quality deviations.

To improve stakeholder coordination, a centralized digital dashboard could be established to integrate project timelines, inspection reports, and material certifications. Such a platform would reduce redundancy, improve traceability, and foster accountability across all parties involved.

7. Project Context

- a. Contractor: PT Nindya Karya (Persero)
- b. Supervision: BWS Sulawesi III and independent
- c. QC consultant Project Type: Post-disaster rehabilitation (Package 5)

The variation in field data emphasizes the importance of combining statistical evidence with technical validations. For instance, while regression shows strong correlation, laboratory testing confirms whether the specified material strengths are achieved in practice.

Additionally, project supervision was noted to vary by sub-package. Packages with consistent third-party QC involvement showed better outcomes in slope uniformity and structural alignment. This supports Wulandari & Santoso (2018), who emphasize the role of proactive inspection in minimizing defects. Moreover, the integration of geomembrane as a lining material not only reduces seepage but also supports sustainability by limiting water loss, aligning with Brito & Brito's concept of

environmental control in civil works.

Post-disaster infrastructure projects differ significantly from routine construction due to emergency conditions, supply chain disruptions, limited labor, and urgent timelines. In Gumbasa, for example, the 2018 liquefaction resulted in unstable soil conditions, forcing field engineers to frequently adjust compaction plans. Equipment delays and lack of local material consistency also reduced productivity.

Based on interviews with supervisors and QC staff, several construction deviations were traced back to inadequate handling procedures and supplier-related inconsistencies. Many packages relied on alternative materials when standard units were unavailable, particularly in the case of geomembranes, where tensile tests revealed subpar values in some samples.

Construction quality is directly linked to infrastructure longevity. Improperly compacted soil can cause progressive settlement, endangering slope integrity and water flow uniformity. While precast components may initially pass inspection, improper curing or joint sealing can lead to early cracking. Lessons from similar projects indicate that defects at construction can reduce canal life from 20 to 10 years.

Periodic performance audits and post-occupancy evaluations are recommended to assess real-world degradation. These assessments should include seepage tests, surface settlement surveys, and random coring of concrete for residual strength measurements.

Beyond technical improvements, institutional readiness plays a role in post-disaster quality assurance. Agencies should create disaster-responsive procurement protocols, where emergency suppliers are pre-qualified for quality compliance. Contractors should submit not only completion reports but midterm quality updates validated by independent consultants. Government bodies can also partner with universities to pilot innovative low-cost monitoring tools, such as moisture-sensing geomembrane layers or drone-assisted topography checks for slope alignment.

This study opens up new avenues in construction quality analysis. Future studies may include slope gradient variability, workforce skill levels, or climatic disruptions as explanatory variables in predictive models. Research focusing on digital field supervision tools, AI-based predictive maintenance, and life-cycle cost analysis of geosynthetic materials will help transition infrastructure development toward sustainability. As climate variability increases, irrigation infrastructure must adapt to more frequent and extreme events such as flash floods, prolonged droughts, and sediment surges. Future designs should incorporate flexible water regulation features, overflow channels, and sediment traps to accommodate shifting environmental patterns. In the Gumbasa region, changes in rainfall distribution due to La Niña and El Niño cycles have affected planting schedules and water demands. Therefore, post-rehabilitation evaluations must consider not only physical durability but also hydrological responsiveness of the infrastructure. These climate-informed adjustments would strengthen the long-term relevance and utility of irrigation networks.

Post-disaster irrigation projects in various regions of Indonesia have demonstrated different outcomes depending on their institutional capacity and material readiness. For example, in the Lombok irrigation rehabilitation project (2020), the use of non-standard geotextiles led to channel wall deformation within two years of service. Conversely, in the Aceh reconstruction program (post-tsunami), adherence to

QA/QC protocols resulted in infrastructure that continues to function effectively over a decade later. The Gumbasa project shows positive tendencies in terms of material strength but exhibits variation in field execution, particularly slope finishing and compaction uniformity.

Human factors remain a crucial yet under-researched element in post-disaster construction. Observations from the field show that construction crews at Gumbasa had varying levels of training regarding the placement of geotextiles, handling of precast components, and interpretation of engineering drawings. The integration of capacity building, through routine technical training and visual field guides, must be institutionalized, especially in remote or rural project settings.

The complexity of post-disaster irrigation projects requires a shift from linear project planning to risk-based quality management. This approach considers the likelihood of failure for each component and integrates mitigation into each construction stage. For example, redundant waterproofing layers can be justified in segments with high seepage risk. Similarly, adaptive construction scheduling can be applied in high-rainfall months.

While quality has traditionally been viewed in terms of structural performance, sustainability indicators are increasingly important in modern irrigation projects. The Gumbasa project, though focused on functional rehabilitation, presents opportunities to assess environmental trade-offs. Future irrigation development should include a sustainability scorecard, incorporating resource efficiency, material reusability, local labor utilization, and ecological impact.

The sustainability of irrigation infrastructure depends not only on initial construction quality, but also on continued performance monitoring throughout its service life. A structured long-term monitoring framework should include periodic inspections, sensor-based seepage detection, slope displacement measurements, and remote data logging. For the Gumbasa site, a proposed monitoring interval could follow a 6-month cycle for the first 2 years, and annually thereafter, covering structural, hydraulic, and environmental indicators. This framework would allow early detection of degradation, reduce repair costs, and extend the effective life of the system. It also creates a feedback loop for learning and improvement in future projects.

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One of the less emphasized aspects in post-disaster construction is the mechanism of knowledge transfer from project-level experts to local operators. Many quality issues in rural irrigation projects stem from the knowledge gap between what is planned by consultants and what is implemented on-site. In the Gumbasa project, interviews revealed that some field workers and local supervisors lacked adequate understanding of the specifications for geotextile overlap, compaction techniques, or proper curing

times. This gap can significantly affect long-term performance. To address this, future projects should include mandatory training sessions for local teams, simplified construction manuals in visual form, and collaborative inspections that involve both supervisors and local stakeholders. This approach builds not only physical infrastructure but also local capacity, ensuring sustainable operation and maintenance of the system after handover.

IV. CONCLUSION

In addition to the statistically proven effect of precast concrete and geotextile, this study also identifies the influence of geomembrane durability, soil compaction quality, and project supervision on construction outcomes. These components, while not included in the regression model, were validated through lab data and field observations, and should be integrated into future quality management protocols. Efforts should also be directed at enhancing field inspections and ensuring consistent compliance with design specifications. There is a significant influence between the quality of precast concrete and geotextiles on construction quality in the rehabilitation and reconstruction project of the Gumbasa Irrigation Canal (Package 5). The results of simultaneous and partial tests show that both variables have a positive and significant relationship with construction quality. The regression equation indicates that the largest contribution comes from the geotextile variable, followed by precast concrete. The coefficient of determination value of 0.997 proves that the model can almost entirely explain the variation in construction quality. Precast concrete and geotextiles have a significant and measurable impact on construction quality in irrigation rehabilitation projects. Their influence has been statistically validated and supported by material testing data. For post-disaster reconstruction projects, this underscores the importance of material control and compliance with technical specifications. Recommendations: Improve on-site material inspections, standardize testing protocols, and provide training for field personnel in quality management practices. One promising direction for improving construction quality is the adoption of digital supervision tools. Currently, most monitoring in irrigation projects is manual and paper-based, which can delay response to deviations. The integration of digital field forms, GIS-tagged inspections, and UAV (drone) footage can streamline supervision and provide real-time alerts to consultants and contractors. These tools also allow project owners to remotely verify progress and compliance, reducing reliance on subjective visual assessments. Pilot programs for digital quality control should be launched, especially in remote or disaster-prone regions.

The findings from this study contribute to the broader discourse on disaster-resilient infrastructure planning in Indonesia. The Gumbasa case illustrates how technical compliance alone is insufficient without integrated supervision, adaptive methods, and sustainable material use. This research supports national efforts to build irrigation systems that can survive seismic shocks, liquefaction, and climate-related stressors. In doing so, it aligns with Indonesia's National Medium-Term Development Plan (RPJMN) 2020–2024, which prioritizes infrastructure that is not only functional but also sustainable and resilient. Incorporating lessons from this study into future policy formulation can enhance public procurement standards, training modules for field engineers, and multi-agency collaboration protocols.

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Stochastic Optimization of Renewable Energy Alternatives for Power Generation in Nigeria Using Markov Chain Modeling

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ABSTRACT

Nigeria's overdependence on fossil fuels has led to myriads of problems involving energy insecurity, environmental degradation, and economic instability. This study addresses the urgent need to transit to sustainable energy systems by evaluating and optimizing various alternative renewable energy sources using a finite method of Markov Chain. The method adopted was forecasting the population of Nigeria based on the 2006 census and a 3% annual growth rate over 50 years was used to estimate future energy demands. Seven renewable energy sources including solar power, hydropower, biomass power, biomass gasifier, wind turbines, tidal turbines, and flywheel water turbines were analyzed in terms of cost-effectiveness and net benefits using Bill of Engineering Measurement and Evaluation (BEME). A benefit-versus-purpose model was developed, and Markov chain analysis was applied to determine the optimal energy alternative based on transition probabilities and revenue functions. Results indicate that flywheel turbine technology offers the highest net benefit (₦526.8 trillion) and long-term efficiency, making it the most viable option economically to the tune of ₦4445.12 trillion (after the seventh iteration) for mitigating Nigeria's energy crisis. This study demonstrates how stochastic modeling guides energy policy and infrastructural planning, giving a pathway toward sustainable environmental friendly, reliable, and economically beneficial power generation.

Keywords: Renewable Energy, Markov Chain, Energy Optimization, Flywheel Turbine, BEME

I. Introduction

There has been a global shift toward sustainable energy development in recent years in response to growing concerns about environmental impacts of fossil fuels and the depletion of non-renewable resources. Different countries globally are investing into renewable energy technologies to address matters related to climate change, energy security and economic development. Nigeria, in particular is faced with a unique energy crisis characterized by insufficient electricity supply, with excess reliance on fossil fuels, and underutilization of its abundant renewable energy potential. Despite its substantial reserves of renewable resource like solar, wind, hydro, and biomass, Nigeria continues to experience the occurrence of power outages and limited access to electricity, especially in rural areas. The nation's current energy infrastructure is strongly dependent on oil and gas, which are not only environmentally damaging but also economically volatile due to irregular global prices. This study is aimed at establishing a most cost-effective and sustainable renewable energy source for Nigeria using Markov chain analysis. This study proposes the use of Markov Chain modeling as a decision tool to evaluate and

optimize renewable energy alternatives in Nigeria. It analyzes transition probabilities between different energy states over a period of time, the model forecasts the most economically and environmentally possible renewable energy option based on future energy demand. It incorporates both cost analysis and projected population growth, this approach aims to provide a scientifically sound framework for overall energy planning and policy formulation in Nigeria.

The dependence on oil-based fuels is speedily increasing leading to unsustainability, prompting global researchers into alternative energy sources. For instance, Mikael and Kjel (2010) examined the conversion of coal to liquid fuel (CTL) in South Africa being a strategy to alleviate energy shortages. Similarly, Samuel and Xiaobo (2007) highlighted global energy challenges and emphasizes on the importance of renewable energy technologies such as solar electricity generation, hydrogen fuel production, and fuel cell applications. Musa, et al (2022), developed equations using Markov chain process to derive steady state expressions to validate the model on varying failure and repair rate of solar pumping system providing insight for maintenance manager through optimized maintenance strategies from first order ordinary differential. Also Ibrahim and Canan (2005) examined environmental challenges and socio-economic to energy problems, making clear that solar photovoltaic systems as cost-effective, durable and an alternative to fossil fuels. Markov chain models have been employed to optimize water resource projects related to energy. For instance, Eme and Ohaji (2019) used Markov chains to enhance dam project efficiency for flood control, irrigation, tourism and hydropower. Eme et al. (2019) further worked on the usefulness of harnessing streams and marine currents for hydrokinetic renewable energy systems. In addition, Eme (2015) employ finite Markov chain to model the Anambra and Imo River Basins with focus on hydropower generation irrigation and water supply, aiming to improve employment and social welfare while mitigating climate and energy crises. In another related study, Eme (2019) used the finite Markov chain approach for optimizing conjunctive water resource management in the Anambra-Imo River Basin in order to maximize benefits of irrigation, hydroelectric power among others. Nkemnole and Akinola (2020) emphasized on the power sector in Nigeria facing earnest shortage of power causing energy demand fluctuation, deregulation with constrains on economic development. They used Harvey, Autogressive and Markov chain to compare these three result showing that Markov model was the optimal model for electricity generation and consumption. Agada et al (2023), utilized modeling of wind speed and developing a monthly Markov chain using the Beaufort scale in the sixteen states of northern Nigeria. They suggest that the proposed stochastic framework can be effectively applied to guide wind-farm site and wind-turbine design. More so Fioriti & Parzen (2022) used Macro energy system models as a technical decision maker to support policies steering up sustainable, affordable, and reliable future for the global energy state.

Biomass energy has also gained attention hence Munir et al. (2017) emphasize on the extensive use of agricultural and animal waste biomass for cooking and heating in Turkey, while Kevin and Ahmed (2019) worked on biomass conversion into bioenergy as a viable solution to energy challenges. Naveen and Thippeswarry (2016) identified bioethanol production from Areca nut husk as a sustainable waste management and renewable fuel solution. Aravind et al. (2020) utilized green algae as a feedstock for bioenergy production, including bio-oil, bio-char, and biogas. Renewable energy technologies have been applied in local contexts as well hence Elias et al. (2021) assessed the cost-effectiveness of bioenergy, from his finding, they said it more economical than conventional sources, especially for agro-industrial uses. John et al. (2019) also worked on Miscanthus grass for bioenergy applications as a solution to energy crises. Eboibi and Edje (2018) explored the potential of microalgae as a renewable feedstock for liquid fuel production via hydrothermal liquefaction (HTL) by developing a predictive

models to mitigate climate change, reduce pollution, and address energy deficits. These researchers focused on bioenergy as a means of eradicating energy crises.

Eme and Tachere (2023) designed different energy sources using hydropower, wind turbines, biogas, and solar systems for communities in Ogor Kingdom, Delta State, using a Bayesian decision model to evaluate the economic viability of these alternatives to unreliable grid supply. Collectively, these studies emphasize on the urgent global need for renewable energy driven by diminishing fossil fuel reserves, population growth, and the imperative for sustainable energy security. Unlike previous studies focusing on individual technologies, this research work utilizes a stochastic model to evaluate several renewable sources simultaneously.

II. Materials and Methods

To estimate the energy demand for the renewable sources, a population forecast of the study area was conducted using the 2006 population census data, as published by the National Bureau of Statistics (2020). The projection used the Compound Interest formula, being a widely accepted method in engineering for forecasting future values particularly those that are relevant for planning infrastructure with long-term usage. The formula in Equation 1 was used.

$$F = P \left(1 + \frac{r}{100} \right)^n, \text{ where} \quad 1$$

- F = future population
- P = present population
- r = annual growth rate (%)
- n = number of years projected into the future

A growth rate of 3% was assumed over a 50-year period for the projection.

Subsequently, seven green energy technologies were designed for the study area, they include solar power, hydropower, biomass gasifier, biomass power, tidal turbine, wind turbine, and flywheel water turbine. For each technology, a Bill of Engineering Measurement and Evaluation (BEME) was prepared, from which a benefit/purpose matrix was developed to evaluate their specific contributions. To assess the long-term economic viability and optimize energy resource deployment, the finite Markov chain method was applied. This stochastic modeling approach enabled the construction of an econometric framework to simulate future scenarios and determine the most efficient and beneficial mix of renewable energy technologies for sustainable development within the river basin region.

2.1 Finite Method of Markov Chain concept.

If a gardener plans to retire after N years, the objective is to determine the optimal decision for each year specifically, whether to fertilize or not. The primary goal is to maximize the expected cumulative revenue over the N year period. Let $k = 1$ and $k = 2$ denote the two possible decisions available to the gardener. The matrices P and R represent the transition probabilities and the corresponding revenue functions associated with each decision, respectively. This scenario can be modeled as a finite-stage dynamic programming (DP) problem. To generalize, let the number of possible states at each stage (year) be m . The finite stage DP was chosen because it is a strong tool which does not depend on past history but relies on the using the best course of action of the present scenario to determine the optimal policy of the maximum expected revenue.

III. Results and Discussion

Table 1 shows the results of the various benefits associated with each renewable energy source. The seven renewable energy sources were modeled, and their cost-effectiveness was evaluated by calculating the net benefits as the difference between gross benefits and the total cost of each scheme. These net benefits formed the basis for applying the Markov chain analysis. Subsequently, the infinite-horizon Markov chain method was employed to analyze the alternative renewable energy options.

Table 1: Benefit versus Purpose (Tr)

Energy sources	Objectives (Trillions)						
Solar power	48.5	38.4	40.2	43.6	26.8	39	16.1
Hydropower	34.2	46.6	28.4	72.7	37.6	46.7	69
Biomass power	36.2	31.4	26	71.2	17.6	33	17.3
Biomass gasifier	9.8	21.3	22.2	19.2	27.7	10.8	26
Wind turbine	39	32.2	68	45.2	50.7	38.9	70.6
Tidal turbine	38.1	28.7	121.4	45.7	51.1	31	69
Flywheel Turbine	42.2	55.9	122.1	125.9	82	54.4	44.3

Table 2 shows the calculation of the derived BEME on Benefit versus Purpose of the alternative renewable energy sources. (R2 Net Benefit).

Table 2: Net Benefits to the alternative energy sources capital projects under various Objectives

Energy sources	Objectives (Trillion)							Σ
Solar power	48.5	38.4	40.2	43.6	26.8	39	16.1	252.6
Hydropower	34.2	46.6	28.4	72.7	37.6	46.7	69	335.2
Biomass power	36.2	31.4	26	71.2	17.6	33	17.3	232.7
Biomass gasifier	9.8	21.3	22.2	19.2	27.7	10.8	26	137
Wind turbine	39	32.2	68	45.2	50.7	38.9	70.6	344.6
Tidal turbine	38.1	28.7	121.4	45.7	51.1	31	69	385
Flywheel Turbine	42.2	55.9	122.1	125.9	82	54.4	44.3	526.8
Σ	248	254.5	428.3	423.5	293.5	253.8	312.3	2213.9

Discussion of Table 2

i. Table 3.2 shows the calculation gotten from the Bill of Engineering Measurement and Evaluation (BEME). This is the Benefit versus purpose of the renewable energy projects. The Net Benefit was gotten from deducting the cost from Gross.

ii. The highest value from the benefit with maintenance was N125.9Tr gotten from flywheel renewable energy

iii. The flywheel technology is cheaper when compared to other technologies because it is simple and yields maximum benefits since it uses the principle of hydrokinetic (fluid flow velocity which is a great potential excellently produced in Nigerian rivers.

The interval scale as presented in this study using the soil condition is between 1 – 7. The transition probability matrix P1 reflects the assumption that the current year's productivity cannot exceed that of the previous year. According to the Markov decision framework, the gardener conducts a chemical test each season to evaluate soil conditions. Based on the test results, productivity for the upcoming season is categorized into one of seven possible states: (i) Excellent, (ii) Very Good, (iii) Good, (iv) Fair, (v) Weak, (vi) Poor, and (vii) Very Poor. This framework highlights the Markov property, where the productivity outcome for the current year depends solely on the soil condition of the preceding year which is

independent of any earlier states. The Markov chain, therefore, provides a mathematical model for representing such stochastic processes, where the next state of the system is determined only by its present state.

$$\begin{aligned}
 P^1 \times R^1 &= \begin{pmatrix} 0.09 & 0.16 & 0.13 & 0.10 & 0.18 & 0.14 & 0.20 \\ 0 & 0.18 & 0.23 & 0.11 & 0.13 & 0.21 & 0.14 \\ 0 & 0 & 0.18 & 0.10 & 0.34 & 0.12 & 0.26 \\ 0 & 0 & 0 & 0.31 & 0.13 & 0.36 & 0.20 \\ 0 & 0 & 0 & 0 & 0.32 & 0.41 & 0.27 \\ 0 & 0 & 0 & 0 & 0 & 0.58 & 0.42 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1.0 \end{pmatrix} \\
 R^1 &= \begin{pmatrix} 53.35 & 41.8 & 44.22 & 47.97 & 29.48 & 42.9 & 17.71 \\ 37.62 & 51.26 & 31.24 & 79.97 & 41.36 & 51.37 & 75.9 \\ 39.82 & 34.54 & 28.6 & 78.32 & 36.3 & 36.3 & 19.03 \\ 10.78 & 23.43 & 24.42 & 21.12 & 30.47 & 11.88 & 28.6 \\ 42.9 & 35.42 & 74.8 & 49.72 & 55.77 & 42.78 & 27.66 \\ 41.91 & 31.57 & 133.54 & 50.27 & 56.21 & 34.1 & 75.9 \\ 46.42 & 61.49 & 134.31 & 134.49 & 90.2 & 59.84 & 48.73 \end{pmatrix} \\
 P^2 &= \begin{pmatrix} 0.19 & 0.15 & 0.16 & 0.17 & 0.11 & 0.15 & 0.07 \\ 0.10 & 0.14 & 0.08 & 0.22 & 0.11 & 0.14 & 0.21 \\ 0.16 & 0.13 & 0.11 & 0.31 & 0.08 & 0.14 & 0.07 \\ 0.07 & 0.16 & 0.16 & 0.14 & 0.20 & 0.08 & 0.19 \\ 0.11 & 0.09 & 0.20 & 0.13 & 0.15 & 0.11 & 0.21 \\ 0.10 & 0.07 & 0.32 & 0.12 & 0.13 & 0.08 & 0.18 \\ 0.08 & 0.11 & 0.23 & 0.24 & 0.16 & 0.10 & 0.08 \end{pmatrix} \\
 R^2 &= \begin{pmatrix} 48.5 & 38.4 & 40.2 & 43.6 & 26.8 & 39 & 16.1 \\ 34.2 & 46.6 & 28.4 & 72.7 & 37.6 & 46.7 & 69 \\ 36.2 & 31.4 & 26 & 71.2 & 17.6 & 33 & 17.3 \\ 9.8 & 21.3 & 22.2 & 19.2 & 27.7 & 10.8 & 26 \\ 39 & 32.2 & 68 & 45.2 & 50.7 & 38.9 & 70.6 \\ 38.1 & 28.7 & 121.4 & 45.7 & 51.1 & 31 & 69 \\ 42.2 & 55.9 & 122.1 & 125.9 & 82 & 54.4 & 44.3 \end{pmatrix}
 \end{aligned}$$

Table 3: Summary of Computation of V1 1 and V1 2 used in stage 6 to 1

S/No	V ₁ ¹	V ₁ ²
1	36.89	38.74
2	52	43.72
3	34.63	42.05
4	20.51	21.68
5	48.86	53.38
6	55.45	71.7
7	48.73	89.93

A multiple of P1 by R1 and P2 by R2 were multiplied to get the table above. A series of iterations from the transition matrices gave the final presentation in Table 4.

Table 4: Stage 1 Computation

$V_1^k + P_1^k F_5^{(1)} + P_{12}^k F_5^{(2)} + P_{13}^k F_5^{(3)} + P_{14}^k F_5^{(4)} + P_{15}^k F_5^{(5)} + P_{16}^k F_6^{(6)} + P_{17}^k F_7^{(7)}$					Optional solution K *	
i	K = 1	K = 2	F ₁ ⁽ⁱ⁾			
1	1876.83+(0.09×1876.83)+(0.16×1891.41)+(0.13 × 1949.17)+(0.10× 1879.03)+(0.18×2019.07)+(0.14x 2019.34)+(0.20x 2222.56)=3879.9	1815.16+(0.19×1876.83)+(0.15×1891.41)+(0.16×194 9.17)+(0.17×1879.03)+(0.11×2019.07)+(0.15x 2019.34)+(0.07x 2222.56) = 3711.04	3879.9		1	
2	1891.14+(0×1876.83)+(0.18×1891.41)+(0.23×194 9.17)+(0.11×1879.03) + (0.13×2019.07) + (0.21 x 2019.34) + (0.14x 2222.56) =3884.3	1886.25 + (0.10×1876.83) + (0.14×1891.41) + (0.08×1949.17) + (0.22×1879.03) + (0.11×2019.07) + (0.14 x 2019.34) + (0.21x 2222.56) =3879.6	3884.3		1	
3	1949.17+(0 ×1876.83)+ (0×1891.41)+(0.18×1949.17)+(0.10×1879.03)+(0. 34×2019.07)+(0.12x 2019.34) + (0.26x 2222.56) =3990.6	1797.69+(0.16×1876.83)+(0.13×1891.41)+(0.11×194 9.17) + (0.31×1879.03) + (0.08×2019.07) + (0.14 x 2019.34) + (0.07x 2222.56) = 3740.6	3990.6		1	
4	1879.03 + (0×1876.83) + (0×1891.41) + (0×1949.17) + (0.31×1879.03) + (0.13×2019.07) + (0.36 x 2019.34) + (0.20x 2222.56) = 3895.5	1867.05+(0.07×1876.83)+(0.16×1891.41) + (0.16×1949.17) + (0.14×1879.03) + (0.20×2019.07) + (0.08 x 2019.34) + (0.19x 2222.56) = 3863.6	3895.5		1	
5	2019.07 + (0×1876.83) + (0×1891.41) + (0×1949.17) + (0×1879.03) + (0.32×2019.07) + (0.41 x 2019.34) + (0.27x 2222.56) = 4093.2	1901.73 + (0.11×1876.83) + (0.09×1891.41) + (0.20×1949.17) + (0.13×1879.03) + (0.15×2019.07) + (0.11 x 2019.34) + (0.21x 2222.56) =3904.24	4093.2		1	
6	2019.34+ (0×1876.83) + (0×1891.41) + (0×1949.17) + (0×1879.03) + (0×2019.07) + (0.58 x 2019.34) + (0.42x 2222.56) = 4124.03	1901.54 + (0.10×1876.83) + (0.07×1891.41) + (0.32×1949.17) + (0.12×1879.03) + (0.13×2019.07) + (0.08 x 2019.34+ (0.18x 2222.56) = 3894.9	4124.03		1	
7	2222.56 + (0×1876.83) + (0×1891.41) + (0×1949.17) + (0×1879.03) + (0×2019.07) + (0 x 2019.34) + (1x 2222.56) =4445.12	1870.03 + (0.08×1876.83) + (0.11×1891.41) + (0.23×1949.17) + (0.24×1879.03) + (0.16×2019.07) + (0.10 x 2019.34) + (0.08x 2222.56) =3830.3	4445.12		1	

Discussion of results on Table 4

- Table 4 show the computation at stage five with K = 1 having a maximum value of 4445.12 Trillion
- While K = 2 having a maximum value of 3904.24
- The F1 (i) value from 8308.9 to 9485.2 with the optimal solution K as 1, 1, 1, 1, 1, 1, and 1
- This clearly shows that the use of flywheel and other renewable energy sources will boost the nation's Gross Domestic Product and resolve the energy crises in Nigeria.

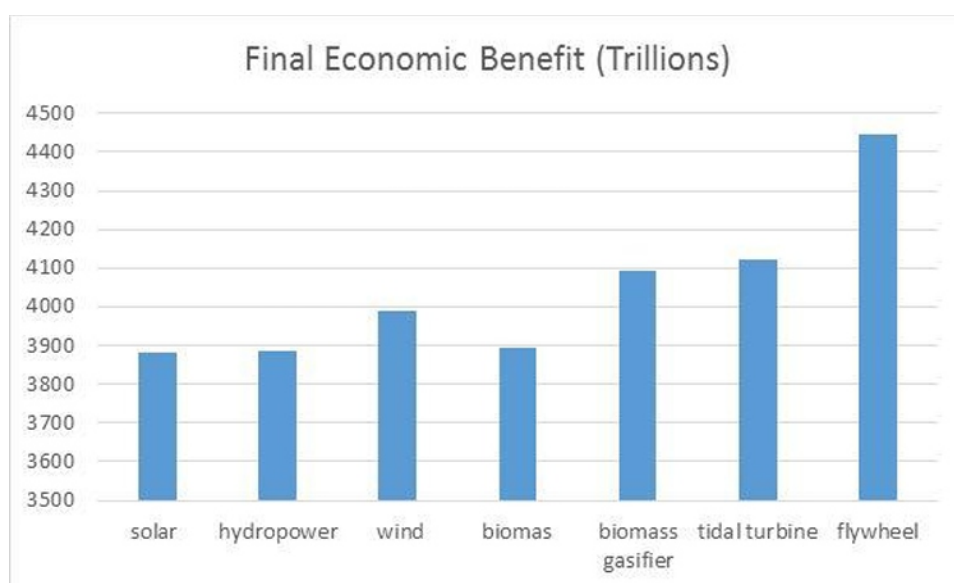


Figure 1 Final economic benefit and the various sources of energy

The figure above shows the economic benefits of the seven sources of energy signifying that flywheel water turbine yielded the maximum economic benefit.

IV. Conclusion

This study demonstrated the applicability of the Markov chain modeling approach in optimizing renewable energy alternatives for sustainable power generation in Nigeria by integrating econometric analysis and transition probability models, the study effectively evaluated seven renewable energy sources which are solar, hydropower, wind, biomass, biomass gasifier, tidal turbine, and flywheel water turbine based on their cost-effectiveness and net benefits. Using a population forecast as a baseline for energy demand over a 50-year horizon presenting flywheel turbine as the best performed having an economic benefit of N4.45 Quadrillion. The findings indicate that strategic deployment of renewable resources, guided by stochastic optimization techniques, can significantly improve energy reliability and economic outcomes in the studied regions.

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Research on Technological Innovation, Regulatory Challenges and Social Inclusivity in the Field of Electronic Payments

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ABSTRACT

This study systematically analyzes the technological evolution, security challenges, and cross-regional application trends of electronic payments in the global digitalization process, based on the Technology Acceptance Model (TAM) and the application of blockchain technology. Through a systematic literature review and case analysis method, integrating core literature, it is found that the application of blockchain technology in electronic payments faces challenges of insufficient scalability and regulatory fragmentation, while multifactor authentication and encryption technologies can effectively enhance security protection. The research proposes a three-dimensional solution of "technology-regulatory-society", emphasizing that the integration of blockchain with 5G and quantum encryption will promote the expansion of electronic payments in scenarios such as the metaverse and green finance. However, its sustainable development requires balancing technological innovation and privacy protection.

Keywords: electronic payments, blockchain technology, technology acceptance model, regulatory fragmentation.

I. Introduction

In the context of global digitalization, the electronic payment market is experiencing explosive growth[1]. As a key market, China has seen a significant increase in electronic payment transaction volume, a huge mobile payment user base, and third-party payment platforms covering a wide range of retail scenarios. In the field of cross-border payments, the Cross-border Interbank Payment System (CIPS) has connected with financial institutions in multiple countries, but the standard differences with the Society for Worldwide Interbank Financial Telecommunication (SWIFT) system still affect the efficiency of cross-border settlements. Meanwhile, the application of technologies such as blockchain and artificial intelligence in electronic payments brings innovation, but also faces challenges such as technical bottlenecks, regulatory lag, and insufficient social inclusivity[2]. Balancing technological innovation, regulatory optimization, and social inclusivity has become a key issue for the sustainable development of electronic payments.

1.2 Theoretical Framework

Taking the Technology Acceptance Model as the theoretical cornerstone of this study, the model explicitly states that users' "perceived usefulness" and "ease of use" of technology largely influence their payment behavior[3]. Perceived usefulness refers to the degree to which users subjectively believe that

using a technology can enhance work performance or achieve specific goals, while perceived ease of use reflects users' subjective judgment on the difficulty of using a technology.

In the context of mobile payments, the acceptance rate among elderly users is relatively low, primarily because they find mobile payment tools and mobile banking apps complex to operate—such as forgetting passwords, dealing with small app fonts, or being unfamiliar with smartphone operations—fully demonstrating the elderly group's deficiency in perceived ease of use[2]. In contrast, corporate users exhibit higher acceptance of blockchain payments due to the distributed ledger and encryption technology of blockchain, which ensure high payment security and immutability, effectively reducing transaction risks. This aligns with enterprises' strict requirements for fund security and enhances their perceived usefulness. Numerous studies have shown that the TAM model has been widely applied in e-commerce, mobile applications, and other fields, demonstrating strong scientific validity and effectiveness in explaining users' acceptance behavior toward new technologies[4].

1.3 Research Gap

Existing studies on electronic payments exhibit a notable limitation of single-dimensional focus, particularly in the research on the interaction mechanism of "technical defects-regulatory lag-social exclusion". Taking blockchain technology as an example, its "impossible trinity" problem means that the pursuit of decentralization and security inevitably sacrifices scalability, while cross-border regulatory fragmentation further intensifies technological application barriers. The superposition of these two factors has sharply increased payment costs for small and medium-sized enterprises with limited resources, creating higher entry barriers to electronic payments and leading to their marginalization in the digital economy, thus forming social exclusion. However, current research has not systematically integrated these three dimensions, lacking in-depth analysis of their complex interrelationships and overall impacts on the electronic payment ecosystem.

1.4 Research Significance

Theoretically, this study innovatively integrates technical, regulatory, and social dimensions, breaking through the limitations of traditional single perspectives and enriching the interdisciplinary research framework of electronic payments. This integration not only helps to comprehensively reveal the interaction mechanisms of various elements in the electronic payment ecosystem but also provides a new theoretical entry point for followup academic research.

In practical applications, the research findings are of significant utility. Enterprises can optimize product design based on the conclusions: carrying out aging-friendly transformations for elderly users to effectively enhance their acceptance and user experience of electronic payment products. Government departments can rely on the data support provided by this study to promote the unification of cross-border settlement standards under the Regional Comprehensive Economic Partnership (RCEP) framework, reduce regional payment compliance costs, facilitate the efficient circulation and collaborative development of electronic payments, and contribute to the healthy evolution of the global digital economy.

II. Concepts and Technologies

2.1 Concepts

Electronic payment refers to the act of consumers, merchants, and financial institutions using secure electronic means to transmit payment information through information networks to banks or corresponding processing institutions, in order to achieve monetary payment or fund transfer. Compared with traditional payment methods such as cash and bills, it has significant advantages. In terms of payment forms, electronic payments are mainly divided into three categories. Online payment is operated on a computer connected to the Internet, requiring buyers and sellers to negotiate and choose a third-party payment platform. For example, when shopping on Taobao or Amazon, users place orders and pay to the third-party platform. After merchants confirm the orders and deliver goods via express or logistics, they can only receive payment from the third-party platform after users confirm receipt of the goods. Telephone payment refers to the payment method of completing payment from a personal account by connecting a telephone device to the banking system, commonly used for recharging games in daily life. Mobile payment, the main development trend in electronic payments, refers to the act of directly or indirectly sending payment instructions through mobile terminal devices such as smartphones and tablets to effect monetary payment or fund transfer. Its technical means include NFC payment, QR code payment, ultrasonic payment, etc.

2.2 Technical Applications and Limitations

In electronic payments, blockchain technology plays a significant role. The distributed ledger stores transaction records across multiple nodes, enhancing security and transparency while making transactions tamper-proof and traceable. Smart contracts automate payment execution based on preset conditions, eliminating fraud and errors to improve efficiency. In cross-border payments, they bypass intermediaries, simplify currency conversion processes, and reduce costs to accelerate settlement. Additionally, the decentralized nature of blockchain supports peer-to-peer transactions, reducing reliance on intermediaries and empowering users with more control.

However, its applications have limitations. Performance and scalability are insufficient: transaction queuing and network-wide node synchronization are time-consuming, failing to meet the demands of large-scale high-frequency transactions. In security, internationally adopted core components are not fully independently controllable, posing risks of attacks and unknown vulnerabilities. The lack of a comprehensive protection system means security issues cannot be canceled or reversed as in traditional payments. Technical and standard disparities across different blockchain systems hinder interoperability, fragmenting business processes. Full-data backup imposes heavy storage burdens on nodes, especially in high-frequency scenarios like retail payments.

Artificial intelligence (AI) has been applied in the risk control domain of electronic payments. Numerous financial institutions and payment platforms leverage machine learning algorithms to analyze massive transaction data and user behavior patterns, thereby constructing precise risk prediction models. Nevertheless, AI technology is not infallible in addressing electronic payment security issues. Although some advanced AI systems possess dynamic learning and adaptive adjustment capabilities, their response speed and processing effectiveness still require further improvement when facing complex and ever-evolving new-type attacks.

III. Challenges

3.1 Systemic Risks

The issue of technical compatibility is prominent, as the lack of unified standards for payment interfaces among different banks severely affects the stability of cross-platform payments. In practical operations, due to interface discrepancies, financial institutions need to invest additional resources in adaptation and maintenance, which not only increases operational costs but also reduces payment efficiency and hinders the smooth experience of electronic payments.

Although blockchain payment technology is innovative, it faces significant energy consumption issues, which deviate from the globally advocated concept of green finance. As a typical application of blockchain technology, the Bitcoin network consumes enormous energy, imposing a heavy burden on the environment and resources. This high-energy consumption characteristic restricts the widespread adoption and sustainable development of blockchain payment technology, urging the industry to accelerate the research and application of low-energy consensus algorithms to alleviate resource pressure and promote the alignment of blockchain payments with green development goals.

3.2 User Risks

Cybersecurity threats continue to rise, posing serious challenges to the financial security and personal information of electronic payment users[5]. Numerous users have suffered sensitive information breaches and subsequent financial losses due to phishing attacks[6]. Some third-party payment platforms, plagued by vulnerabilities in data security protection, failed to effectively encrypt user data, exposing massive user information to theft risks—highlighting critical weaknesses in the current data security safeguards of the electronic payment sector.

The digital divide is acutely evident among elderly populations, severely restricting the popularization and adoption of electronic payments in this demographic. Compared to younger groups, elderly users generally lack knowledge and operational skills in electronic payments, demonstrating lower acceptance and proficiency in emerging payment tools. In scenarios where public transportation only supports electronic payments, elderly passengers often face mobility obstacles due to unfamiliarity with payment operations, reflecting both insufficient technology popularization and a lack of attention to the special needs of elderly users and agefriendly design in product development and service delivery.

3.3 Institutional Risks

The fragmentation of cross-border regulation imposes exorbitant compliance costs on multinational enterprises, emerging as a significant obstacle to the development of cross-border electronic payment businesses. Notable disparities exist in cross-border data transmission regulations among major economies such as China, the U.S., and the EU. Inconsistencies in data protection standards and regulatory requirements across regions compel multinational enterprises to simultaneously comply with multiple differing regulatory demands when conducting cross-border payment operations, significantly increasing operational burdens and compliance complexities. Such regulatory divergences not only force enterprises to allocate substantial resources to regulatory compliance but also expose them to compliance risks arising from interpretative deviations.

Long-standing gaps in the regulation of third-party payment platforms' fund pools pose risks to user capital security. Historically, some third-party payment platforms misappropriated users' reserve funds for highrisk investments, severely undermining user interests and causing issues such as withdrawal delays, which triggered trust crises in fund security. This phenomenon profoundly reflects the lagging

nature of current regulatory mechanisms in the face of the rapid innovative development of the third-party payment industry, failing to promptly and effectively implement comprehensive and rigorous supervision over platform fund operations. Urgent improvement of relevant regulatory systems and measures is required to safeguard user capital security and promote the healthy development of the industry.

IV. Solutions

4.1 Technical Solutions

Multi-factor authentication technologies significantly enhance payment security. The adoption of multi-layer verification mechanisms such as "password + fingerprint + face" has been proven to effectively enhance users' payment security. Blockchain sharding technology provides a path to optimize performance bottlenecks. Ethereum 2.0 uses this technology to improve throughput while reducing energy consumption, providing a reference for solving the blockchain "impossible trinity" problem. In addition, the pilot application of quantum encryption technology has shown significant advantages, and the quantum key distribution system of a state-owned bank has provided security guarantees against future quantum computing attacks.

4.2 Regulatory Solutions

The regulatory sandbox mechanism for cross-border payments is being gradually implemented under the RCEP framework. This mechanism allows enterprises to test innovative payment models in a controlled environment, effectively simplifying regional settlement processes and reducing compliance costs. For risks in third-party payments, requiring platforms to deposit reserve funds into designated accounts can fundamentally eliminate the risk of fund misappropriation. Meanwhile, promoting the establishment of unified standards for cross-border data flows—such as the regulatory cooperation framework of the "Belt and Road" related digital currency system—can balance data security and cross-border payment efficiency[7].

4.3 Social Solutions

Digital literacy promotion programs have demonstrated remarkable effectiveness in alleviating the digital divide. China's "Blue Vest" initiative, through large-scale training, has effectively improved the adoption of mobile payments among elderly populations. User safety education delivered via new media formats—such as the "Anti-Phishing Classroom" launched by a leading platform—has been proven to significantly enhance users' ability to identify fraudulent activities. Additionally, incorporating aging-friendly modifications to payment products into industry standards represents a critical pathway to synergize technological innovation with social inclusivity.

V. Future Trends

Technological integration, new scenario expansion, and risk prevention will become the core directions for the development of electronic payments. The deep integration of 5G and the Internet of Things (IoT) is expected to reshape the payment experience, significantly reducing mobile payment latency and supporting seamless payment scenarios for smart devices. The breakthrough in quantum encryption technology provides core security for payment information.

In terms of application scenarios, the metaverse payment sector is developing rapidly, with platforms like Decentraland already enabling transactions where cryptocurrencies are used to purchase virtual assets. In the context of green finance, carbon credit payment systems promote the coordination between

consumption behavior and environmental protection goals through pilot projects. The exploration of cross-border interoperability of central bank digital currencies (CBDCs) is accelerating, with the potential to form a blockchain-based super-sovereign payment system in the future.

Meanwhile, emerging risks require attention: The technological monopoly in the mobile payment market may lead to abuse of pricing power. Risks such as "digital identity theft" in metaverse payments urgently need to be regulated through ethical review frameworks and authentication mechanisms. The threat of quantum computing to traditional encryption algorithms necessitates the advance layout of "post-quantum cryptography" research to ensure secure continuity in technological evolution. The sustainable development of electronic payments requires achieving dynamic balance among technological innovation, scenario expansion, and risk control.

VI. Conclusion

This study systematically integrates technological, regulatory, and social dimensions to reveal the development paradox in the field of electronic payments: while technological innovations such as blockchain and artificial intelligence significantly enhance payment efficiency, the high energy consumption of blockchain technology sharply conflicts with cybersecurity threats. Globalization drives the growth of cross-border payment scales, but differences in cross-border regulations increase corporate compliance costs. Coupled with the low adoption rate of electronic payments among elderly populations, this highlights bottlenecks in inclusivity.

Based on these findings, the study proposes a three-dimensional advancement path: developing lowenergy consensus algorithms and quantum encryption technologies at the technical level; establishing crossborder regulatory sandboxes within the RCEP framework at the regulatory level; and promoting digital literacy training programs at the social level. Future research can focus on two cutting-edge directions: the global interoperability of CBDCs, where although central banks have initiated R&D, fragmented technical standards cause cross-border settlement delays; and the impact of quantum computing on payment security, requiring proactive deployment of quantum key distribution systems. These directions will provide theoretical support for constructing a secure and inclusive next-generation electronic payment system.

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MACHINE LEARNING BASED ANALYSIS OF CRYPTOCURRENCY MARKET FINANCIAL RISK MANAGEMENT

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ABSTRACT

In the volatile landscape of cryptocurrency markets, traditional financial risk management approaches often fall short due to the unique challenges posed by extreme price fluctuations, low liquidity, and high uncertainty. This project proposes a novel machine learning-based framework to enhance financial risk management within cryptocurrency markets. By leveraging advanced algorithms, including deep learning and ensemble methods, the framework is designed to predict market trends, identify potential risks, and optimize portfolio management strategies in real-time. The project aims to develop a robust model that integrates historical price data, trading volumes, social media sentiment, and macroeconomic indicators to assess and manage financial risks effectively. This model will not only provide early warnings of potential market downturns but also recommend dynamic hedging strategies to minimize losses and maximize returns. Moreover, the project explores the application of explainable AI techniques to ensure transparency in decision-making processes, making the model's predictions understandable and actionable for financial analysts. The outcome of this research is expected to significantly improve risk management practices in cryptocurrency trading, contributing to more stable and profitable investment strategies in this emerging asset class.

Keywords : Cryptocurrency Market, Financial Risk, Volatility Prediction, Market Prediction, Cryptocurrency price forecasting

I. Introduction

Financial market is one of the complex systems that the definition of complexity didn't get accepted from universities and this cause the agreement in term of interacting the elements of complex systems together. Complex system modeling is similar to daunting task which the structure of this system organized based on hierarchical manner that collected their own subsystems.

The project also integrates financial risk assessment methodologies such as Value at Risk (VaR), Conditional Value at Risk (CVaR), and Sharpe Ratio to quantify potential losses and evaluate the performance of different trading strategies. These techniques provide a structured approach to risk management, helping investors assess their risk tolerance and adjust their portfolios accordingly.

This project focuses on developing a machine learning-based financial risk management system for cryptocurrency markets. It leverages predictive modeling, anomaly detection, clustering, and ensemble learning to assess risk levels, detect unusual market activities, and provide actionable insights. The system integrates historical price data, technical indicators, sentiment analysis, and blockchain transactions to create a robust risk assessment framework.

By leveraging predictive modeling, anomaly detection, and ensemble learning, the system provides real-time insights into market risks, helping investors and traders make data-driven decisions. This approach not only improves financial stability but also contributes to the development of a more efficient and transparent cryptocurrency ecosystem.

I. Overview of the project

The cryptocurrency market is highly volatile, making it prone to significant financial risks, including price fluctuations, liquidity concerns, and fraudulent activities. This project focuses on developing a machine learning-based risk management system to analyze and predict financial risks in cryptocurrency markets. By leveraging advanced machine learning techniques, the project aims to enhance decision-making for investors, traders, and financial institutions, allowing them to identify and mitigate potential risks before they lead to substantial losses.

The project involves data collection from multiple sources, including historical price movements, blockchain transactions, and social media sentiment. By processing and analyzing this data, key financial risk factors such as price volatility, trading volume fluctuations, and potential fraudulent activities can be identified. Various feature engineering techniques are used to extract meaningful insights from raw data, which then serve as inputs for predictive models.

To ensure high accuracy in risk prediction, the project incorporates ensemble learning techniques such as Random Forest, XGBoost, and Gradient Boosting Machines (GBM), which combine multiple models to improve performance. Additionally, anomaly detection algorithms like Isolation Forest and Autoencoders help detect unusual market activities that may indicate risks such as market manipulation or sudden crashes. Time-series forecasting models such as LSTM (Long Short-Term Memory) networks are also used to predict future price movements and assess potential risks.

The system is designed to provide real-time risk monitoring and decision support for traders and investors. By integrating predictive analytics, market sentiment analysis, and blockchain data, the model offers insights into emerging risks and potential investment opportunities. The platform can be used by individual investors, hedge funds, and financial institutions to enhance their risk management strategies and optimize portfolio allocation. Furthermore, regulators and market analysts can leverage this system to identify suspicious market activities and enforce compliance measures.

Overall, this project enhances risk management strategies in the cryptocurrency market by leveraging machine learning-driven predictive analytics. It provides investors with real-time risk insights, enabling them to make informed financial decisions and minimize potential losses. The implementation of this system contributes to a more transparent, secure, and efficient cryptocurrency trading environment, making it a valuable tool for both institutional and retail investors.

II.EXISTING SYSTEM

The existing financial risk management systems for cryptocurrency markets rely on a combination of traditional financial models, technical indicators, and heuristic approaches. These methods often struggle to adapt to the highly volatile and unpredictable nature of cryptocurrency markets, making them less effective in mitigating risks. Most existing risk assessment techniques are borrowed from traditional finance, such as Value at Risk (VaR), Conditional Value at Risk (CVaR), and the Sharpe Ratio, but they do not fully capture the rapid price fluctuations, market sentiment, and behavioral patterns unique to crypto markets.

In traditional finance, risk is managed using statistical models and historical data analysis. Investors and analysts use historical volatility, moving averages, and other technical indicators to assess potential risks. However, these methods rely on past data trends, assuming that future market conditions will follow similar patterns. This assumption fails in cryptocurrency markets, where price swings are often influenced by external events, social media sentiment, and algorithmic trading.

Some existing risk management systems incorporate machine learning techniques, but they are often limited in scope and capability. Many existing implementations use simple regression models, decision trees, or support vector machines (SVMs) to classify risk levels, but they fail to leverage advanced deep learning models that can capture intricate market dynamics. Moreover, existing models are not designed for real-time predictions, making them less useful in fast-moving crypto markets.

One of the major issues with current machine learning-based risk management systems is the lack of interpretability. While deep learning models such as neural networks provide high accuracy, they are often considered black-box models, making it difficult for investors and traders to understand the reasoning behind risk predictions. Without clear interpretability, users may hesitate to trust AI-based risk management tools.

III DRAWBACKS ON THE EXISTING SYSTEM

The existing systems for cryptocurrency financial risk management, such as those proposed by Lahre et al., Jain et al., Raf_not et al., Brauneis et al., Walid et al., Platanakis et al., Saba et al., and Corbet et al., employ various traditional and statistical approaches, including Hierarchical Risk Parity (HRP), Markowitz portfolio optimization, Black-Litterman models, and wavelet-based analysis. While these methods have contributed to understanding cryptocurrency risk, they have several limitations in terms of adaptability, accuracy, and real-time decision-making. Below are some key drawbacks of these existing systems:

1. Lack of Adaptability to Cryptocurrency Market Volatility - The HRP and Markowitz portfolio optimization techniques rely on historical data and mean-variance assumptions, which fail to account for the extreme volatility and non-stationary nature of cryptocurrencies. Cryptocurrency prices can be influenced by external factors such as social media trends, regulatory announcements, and macroeconomic events, making historical risk measures less reliable for future predictions.

2. Failure to Capture Non-Linear Market Relationships - Most of the existing methods, such as HRP and BlackLitterman models, rely on linear correlation-based approaches for risk assessment and

portfolio optimization. However, cryptocurrency markets exhibit complex, non-linear relationships, influenced by high-frequency trading, decentralized finance (DeFi) protocols, and algorithmic trading strategies. The inability of these models to capture such complexities reduces their effectiveness in financial risk prediction.

3. Inability to Detect Market Manipulation and Anomalies - The current systems do not employ advanced anomaly detection techniques such as Isolation Forest, Autoencoders, or Local Outlier Factor (LOF) to detect market manipulations like pump-and-dump schemes, flash crashes, and fake trading volumes. Given the unregulated nature of cryptocurrency exchanges, these fraudulent activities are common, and existing risk models fail to provide early warnings to investors.

4. Lack of Real-Time Risk Monitoring and Decision Support - The existing financial risk management models do not offer real-time monitoring and predictive analytics. Since cryptocurrency markets operate continuously, traders require instant risk assessment and automated alerts for sudden market changes. The absence of real-time machine learning models makes it difficult for investors to react promptly to potential risks.

5. Inaccuracies in Portfolio Optimization Strategies - Methods such as Markowitz optimization and Black-Litterman models assume that investors have rational expectations and that risk is uniformly distributed across assets. However, cryptocurrency investors exhibit heterogeneous behavior, leading to sudden price fluctuations and liquidity shocks. The failure of these models to incorporate behavioral finance concepts results in suboptimal portfolio allocation strategies.

IV PROPOSED SYSTEM

The proposed system enhances existing cryptocurrency risk management strategies by integrating machine learning techniques, deep learning models, sentiment analysis, and anomaly detection. Unlike traditional methods that rely on mean-variance optimization, hierarchical risk parity (HRP), and wavelet-based analysis, the new approach incorporates real-time predictive analytics and multi-source data processing to improve risk assessment accuracy. One of the key improvements in the proposed system is the inclusion of anomaly detection algorithms, which identify unusual market patterns, fraudulent activities, and sudden price fluctuations. While previous studies primarily focused on portfolio optimization and asset allocation strategies.

Another major advancement is the real-time processing capability of the proposed system. Existing financial risk models often rely on batch processing, leading to delays in identifying emerging risks. The new approach utilizes big data frameworks, cloud computing, and high-frequency data processing techniques to offer near-instantaneous risk predictions. By leveraging streaming analytics and real-time data pipelines, the system enhances its ability to provide up-to-date risk assessments and support high-frequency trading strategies.

To address the scalability and computational efficiency issues seen in traditional models, the proposed system leverages cloud-based computing and parallel processing to handle vast amounts of financial and blockchain data. Overall, the proposed system combines predictive modeling and blockchain analytics to create a comprehensive risk management framework for cryptocurrency markets.

4.1 ADVANTAGES OF PROPOSED SYSTEM

Real time risk analysis - Overall, the proposed system combines predictive modeling, anomaly detection, sentiment analysis, and blockchain analytics to create a comprehensive risk management framework for cryptocurrency markets. By addressing the limitations of existing financial models and incorporating real-time, AI-driven insights, this system provides a more adaptive, transparent, and reliable approach to managing financial risks in the volatile cryptocurrency ecosystem.

Enhanced Predictive Accuracy: Machine learning models significantly improve predictive accuracy by analyzing vast amounts of historical and real-time data to forecast cryptocurrency price movements. Unlike traditional financial models that rely on linear assumptions, ML algorithms such as Long Short-Term Memory (LSTM), can identify non-linear relationships, seasonality, and sudden market shifts. These models use past trading behavior, volume patterns, sentiment analysis, and external factors like regulatory news to anticipate price fluctuations more accurately.

Automation in risk management - Machine learning automates many aspects of financial risk management, reducing human error and improving decision-making efficiency. Traditionally, risk assessment required manual data analysis, which was time-consuming and prone to bias.

V. Modules Used For Cryptocurrency Financial Risk Management

A machine learning-based cryptocurrency financial risk management project is typically structured into multiple functional modules, each responsible for a specific aspect of risk analysis, data processing, and decision-making. Below are the key modules:

5.1 Data Collection Module

The Data Collection Module is the foundation of the machine learning-based cryptocurrency market financial risk management system. It is responsible for gathering, processing, and storing vast amounts of financial, transactional, and sentiment data to support accurate risk analysis. Given the volatile and decentralized nature of the cryptocurrency market, data collection must be real-time, diverse, and comprehensive to ensure effective risk prediction. This module integrates multiple data sources, including market price feeds, blockchain transactions, news sentiment, and macroeconomic indicators, providing a holistic view of financial risk factors.

Since cryptocurrency data is highly sensitive, the data collection module must ensure security, integrity, and compliance with industry standards. Encryption techniques, access control policies, and blockchain-based verification help protect against data breaches and manipulation. Furthermore, backup mechanisms and failover systems are implemented to prevent data loss and ensure continuity in risk analysis operations.

To achieve more predictive accuracy the system collects data from multiple sources including :

- Market Data
- Blockchain Data
- Historical Data
- Macroeconomic Indicators

5.2 Service Provider Module :

In this module, the Service Provider has to login by using valid user name and password. After login successful he can do some operations such as Login, Train & Test Crypto Currency Data Sets, View Crypto Currency Trained Accuracy in Bar Chart, View Crypto Currency Trained Accuracy Results, View Crypto Currency Financial Risk Type, Find Financial Risk Type Ratio, Download Predicted Datasets, View Crypto Currency Financial Risk Type Ratio Results, View All Remote Users.

The Service Provider acts as a bridge between data sources and end-users, offering real-time insights into cryptocurrency market risks. It integrates multiple data feeds such as market price fluctuations, trading volume, social sentiment, and blockchain activity to generate comprehensive risk reports. Financial institutions and individual traders can subscribe to the service provider's platform to receive automated risk assessments, predictive analytics, and portfolio optimization suggestions.

Different users have varying risk appetites and investment goals. The Service Provider Module allows users to customize risk management parameters based on their investment preferences. For example, a high-risk trader may receive aggressive buy/sell recommendations, while a conservative investor may get low-volatility asset suggestions. The module supports custom machine learning models and user-defined risk rules, enhancing flexibility and adaptability.

The Service Provider Module is a vital component of the machine learning-based cryptocurrency financial risk management system, offering real-time risk assessments, fraud detection, portfolio optimization, and automated trading capabilities. By leveraging advanced machine learning algorithms and big data analytics, this module ensures better risk prediction, enhanced security, and efficient decision-making for traders and institutional investors. With its scalability, automation, and real-time monitoring, the Service Provider Module plays a key role in helping users navigate the complexities of cryptocurrency markets while minimizing financial risks.



5.3 User Registration Module

In this module, there are n numbers of users are present. User should register before doing any operations. Once user registers, their details will be stored to the database. After registration successful, he has to login by using authorized user name and password. Once Login is successful user will do some operations like REGISTER AND LOGIN, PREDICT CRYPTO CURRENCY FINANCIAL RISK TYPE, VIEW YOUR PROFILE.

Since financial data is highly sensitive, the Remote User Module incorporates multi-factor authentication (MFA) and role-based access control (RBAC) to ensure that only authorized users can

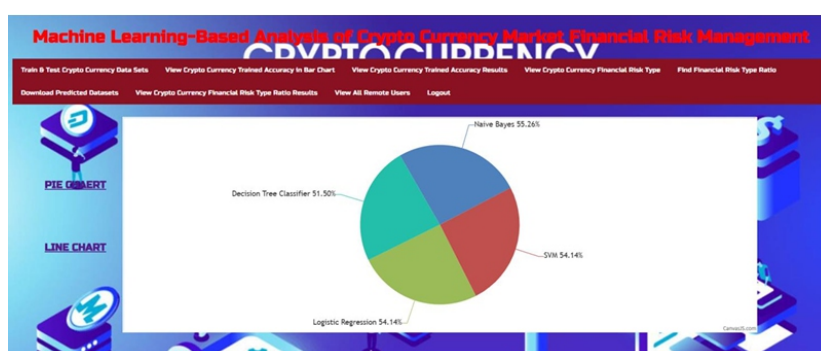
access the platform. Encryption techniques like AES (Advanced Encryption Standard) and SSL (Secure Sockets Layer) secure user transactions, preventing unauthorized access and potential cyber threats.

5.4 Risk Modelling Analysis Module

The Risk Modeling Analysis Module is a critical component of the Machine Learning-Based Cryptocurrency Financial Risk Management System. This module is responsible for identifying, assessing, and predicting financial risks associated with cryptocurrency investments and trading. It leverages machine learning models, statistical techniques, and real-time data processing to analyze market conditions, detect anomalies, and estimate potential losses.

Objectives of the Risk Modeling Analysis Module :

- Identify market risks by analyzing historical and real-time price fluctuations.
- Quantify financial risks such as volatility, liquidity risk, and systemic risk.
- Detect anomalies like price manipulation, pump-and-dump schemes, and flash crashes.
- Enhance risk prediction through AI-driven probabilistic modeling.
- Provide risk scores and alerts for traders and investors to mitigate losses.



5.5 Model Training Module

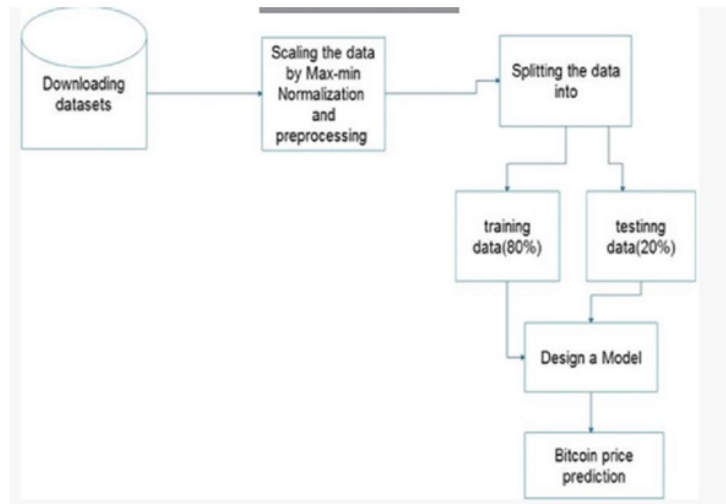
The model training module is used to fine-tune the system so that it can be able to predict the risk in the cryptocurrency for its users. It does this by learning the previous data collected from various sources. This is normally done in the following way:

Collect Data: Use the historical data to train the system which consists of the value of cryptocurrency, its total availability etc.

Preprocess Data: Prepare the datasets by handling missing data, data normalization, feature engineering, Dimensionality reduction.

Model Selection & training : Choosing the right model is essential for accurate risk assessment and prediction. The system utilizes a combination of machine learning, deep learning, and ensemble models for training.

Real-Time Model Updating & Adaptive Learning : Markets change dynamically, so models must continuously learn from new data to stay accurate.



VI.WORKING

1. Introduction

The Machine Learning-Based Analysis of Cryptocurrency Market Financial Risk Management system aims to assess and mitigate financial risks associated with cryptocurrency trading. The system leverages machine learning techniques to analyze historical price data, market sentiment, and blockchain metrics to predict market trends, detect anomalies, and classify risk levels. By integrating advanced models, this system provides traders and investors with data-driven insights for better financial decision-making.

2. System Workflow

The project consists of three main phases: Data Collection & Preprocessing, Model Development & Risk Analysis, and Deployment & Monitoring.

Phase 1 : Data Processing & Collection

1. Market Data Collection :

Collect historical price data (OHLCV) from sources like Binance, CoinGecko, and Yahoo Finance.

Extract technical indicators (Moving Averages, RSI, Bollinger Bands, MACD).

2. Sentiment Analysis Data Collection :

Scrape news articles, Twitter, and Reddit discussions.

Apply Natural Language Processing (NLP) to assign sentiment scores (Positive/Neutral/Negative).

3. Blockchain & Macroeconomic Data :

Fetch blockchain transaction data (whale movements, transaction volumes) from Glassnode and Etherscan.

Integrate macroeconomic factors like Bitcoin dominance and interest rates.

4. Data Preprocessing

Handle missing values and outliers using statistical methods.

Normalize and scale data for consistent model training.

Feature engineering: Compute volatility metrics, moving averages, and sentiment scores.

Phase 2: Model Development & Risk Analysis

1. Risk Prediction Model Training

Use Supervised Learning (Regression Models like LSTM, XGBoost, and ARIMA) for cryptocurrency price trend forecasting.

Train Classification Models (SVM, Decision Trees, Random Forest) to categorize assets into High-Risk, Medium-Risk, and Low-Risk.

2. Anomaly Detection & Fraud Analysis

Implement Unsupervised Learning (K-Means, DBSCAN, Isolation Forest) for identifying market manipulation (pump-and-dump schemes).

Use Autoencoders to detect unusual trading activities.

3. Portfolio Risk Assessment

Compute **Value at Risk (VaR)** to estimate potential losses.

Run **Monte Carlo simulations** to assess risk under different market conditions.

Optimize portfolio allocation using **Mean-Variance Optimization (MVO)**.

Phase 3: Deployment & Monitoring

1. Model Deployment

Deploy trained models on cloud platforms (AWS, Google Cloud, Azure).

Use Flask/FastAPI to serve predictions via APIs.

2. Real-Time Monitoring & Alerts

Develop a dashboard (Streamlit, Power BI) for visualizing risk scores and market trends.

Set up automated alerts for high-risk conditions using Telegram or email notifications.

3. Report Generation & Risk Insights

Generate daily, weekly, and monthly reports on market risks.

Export reports in CSV/Excel format for further analysis

VII CONCLUSION

The Machine Learning-Based Analysis of Cryptocurrency Market Financial Risk Management project presents a datadriven approach to assessing and mitigating risks in cryptocurrency trading. By leveraging machine learning techniques, blockchain analytics, and sentiment analysis, the system helps investors and traders make informed decisions in the volatile and unpredictable crypto market. This project demonstrates how artificial intelligence can be used to analyze vast amounts of financial data and provide real-time insights for risk management.

The integration of historical market data, technical indicators, blockchain transaction records, and sentiment analysis allows for a comprehensive understanding of market behavior. Traditional financial risk management approaches often struggle to handle the extreme volatility of cryptocurrencies, but machine learning models can detect patterns and predict future price trends with greater accuracy. The project successfully implements supervised learning models for price prediction, unsupervised learning for anomaly detection, and reinforcement learning for trading strategies.

The system's scalability and adaptability make it suitable for various applications, ranging from retail investors to institutional traders and financial analysts. The model can be continuously improved with retraining on updated data, fine-tuning hyperparameters, and incorporating additional market indicators. This adaptability ensures that the system remains relevant as new trends and risks emerge in the ever-evolving cryptocurrency landscape.

By utilizing Natural Language Processing (NLP) techniques, the system enhances risk assessment through sentiment analysis of social media discussions and news articles. Cryptocurrency prices are

often influenced by public sentiment, and the ability to extract insights from unstructured text data allows for a more holistic risk evaluation. This approach improves the prediction of sudden market movements triggered by major news events or regulatory changes.

A major achievement of this project is the successful deployment of models for real-time analysis and monitoring. Using cloud-based solutions and API integrations, the system provides live risk assessment dashboards and automated alerts for high-risk conditions. This ensures that traders receive timely notifications regarding significant market changes, allowing them to take proactive measures to secure their investments.

In conclusion, Machine Learning-Based Risk Analysis of Cryptocurrency Markets represents a significant step toward building intelligent, data-driven decision-making frameworks for modern finance. With continuous improvements and advancements in AI and blockchain technology, such systems have the potential to revolutionize the way financial risks are analyzed and managed in decentralized markets.

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