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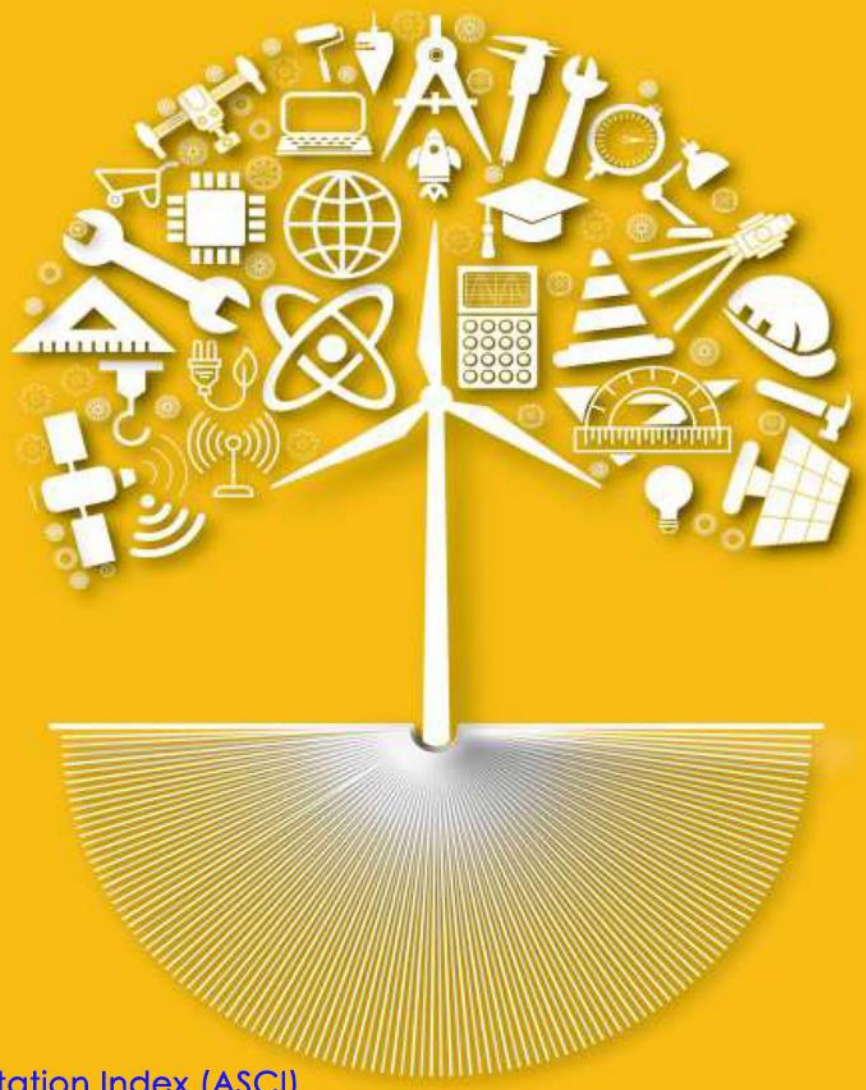

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EFFECTIVENESS OF SELECTED LOW IMPACT DEVELOPMENT (LIDS) FOR SUSTAINABLE STORMWATER MANAGEMENT IN FAST-URBANIZING RESIDENTIAL AREAS

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Abstract

The global trend of urbanization has led to the widespread conversion of natural land cover to impermeable surfaces. This, in turn, is hindering water infiltration and exacerbating runoff from precipitation. This phenomenon has detrimental effects on the natural environment and water quality. To address these issues of stormwater generation, this study employed the Storm Water Management Model (SWMM) in conjunction with MapWindow Geographical Information System (GIS) v4.X, a hydrologic data software for data, visualization, editing, and integration with other modeling tools to simulate the impact of various Low Impact Developments (LIDs) on mitigating stormwater in the study area. The study area was divided into six sub-basins within the GIS environment and imported into SWMM to assess the effects of selected LIDs, including green roofs, rain gardens, vegetative swales, and permeable pavements. The SWAT model was used to predict water flow in the Malete watershed and surface runoff. The study identified areas susceptible to erosion and categorized them as low, moderate, severe, and extreme. The results showed that permeable pavements exhibited the highest reduction rate, reducing stormwater by approximately 50% across all sub-basins, while green roofs showed the lowest reduction rate of only 0.003%. Regional calibration was implemented, revealing a significant correlation of 71% between simulated and observed flows in the study area. The findings of this study can serve as a valuable decision-support tool for stakeholders and authorities when selecting appropriate LID practices to mitigate the urban impact of stormwater generation.

Keywords: ***Low Impact Development (LIDs), Malete, MapWindow GIS, MWSWAT,*** **Soil** ***Erosion, Stormwater, SWMM***

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I. INTRODUCTION

Stormwater refers to precipitation originating from rain, sleet, or melting snow. In natural environments, only a small portion of this precipitation becomes surface runoff. Runoff typically flows into nearby streams, creeks, rivers, lakes, or wetlands. However, owing to rapid global urbanization, the characteristics of natural land cover are transforming into impermeable surfaces, leading to the degradation of natural surroundings. These negative impacts include increased runoff, heightened peak flows that result in flash floods, degradation of water quality, and other water-related challenges [1].

As reported in several works of literature [2-5], climate change exacerbates these issues, making urban areas susceptible to erosion and recurrent flooding which has led to various climate change impact studies in urban catchments. The combination of climate change and urban growth has disrupted hydrological patterns, elevated runoff volumes, and caused erosion, floods, and ecosystem deterioration. In recent times, the use of Low-impact development (LID) strategies has advocated for decentralized stormwater management systems distributed across the catchment area, as opposed to centralized approaches. LIDs offer benefits such as curbing storm runoff volume [6], enhancing stormwater quality and river conditions, reducing flood peaks, boosting infiltration rates and base flow, restoring the water cycle equilibrium, and disrupting urbanization [7, 8]. Traditionally, urban flood control methods have focused on constructing drainage channels to convey the generated runoff [9, 10]. However, such drainage systems yield only short-term effects and fail to address the root problems.

In recent times, Low Impact Development (LID) practices have come to the forefront as a viable approach to mitigate the negative effects of urbanization and restore natural water cycles in urban areas, promoting a more sustainable future. Various hydrological models, such as the Storm Water Management Model (SWMM), can simulate the impact of diverse LIDs and replicate natural hydrological conditions to a great extent [11, 12]. Numerous studies have been published on modeling Low Impact Developments (LIDs) to sustainably manage runoff across various catchment scales. For instance, researchers in a study [13] developed models for detention ponds and infiltration trenches to assess their impact on runoff volume. The results showed that Low

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Impact Development (LID) practices significantly reduce stormwater runoff for small rainfall events but have limited effectiveness during flood events. Similarly, another study [14] investigated the effectiveness of green roofs in mitigating runoff using the Storm Water Management Model (SWMM). The simulation revealed that green roofs are an excellent solution for reducing runoff. A study [13] integrated detention ponds and infiltration trenches into an existing hydrological model to evaluate their effect on runoff volume. The findings confirmed that LID practices effectively control stormwater during small rainfall events but have limited influence during flood events. This approach is widely adopted to mitigate the adverse effects of urban stormwater runoff.

However, very few of these studies could be found in the literature to address the issue of stormwater reduction in Africa or sub-Saharan African watersheds. A notable study [15] investigated the impact of Low Impact Developments (LIDs) on runoff generation in Eldoret, Kenya, using the Storm Water Management Model (SWMM). The study findings revealed that infiltrating 100% of impervious areas with infiltration trenches led to a 25% reduction in average runoff flow and a 19.6% decrease in total runoff volume. Additionally, bio-retention ponds were found to reduce average runoff flow and volume by 1.6% and 4.4%, respectively. Another African application of LIDs was explored by a study [16], which discovered that combining Permeable Pavement and Rain Barrels offered the most effective runoff control, achieving a remarkable 57% removal rate

The choice of Malete, a town situated in Kwara State, Nigeria is because the town is experiencing rapid growth, largely attributed to the establishment of Kwara State University. Over the past decade, the University has witnessed a significant rise in student enrollment and staff numbers, leading to the extensive construction of student hostels within the town. This urban expansion has amplified the generation of stormwater runoff, potentially causing issues such as waterlogging, traffic congestion, the submergence of infrastructure, and disruptions to utility pipelines such as gas and electricity. Urban waterlogged areas severely affect human safety and properties. This study aimed to assess the impact of selected Low Impact Development (LID) techniques on managing stormwater generation in the study area. The outcomes of this study could provide

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valuable insights and a decision-making criterion for local authorities and developers in the implementation of the most effective LID alternatives for stormwater management in the region.

II. METHODOLOGY

A. Description of the Study Area

The study site is situated in Malete town, located between latitudes $8^0$36' and $8^0$24' North and longitudes $4^0$36' and $4^0$10' East. It covers a total area of 1,230.0 square kilometers and is a small town within the Moro Local Government Area of Kwara State of Nigeria. The administrative center of this locality is in Bode Saadu, a town located along Jebba Road. The Moro Local Government comprises five districts: Lanwa, Ejidongari, Olooru, Malete, and Ipaye. The terrain of the area closely resembles the surrounding plains, which are characterized by gently undulating slopes. The town employs a combination of open stormwater drainage systems and earthen drains to manage the stormwater flow generated within the vicinity. Malete town is home to Kwara State University, which was established in 2009. The primary occupations of Malete residents are farming and trading. It is a predominantly Yoruba-populated agrarian community. In addition to agriculture, the residents of Malete also participate in hunting and fishing activities. Nevertheless, its fertile soil renders it particularly favorable for extensive farming and agro-industries. Fig. 1 shows the location of Malete Town in Kwara State.

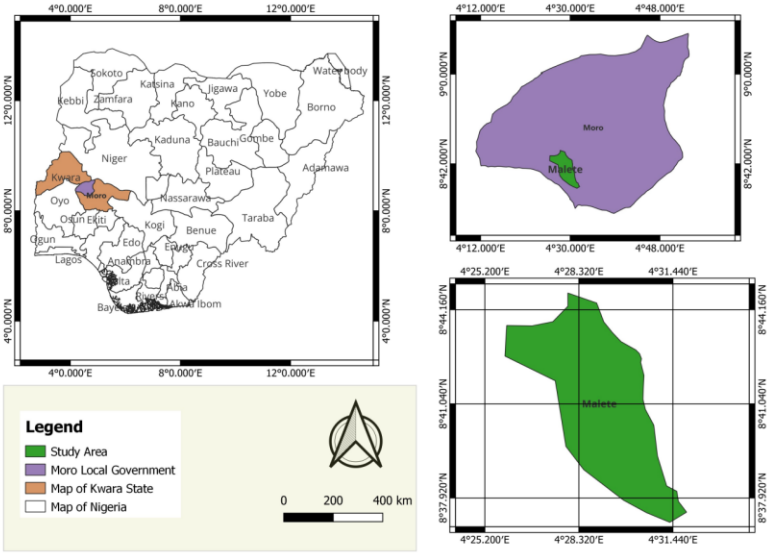

Fig. 1. Map of Nigeria showing the location of the study area

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B. Data Collection and Description

This study utilized a range of data for its analysis. This includes 90 m resolution topography data from the Shuttle Radar Topography Mission's (SRTM) final version, which employed radar technology to generate a detailed digital elevation model of the Earth's surface. Land use and land cover (LULC) data was obtained from the Global Land Cover Characterization (GLCC) database, with a spatial resolution of 1 kilometer and 24 classes of land-use representation, used to estimate vegetation and other parameters representing the watershed area [17,18] [19]. The land use map of the study area is shown in Fig. 2. Digital soil data was extracted from the harmonized digital soil map of the world (HWSD v1.1), produced by the Food and Agriculture Organization of the United Nations, providing information on 16,000 different soil mapping units, with data available for two layers (0-30 cm and 30-100 cm depth), and complemented with additional soil data collected and analyzed from various locations within the watershed area [20]. Finally, weather data was obtained from the Nigeria Meteorological Agency (NIMET), covering a period of 30 hydrological years, including daily precipitation, maximum and minimum temperatures, solar radiation, relative humidity, and wind speed, with 19 years of data (from 2001-2019) used specifically for the SWMM Model.

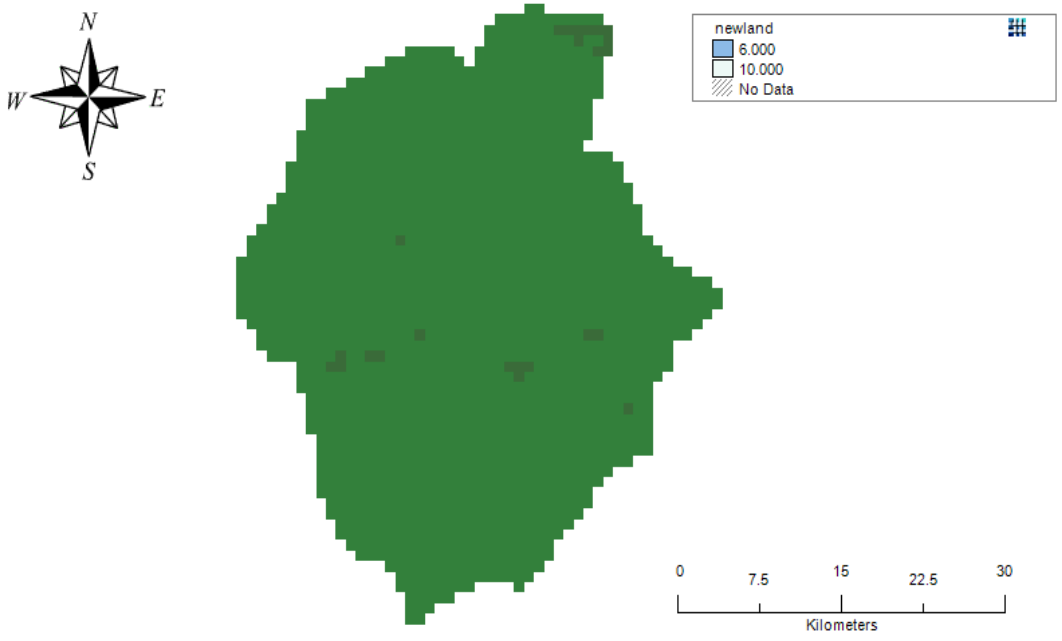

Fig. 2. Land use map of the study area

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C. Geo-Processing of Data and SWAT Model Setup

The physical model used in this study for the prediction of sediment yield and identification of erosion-prone areas is the Soil and Water Assessment Tool, SWAT [21, 22]. SWAT has been used by many researchers and its availability and efficacy in the prediction of different hydrological processes has also been reported in many studies [23-27]. The primary spatial data needed for the modeling of the study area is the Digital Elevation Model (DEM) which was geo-processed using the Automatic Watershed Delineation (AWD) tool embedded in the MapWindow GIS interface. This involved configuring the elevation units, and threshold size, and defining an outlet for the watershed. Additional spatial data, such as land use and soil maps, played a pivotal role in delineating the watershed into sub-basins. The land use map served as a basis for estimating parameters such as vegetation within the study area. Using the GIS component of the MWSWAT, the study area was subdivided into six subbasins and 11 hydrologic response units (HRUs). Notably, the HRU represents the smallest spatial unit within the model.

In this study, the SWAT analysis was conducted utilizing the Runoff Curve Number approach to assess surface runoff resulting from precipitation. The SCS curve number method, serving as a rainfall-runoff model designed for computing excess rainfall or direct runoff, assumes an initial abstraction related to the curve number before ponding occurs. The rationale for employing this method in the study lies in its widespread application across many countries attributed to its perceived simplicity, predictability, stability, and reliance on a single parameter, as noted by a study [28]. Additionally, [29] demonstrated that the curve number method exhibits superior predictive performance in SWAT applications compared to the Green-Ampt method. For the estimation of potential evapotranspiration, the Hargreaves method was adopted due to its simplified equation, which relies only on two climatic parameters: temperature and incident radiation. This method is particularly recommended in situations where reliable data are lacking, as highlighted by [30]. In the simulation of channel water routing, the variable-storage routing method was chosen. This method links the outflow volume to both the storage coefficient and the volume stored, providing a comprehensive approach to simulate the dynamics of water routing in channels.

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D. Modeling in SWMM

This study adopted a Storm Water Management Model (SWMM), which is a comprehensive simulation model for hydrology and water quality. This model is used to simulate runoff events in urban areas, either for event-based or continuous simulations [31]. The fundamental input parameters required to simulate hydrographs encompass the rainfall hyetograph and physical attributes of the sub-catchments. The infiltration loss on pervious surfaces was determined using the Horton equation by leveraging available soil data. The EPASWMM is a deterministic physically based model designed to replicate the movement of water inflows, outflows, and storage within sub-catchments. Fig. 3 shows the schematic diagram of SWAT and SWMM modeling processes for the simulation of flow and performance evaluation of LIDs of the study area. The entire catchment was composed of six sub-catchments, ten junctions, ten conduit links, one outfall, and one rain gauge station as shown in Fig. 4. SWMM software was utilized to calculate the quantity of runoff generated within each sub-catchment and to determine flow rates and depths within conduits during the simulation period, which involved multiple time steps.

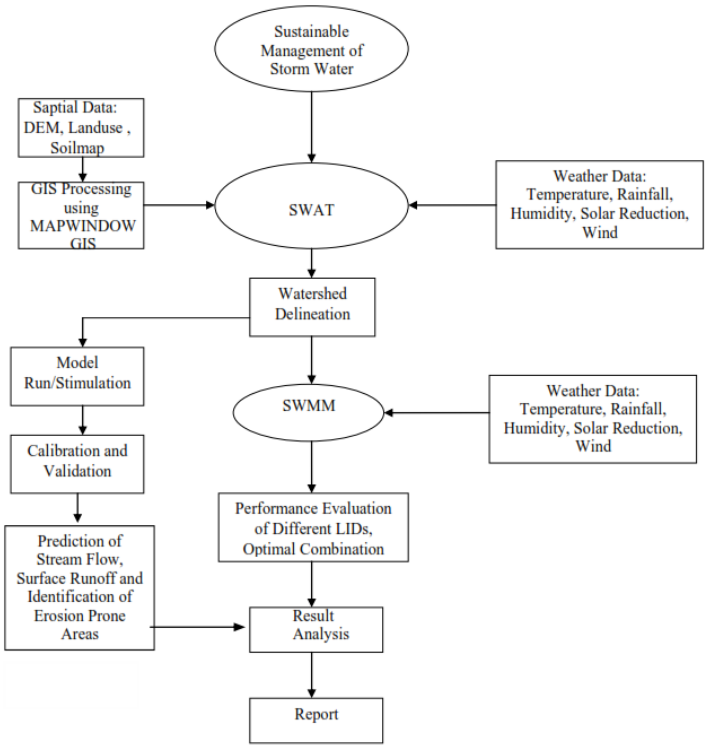

Fig. 3. Graphical representation of processes involved in the methodology.

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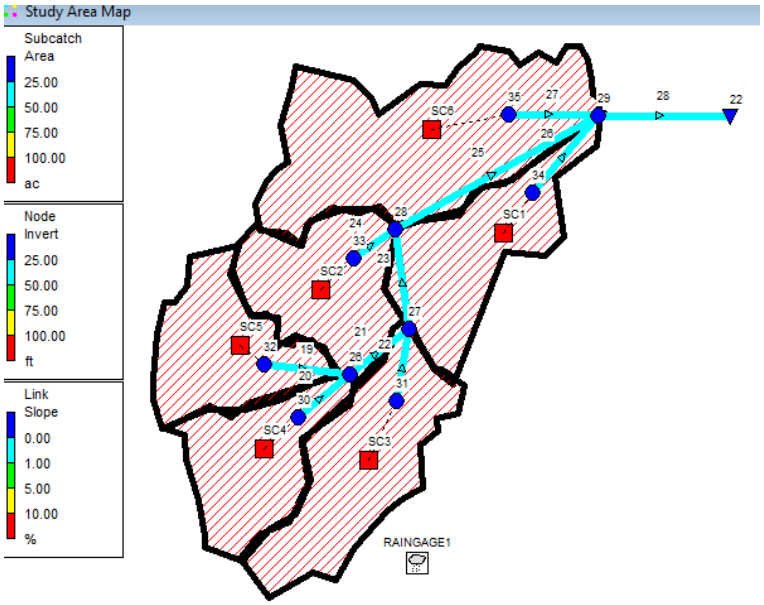

Fig. 4. Watershed delineation of the study area

E. Implementation of Low Impact Development (LID) for Runoff Reduction

Selected LIDs were modeled in the study area to study their effectiveness in the reduction of runoff generated. These techniques have been shown to effectively reduce stormwater pollutants, with Rain Gardens capable of removing solids, organics, nutrients, and heavy metals [32]. Green Roofs, consisting of a vegetative covering on a water-resistant material, have also been proven to be effective [33-36]. To evaluate the efficiency of these LID practices in mitigating runoff, the Storm Water Management Model (SWMM) was employed as an analytical tool. The selected LID controls were integrated into the model for each sub-catchment, allowing for a detailed analysis of their impact on runoff reduction. The core methodology of this study involved using SWMM as a modeling tool to explore the impact of LID practices on stormwater reduction. The results of the study are presented in the following section, highlighting the effectiveness of the selected LIDs in reducing stormwater runoff.

III. RESULTS AND DISCUSSION

A. Prediction of Total Stream Flow in the Sub-Basin

Fig. 5 displays the predicted streamflow data for each sub-basin. Sub-basin 4 had the highest streamflow rate at 216.67 m^3/s, while sub-basin 2 had the lowest at 65.56 m^3/s. This significant

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difference is due to the unique geological formations and land cover characteristics of sub-basin 4, which result in a high streamflow rate and increased susceptibility to erosion and flooding. In contrast, sub-basin 2's more permeable layer allows for greater groundwater infiltration, leading to reduced streamflow, erosion, and flooding risks. Overall, the total streamflow at the study area's outlet is predicted to be 451.91 m^3/s during the simulation period.

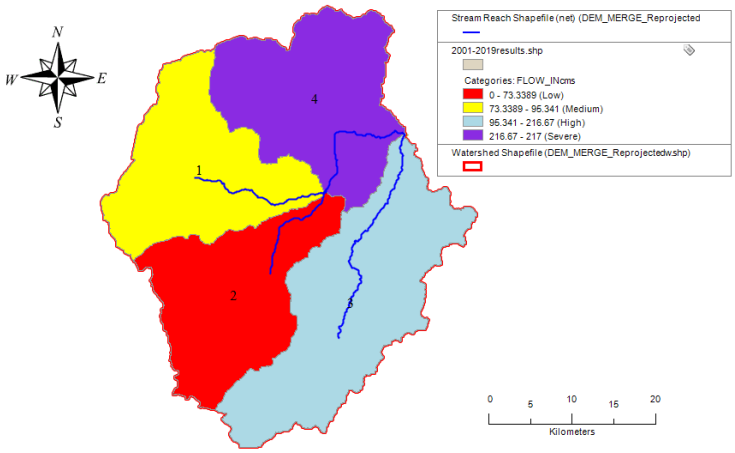

Fig. 5. Spatial variation in stream flow in the study area

B. Prediction of Total Surface Runoff in the Sub-basin

The model predictions revealed significant variations in total surface runoff across the sub-basins during the simulation period. Sub-basin 1 exhibited the highest predicted surface runoff, with a value of 313.09 mm, while sub-basin 2 experienced the lowest, at 292.59 mm. The geological formations and land cover characteristics of sub-basin 1 likely contributed to its high surface runoff rate, making it prone to erosion and flooding. This high runoff may be attributed to impermeable soil, steep terrain, or land cover types that hinder effective water absorption, resulting in excess water flowing over the surface and leading to erosion and potential flooding.

In contrast, the sub-basin 2 low surface runoff rate is attributed to its relatively permeable layer, which facilitates higher infiltration rates and allows water to recharge groundwater. This results in less surface runoff, reduced erosion, and a lower risk of flooding. Fig. 6 provides a visual representation of the predicted surface runoff distribution across the study area, while Table I provides a detailed breakdown of the predicted total flow and total surface runoff in each sub-basin.

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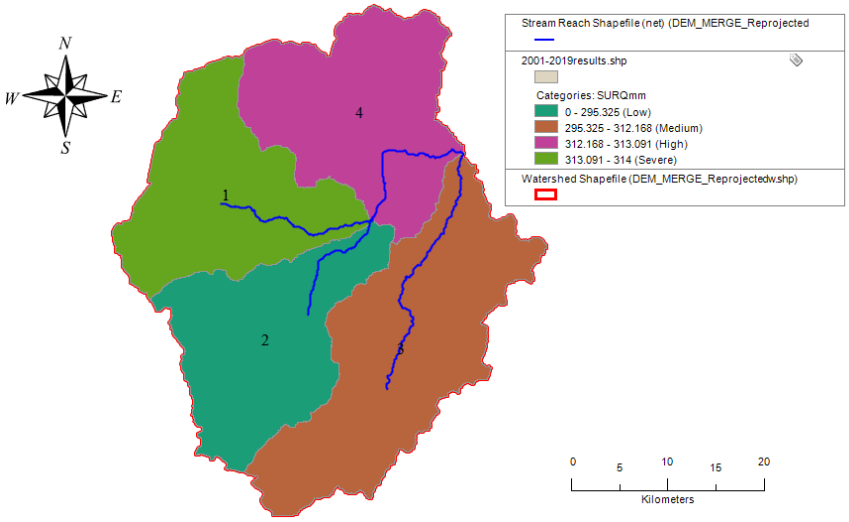

Fig. 6. Variability in surface runoff across the study area

Table I: Sub-basin-specific predictions of total flow and total surface runoff

Basins Number	Area (km^2)	Flow (m^3/s)	Surface runoff (mm)
1	324.94	73.34	313.09
2	318.53	66.56	292.59
3	447.96	95.34	295.32
4	349.13	216.67	312.17
	Total	451.91	1213.17

C. Identification of Erosion Prone Area

The areas vulnerable to erosion were classified into four categories: low, moderate, severe, and extreme. This categorization helps understand the erosion risk across the watershed. The results show that sub-basin 4 has a high proportion of areas at severe risk of erosion, while sub-basin 3 has a significant presence of erosion-prone areas. In contrast, sub-basin 2 is largely composed of areas with low erosion risk. In sub-basin 4, the significant presence of severe erosion is likely attributed to the steep slope gradient, which increases water runoff velocity and contributes to more pronounced erosion. Additionally, poor vegetative cover exposes the soil to erosion, diminishing its protection against the impact of rainfall. The soil characteristics, such as low cohesion or high erodibility, could further exacerbate vulnerability. Unsustainable land use practices, such as

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improper agricultural methods or construction activities, may also play a role in enhancing erosion risk in this sub-basin.

Sub-basin 3 exhibits a high occurrence of erosion-prone areas, possibly due to intensive agricultural practices. Extensive plowing and the absence of cover crops contribute to soil erosion. Urbanization in this sub-basin may lead to impervious surfaces, altered drainage patterns, and increased erosion risk. Furthermore, changes in the hydrological cycle, such as altered precipitation patterns or heightened storm intensity, could elevate the overall vulnerability to erosion in sub-basin 3. Contrastingly, sub-basin 2 is primarily characterized by low erosion-prone areas. This might be attributed to the presence of sufficient vegetative cover, either through natural vegetation or well-managed land cover, contributing to soil stabilization and reduced erosion. The gentle slopes in this sub-basin may also play a role in minimizing erosion risk. Effective conservation practices, such as contour plowing or afforestation, could be implemented, further reducing the susceptibility to erosion in sub-basin 2. The spatial map of the erosion-prone areas is shown in Fig. 7.

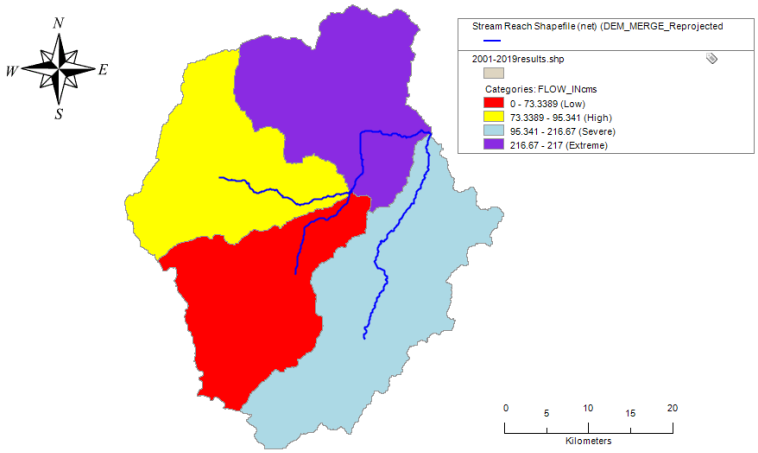

Fig. 7. Classification of erosion-prone areas

D. Model Calibration, Validation, and Performance Evaluation

Due to a lack of observed data for the study area, regional calibration was adopted to calibrate and validate the model. Regional calibration of hydrological models is a process used to enhance the accuracy and reliability of hydrological simulations over a larger geographic area by adjusting

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model parameters to better reflect the specific characteristics and behaviors of different sub-regions within the area. This process is crucial for understanding water resources, predicting floods, and managing water systems effectively. It involved using observed data from nearby Asa River located between latitude 8^0 36' and 8^0 24' North and longitudes 4^0 36' and $4^0$10' East with the predicted flow values in the watershed to establish a calibration for the model. Fig. 8 shows the correlations between the observed and simulated flow with a correlation coefficient of 0.7099 indicating a good correlation between the observed and simulated flow. In other words, the strength of the relationship between these two variables is constrained to approximately 71 %. It is imperative to state that this approach may have its limitations; however, it is supported by various relevant literature sources that reported similar levels of correlation between [11, 37-40]

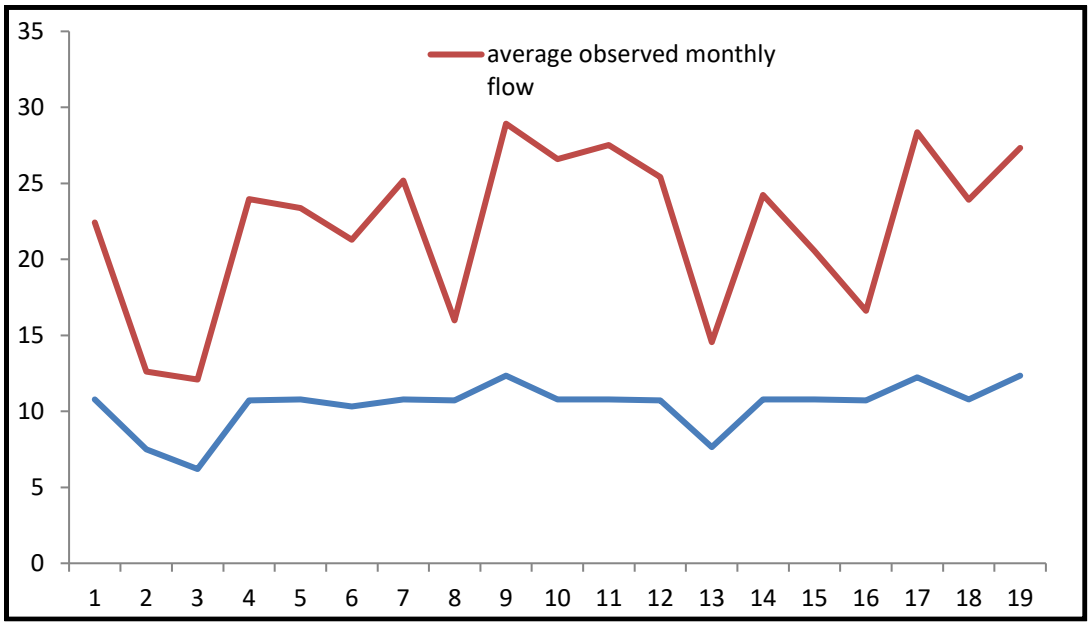

Fig. 8. Graphical representation of the predicted flow and observed flow for the calibration period.

E. Effect of Application of Permeable Pavement on Stormwater Reduction

The findings of the study as presented in Fig. 8 revealed a significant insight into the effectiveness of various LID models in reducing stormwater generation across the sub-basins within the study area. Notably, all LID models demonstrated the capacity to reduce stormwater generation to varying degrees. However, the permeable pavement was identified as the most performing among the LID techniques in the reduction of surface runoff, flood peaks, and delaying peak flow. On

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average, an impressive stormwater reduction of approximately 50% was achieved. This result indicated that permeable pavement can be used effectively and efficiently in the reduction of stormwater generated in the study area. The result obtained in this study also aligned with the results that were obtained in the literature [41-43]. The consistency in findings can be attributed to factors such as the high rainfall intensity in the study area and the presence of substantial vegetative cover. These factors contributed to the efficacy of permeable pavement, rendering it a reliable option for stormwater management in regions with analogous environmental conditions. In conclusion, the results of this study highlight the efficacy of Low Impact Development (LID) techniques in mitigating stormwater generation, emphasizing their potential as effective strategies for managing urban runoff, and promoting sustainable water management practices

F. Impact of Vegetative Swale Implementation on Stormwater Mitigation

The implementation of vegetative swales in the study area yielded a runoff reduction percentage ranging from 13.95 % to 15.56 %, making it the second most effective Low Impact Development (LID) technique. While this reduction is substantial, it falls short of the results reported in previous studies [44-45]. The inconsistencies in outcomes may be attributed to regional factors unique to the study area. A plausible explanation for the relatively lower runoff reduction achieved by vegetative swales is the climatic conditions, which differed from those in the regions where studies [44] and [45] conducted their research experiments. Specifically, the study area may have experienced a lower frequency of rainfall events, lower rainfall intensity, and shorter rainfall durations, which could have impacted the effectiveness of vegetative swales in reducing runoff. This highlights the importance of considering local climatic conditions when implementing and evaluating the effectiveness of Low Impact Development (LID) techniques. The reduced rainfall frequency, intensity, and duration may have limited the swales' ability to capture and filter stormwater, resulting in a lower runoff reduction percentage.

G. Impact of Rain Garden Implementation on Stormwater Mitigation

The rain gardens in the study area demonstrated a negligible runoff reduction, with values ranging from 0.0003% to 0.31%. These findings are consistent with the results reported by a study [46] but diverge from those obtained by [47]. The inconsistencies in these findings can be attributed to

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various factors, including the unique rainfall patterns and land use characteristics of the study areas. Notably, the effectiveness of rain gardens in reducing runoff appears to be limited in this context. Reduction in the runoff generation is an indication that rain gardens may not be a suitable strategy for mitigating stormwater runoff in this region, potentially due to the high rainfall intensity or land use practices that impede the performance of rain gardens.

H. Impact of Green Roofs on Stormwater Reduction

Application of Green roofs in the management of stormwater in the study area has the least impact as a management strategy with a negligible 0.0003% reduction observed in the study area. This finding aligns with the results of a previous study [14]. The limited effectiveness of green roofs in reducing stormwater runoff in this study can be attributed to various factors. The capacity of green roofs to capture, retain, and release rainwater is heavily dependent on the vegetation and soil substrate used. Factors such as vegetation type, soil composition, and substrate depth can significantly influence green roof performance. The consistency of these results with the study [14] suggests that both studies share commonalities in terms of climate, vegetation type, and green roof design, leading to similar outcomes.

I. Effects of Combination of LIDs on Stormwater Reduction

The study of various Low Impact Development (LID) technique combinations on stormwater reduction in the study area yielded insightful results, as illustrated in Fig. 9. The outcome of this study showed that the combination of permeable pavement and vegetative swale may reduce the stormwater generation up to about 65.09 percent in the study area, showcasing exceptional efficiency in mitigating stormwater runoff. However, these results diverge from those reported by the study [14], suggesting that the performance of LID techniques can be significantly influenced by local conditions, including rainfall patterns, soil characteristics, and the built environment. In contrast, the combination of Green Roof and Rain Garden yielded the lowest stormwater reduction percentage of 0.19 %, indicating limited effectiveness in stormwater management. It is essential to acknowledge that the combined performance of LID techniques can vary substantially depending on the specific attributes of the study area, including climate, land use, and soil composition.

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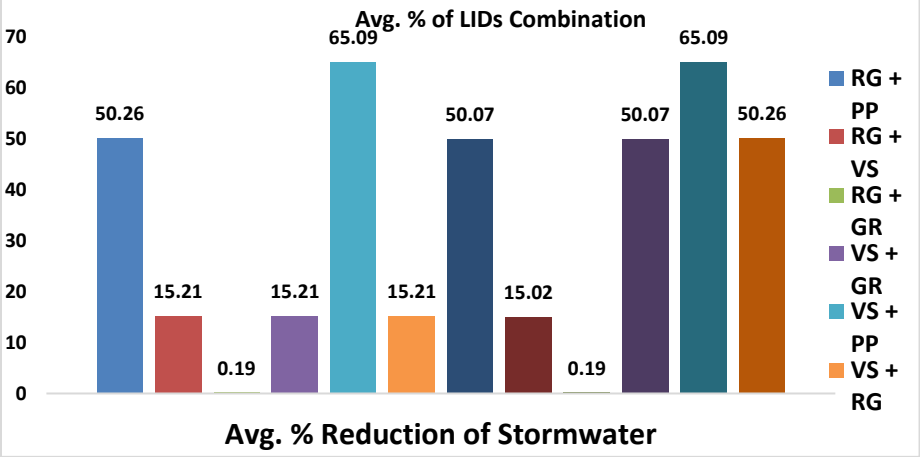

Fig. 9. Average percentage reduction of stormwater generation using varieties of LID combination.

IV. CONCLUSION

The study and experimental analysis revealed that annual stream flow and surface runoff values showed significant variation, with stream flow ranging from 1264.66 m^3/s to 4116.74 m^3/s and surface runoff varying from 1264.66 mm to 5931.9 mm. The study identified areas prone to erosion and categorized them into four levels of susceptibility: low, moderate, severe, and extreme. This identification is crucial for targeted mitigation efforts. The simulation results demonstrated the effectiveness of Low Impact Development (LID) techniques in reducing the environmental and water quality impacts of stormwater. All examined LID techniques showed positive results.

Among the LID techniques, permeable pavement showed the highest percentage reduction in runoff, while green roofs had the lowest percentage reduction. Combining LID techniques resulted in varying levels of effectiveness, with the combination of permeable pavement and vegetative swale achieving the highest percentage reduction in stormwater. In contrast, the combination of green roofs and rain gardens showed the lowest percentage reduction. The regional calibration of the model revealed a strong correlation of 71 % between predicted and observed flow data, indicating a significant relationship between the two datasets. This calibration enhances the reliability of the model's predictions.

Therefore, it was concluded that the integration of SWAT and SWMM models can provide a robust decision-support framework for stakeholders and authorities in the region. By leveraging these models, policymakers and practitioners can make informed decisions about effective stormwater

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management practices, ultimately contributing to the sustainability and resilience of urban water systems. The use of these models can also help identify areas with high stormwater generation potential and prioritize interventions aimed at reducing runoff and improving water quality.

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Conflict of interests

The authors declare that there is no conflict of interest

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SQL INJECTION ATTACKS DETECTION: A PERFORMANCE COMPARISON ON MULTIPLE CLASSIFICATION MODELS

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Abstract

SQL injection attacks pose a significant threat to web applications because they allow unauthorized access to sensitive data and manipulation of databases. Detecting and preventing these attacks is essential for ensuring the security of web applications. While there have been numerous studies on using machine learning to detect SQL injection attacks, there is a lack of comprehensive analysis comparing the performance of different classification models. This research aims to evaluate and compare the effectiveness of various classification models, including KNN, decision trees, support vector machines, Naïve Bayes, and neural networks, in detecting SQL injection attacks. Using a Kaggle dataset with 30919 cases, the study employed an 80%:20% split ratio for training and testing. Data preprocessing was conducted to clean the data by addressing missing values, reducing noise, resolving inconsistencies, and eliminating outliers. The results showed that CNN achieved the highest accuracy (96.55%), with a good balance between precision (98.92%) and recall (91.71%). By evaluating and comparing different classification models, this study contributes to enhancing the security of web applications against SQL injection attacks and advancing research in cybersecurity and machine learning. The study's results can strengthen cybersecurity practices, and defense strategies and empower organizations to proactively defend against evolving threats by creating a better-secured digital environment for web applications and databases.

Keywords: ***Machine learning, Performance Evaluation, SQL injection attacks, Cyber Security, Web applications, Databases***

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I. INTRODUCTION

SQL injection attacks represent a prevalent and persistent threat to the security of web applications, posing significant risks to the confidentiality, integrity, and availability of sensitive data. These attacks exploit vulnerabilities in input validation mechanisms, allowing malicious actors to execute arbitrary SQL queries and gain unauthorized access to databases. The consequences of successful SQL injection attacks can be severe, ranging from data breaches and financial losses to reputational damage and legal liabilities [1-4].

In response to the growing sophistication and prevalence of SQL injection attacks, researchers and practitioners have increasingly turned to machine learning techniques for intrusion detection and prevention. By leveraging the inherent patterns and characteristics of SQL injection attempts, machine learning models can effectively distinguish between legitimate user inputs and malicious payloads, enabling proactive defense against cyber threats [5-7].

However, the selection and evaluation of appropriate classification models for detecting SQL injection attacks present considerable challenges. Different machine learning algorithms exhibit varying degrees of performance in terms of accuracy, precision, recall, and computational efficiency. Moreover, the effectiveness of these models can be influenced by factors such as the size and diversity of the training dataset, feature selection, and the presence of noise and imbalanced classes [8-10].

This research focuses on evaluating and comparing the effectiveness of various classification models in detecting SQL injection attacks. The models assessed include K-Nearest Neighbors (KNN), Decision Trees, Support Vector Machines (SVM), Naïve Bayes, and Neural Networks. Utilizing a Kaggle dataset consisting of 30,919 instances, the study employed an 80:20 split ratio for training and testing purposes. Data preprocessing was meticulously conducted to clean the dataset, which involved addressing missing values, reducing noise, resolving inconsistencies, and eliminating outliers.

The experimental results indicated that the Convolutional Neural Network (CNN) model achieved the highest accuracy at 96.55%, exhibiting a strong balance between precision (98.92%) and recall (91.71%). By thoroughly evaluating and comparing these classification models, the study contributes to enhancing the security of web applications against SQL injection attacks and advancing the fields of cybersecurity and machine learning.

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II. LITERATURE REVIEW

Several studies have investigated the use of machine learning techniques for detecting SQL injection attacks in web applications. These studies have explored various classification models, feature selection methods, and evaluation metrics to enhance the accuracy and effectiveness of SQL attack detection systems. In this section, we reviewed some of the selected and most relevant state of art research efforts in this domain.

The research study [11] investigates the use of machine learning techniques to identify and combat SQL injection attacks, a prevalent threat to web applications. SQL injection attacks exploit vulnerabilities in web applications to steal or manipulate data. Traditional methods struggle against evolving attack techniques. The study explored machine learning as a promising approach for detecting SQL injection attacks. The authors trained and compared various machine learning models using datasets containing both benign and malicious web traffic. The models were then assessed based on their ability to identify attacks while minimizing false positives accurately.

A study [12] provides a comparative analysis of various machine-learning algorithms for detecting SQL injection attacks. In this study, the authors evaluated the performance of algorithms such as SVM, Decision Trees, and Neural Networks using features extracted from HTTP requests. Results indicate that ensemble methods, particularly Random Forest, outperform individual classifiers in terms of accuracy and robustness.

Another research paper[13] explored ways of detecting SQL injection attacks using machine learning techniques. The study indicated that Web applications are vulnerable to SQL injection attacks, where malicious code is injected into user queries to manipulate databases. Machine learning models can be trained to analyze SQL queries and identify patterns indicative of attacks. The study might be evaluated on various models like Support Vector Machines (SVM), Decision Trees (DT), or Naive Bayes (NB)on a dataset of labeled SQL queries (malicious vs. legitimate). The research aimed to demonstrate that machine learning models can effectively classify queries and highly accurately detect SQL injection attempts. However, the model's performance might depend on the training data's quality and size. Complex models can be difficult to interpret, hindering understanding of their decision-making process.

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A study [14] proposed an ensemble classification approach for detecting the attack level of SQL injections in web applications. The research introduced a novel method that combines multiple classification algorithms to accurately identify the severity or level of SQL injection attacks. By leveraging the strengths of ensemble learning, the approach aims to enhance detection accuracy and robustness. Experimental results demonstrated the effectiveness of the proposed method in accurately classifying SQL injection attacks based on their severity, thus providing valuable insights for improving cybersecurity measures in web applications.

Similar studies [15, 16] presented a novel method for detecting SQL injection attacks in web applications. The research utilizes Convolutional Neural Networks (CNNs), a type of deep learning architecture, to automatically learn and identify patterns indicative of SQL injection attempts from raw HTTP request data. By leveraging the hierarchical feature extraction capabilities of CNNs, the proposed approach achieves high accuracy in distinguishing between benign and malicious HTTP requests. Experimental results demonstrate the effectiveness of the CNN-based approach in mitigating SQL injection threats and showcase its potential for enhancing cybersecurity measures in web application environments.

A study [17] explores the effectiveness of machine learning techniques in detecting SQL injection attacks by analyzing multiple data sources. It investigates various machine learning algorithms and evaluates their performance in identifying SQL injection attempts using diverse datasets. By considering different data types and feature sets, the research aims to enhance the accuracy and robustness of intrusion detection systems. The findings provide valuable insights into selecting optimal machine learning techniques and feature representations for effectively detecting SQL injection attacks across various web application environments.

Another study [18], proposed a detection model for SQL injection attacks that leverages the Chi-Square statistic along with classification techniques. The research introduced a novel method that combines feature selection through Chi-Square analysis with various classification algorithms to accurately identify SQL injection attempts in web applications. By selecting relevant features and employing classification techniques, the model aims to effectively distinguish between benign and malicious SQL queries. Experimental results demonstrated the efficacy of the proposed approach in detecting SQL injection attacks and highlighted its potential for enhancing cybersecurity measures in web application environments.

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A very relevant study[19], presents an approach to detect SQL injection attacks using machine learning classifiers. The study utilizes features extracted from HTTP requests to train classifiers, such as Support Vector Machines (SVM) or Decision Trees, to distinguish between legitimate and malicious queries. By leveraging machine learning, the method aims to enhance the accuracy and efficiency of detecting SQL injection attacks in web applications. Experimental results demonstrated the effectiveness of the classifier in identifying suspicious queries, thus offering a promising solution to bolster cybersecurity measures against SQL injection threats.

The rigorous review of the state-of-the-art studies indicates that there is a critical need for comprehensive performance evaluation studies to assess the efficacy of multiple classification models in detecting SQL injection attacks. Such evaluations can provide valuable insights into the strengths and limitations of different machine learning approaches, inform the selection of optimal detection strategies, and guide the development of more robust and resilient security mechanisms for web applications.

This paper aims to fill this research gap by conducting a thorough performance evaluation of various classification models for detecting SQL injection attacks. Specifically, the study analyzes the effectiveness of K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Decision Tree (DT), Naive Bayes (NB), and Convolutional Neural Network (CNN) in accurately identifying and classifying SQL injection attempts. By comparing and contrasting the performance of these models across multiple metrics, including accuracy, precision, and recall, we seek to provide insights that can inform the design and implementation of effective security measures for mitigating the risks posed by SQL injection attacks.

This research aimed to propose a novel approach for detecting SQL injection attacks in web applications by leveraging deep learning techniques. The primary objectives of the study were:

1) Developing a machine learning model trained on a large dataset of benign and malicious SQL queries to automatically learn the patterns and characteristics of SQL injection attacks.
2) Demonstrating the effectiveness and robustness of the proposed machine learning approach through extensive experimentation and evaluation of various datasets.
3) Comparing the performance of the deep learning model with other machine learning-based detection methods to showcase its superiority in terms of accuracy, sensitivity, and specificity.

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4) Highlighting the adaptability of the deep learning model to new and unseen attack patterns
5) Enhancing the security posture of web applications against SQL injection attacks.
6) Contributing to the advancement of security mechanisms for web applications by introducing a sophisticated and efficient method for detecting SQL injection attacks using deep learning techniques.

III. METHODOLOGY

The methodology as shown in Fig. 1 provides a framework for evaluating the performance of multiple classification models in detecting SQL injection attacks.

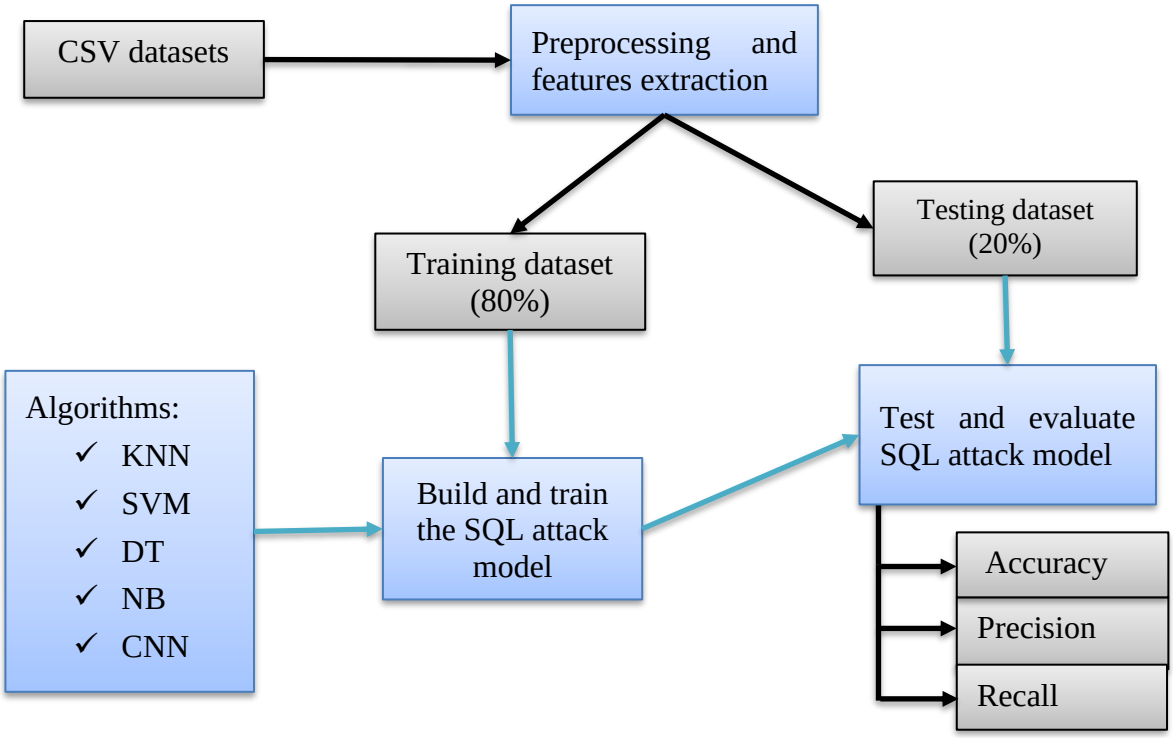

Fig. 1. Framework for proposed SQL injection attack detection

A. Dataset Information and Preprocessing

Whatever the dataset size, building a well-cleaned representative dataset is more important than deciding on a particular learning method [20]. We employed an 80%:20% split ratio to train and test the proposed model, respectively. The Kaggle dataset contains a separate SQL injection attack dataset with 19,589 cases labeled 0 indicating the legitimate query and 11,330 instances labeled 1 indicating the malicious query. The study was conducted using 30,919 cases in total. The

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heterogeneous origin of most real-world machine-learning datasets makes them particularly prone to missing, inconsistent, and noisy data. Data preprocessing was used to clean the data by correcting missing values, reducing noise, resolving inconsistencies, and eliminating outliers.

B. Implementation of Tools and Algorithms

Python was selected as the study's implementation language due to the number of libraries and packages designed specifically for Deep learning research. Python offers popular libraries like Scikit-learn, TensorFlow, and PyTorch for building and evaluating models. The study conducted extensive experiments utilizing Google Collaboratory to test and train the neural network[21-27].

C. Performance Evaluation Metrics

To forecast which class instance belongs to which class in a computational issue like classification and detection, evaluation measures like accuracy, precision, recall, and F1-score are used. The model's performance in each class was shown by those measures, which were calculated using classification metrics. The confusion matrix value is used to calculate the following metrics: TP (True Positive), TN (True Negative), FP (False Positive), and FN (False Negative). In this study, we use accuracy, precision, recall, and confusion matrix to evaluate the models' strengths and weaknesses as shown in Table I [28, 29].

Table I: Proposed SQL injection attack detection evaluation matrix

Evaluation metrics	Formula
Accuracy	$\text{Accuracy} = \frac{TP+TN}{P+N}$
Precision	$\text{Prcision} = \frac{TP}{TP+FP}$
Recall	$\text{Recall} = \frac{TP}{TP+TN}$

IV. RESULTS AND DISCUSSIONS

A. Experimental Setups

In this study, the employed machine learning and Deep learning algorithms are different hyperparameters. The CNN algorithm's hyperparameters include the optimization algorithm, learning rate, loss function, number of epochs, and batch size as shown in Table II and Table III.

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Table II: Hyperparameter value summary for machine learning

Learning algorithm	Optimal values		
KNN	n-neighbors=3	Weights='uniform'	The default for other parameters
SVM	Kernel='rbf'	C=1.0	Gamma='auto'
DT	DT classifier		
NB	function= gaussianNB()		

Table III: Hyperparameter value summary for CNN

Hyperparameters	**Selected**
Optimization algorithm	Adam
Learning rate	0.01
Activation function	Sigmoid
Loss function	Binary cross-entropy
Epoch	10
Batch size	32
Dense layer	256

B. Experimental Results and Discussion

The manuscript employed five selected machine-learning algorithms to unleash their performance using the Kaggle SQL attack dataset. Table IV shows the performance metrics (accuracy, precision, and recall) of five different classification models namely; K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Decision Tree (DT), Naive Bayes (NB), Convolutional Neural Network (CNN).

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Table IV: Multiple classification models for detecting SQL injection attacks result

Metrics	KNN	SVM	DT	NB	CNN
Accuracy	82.6	77.02	91.51	80.27	96.55
Precision	71.35	99.88	87.61	65.42	98.92
Recall	88.61	38.028	89.78	99.17	91.71

As shown in Table IV, CNN achieved the highest accuracy (96.55%) in correctly classifying both malicious and legitimate SQL queries. SVM (77.02%) and NB (80.27%) had lower accuracy, indicating a higher rate of misclassified queries. DT (91.51%) and KNN (82.6%) performed better than SVM and KNN in terms of accuracy.

The SVM (99.88%) achieved exceptionally high precision, indicating that most of the queries it classified as malicious were truly malicious (low rate of false positives). However, SVM's lower accuracy (77.02%) suggests it might have missed a significant portion of malicious queries (high rate of false negatives). This is supported by its low recall value (38.028%). CNN (98.92%) achieved a good balance between precision and recall, indicating it correctly identified most malicious queries it classified (low false positives) while also catching a good portion of actual attacks (refer to recall for details).

NB (99.17%) achieved the highest recall, meaning it identified a very high proportion of actual malicious queries. However, its lower accuracy (80.27%) suggests it might have classified many legitimate queries as malicious (high false positive rate) which is further supported by its lower precision (65.42%). CNN (91.71%) achieved a good recall, indicating it captured a significant portion of malicious queries (low rate of false negatives).

For this task, CNN seems to be the most reliable model when taking into account all criteria (accuracy, precision, recall). It exhibited the best balance between detecting fraudulent queries and reducing false alarms, as seen by its greatest accuracy and good precision and recall.

Finally, the proposed model was evaluated using the evaluation metrics mentioned in the earlier section. The confusion metrics of the implemented machine learning algorithms are described in Fig 2, Fig 3, Fig 4, Fig 5, and Fig 6.

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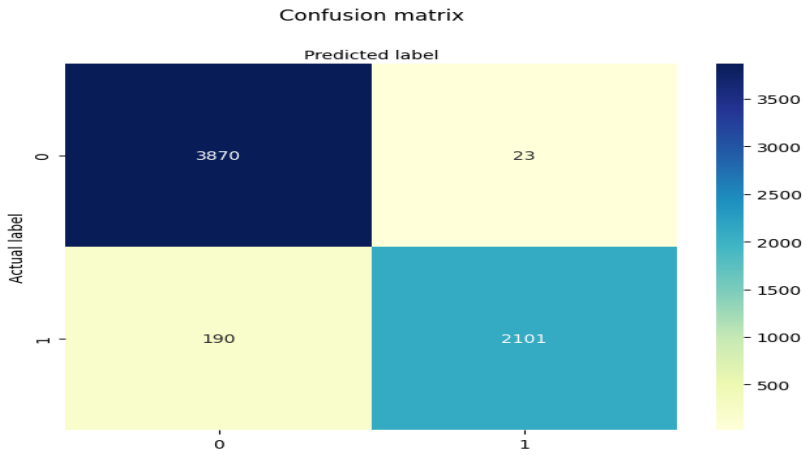

Fig. 2. Confusion metrics for KNN Algorithm

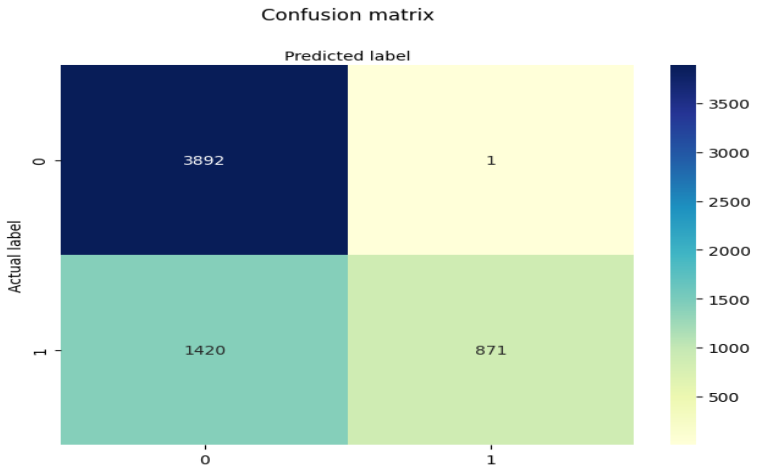

Fig. 3. Confusion metrics for SVM Algorithm

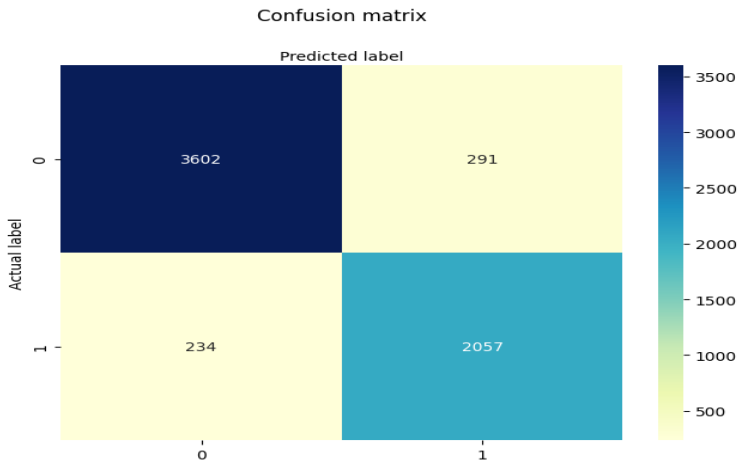

Fig. 4. Confusion metrics for DT Algorithm

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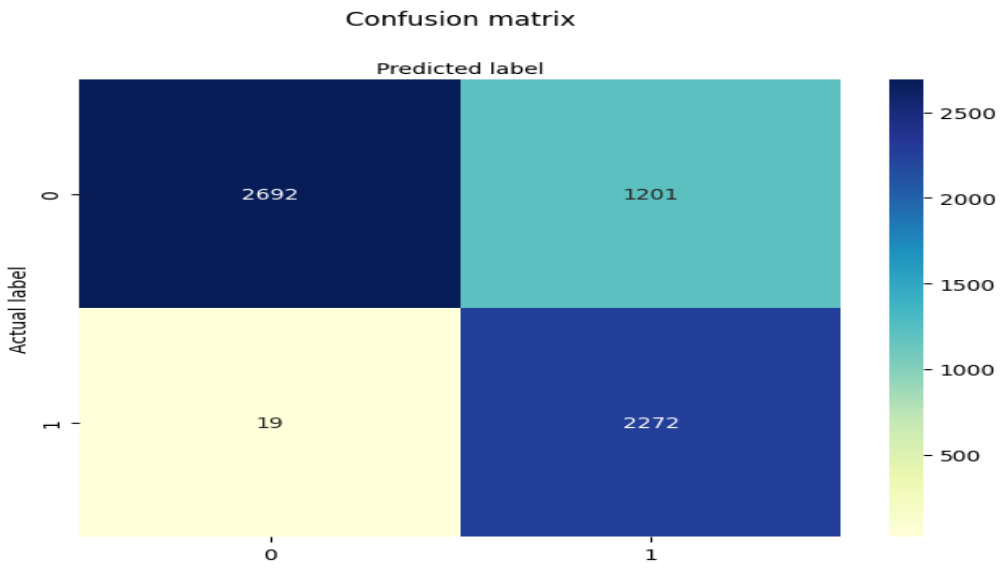

Fig. 5. Confusion metrics for NB Algorithm

Fig. 2 shows the training and testing accuracy of a CNN model. The x-axis represents the epoch, which is a full pass through the training data. The y-axis represents accuracy, a measurement of how well the model performs on a given SQL attack dataset.

The training accuracy (blue line) consistently increases as the number of epochs increases. This suggests that the model is learning the patterns in the training data and improving its ability to classify data points correctly. The testing accuracy (green line) increases similarly to the training accuracy but remains slightly lower. This is a good sign because it suggests the model is not overfitting the training data.

A smaller gap suggests better generalization, where the model can perform well on new data it has not been explicitly trained on. It suggests that the CNN model is effectively learning from the training data and generalizes reasonably well to unseen data. The model achieves high training accuracy and maintains good testing accuracy.

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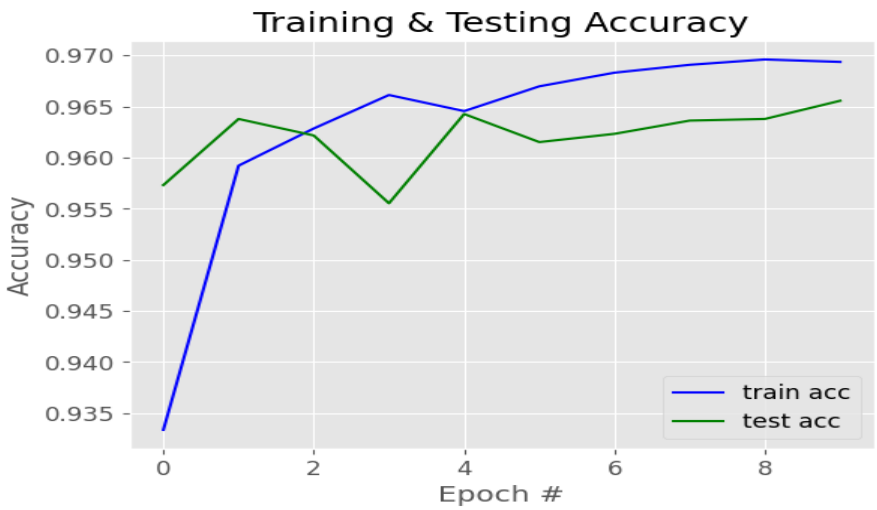

Fig. 2. Training and testing accuracy of the CNN Algorithm

The Fig. 3, depicts a line graph showing the training and testing loss of a Convolutional Neural Network (CNN) model. The x-axis represents the epoch, which signifies one complete pass through the training data. The y-axis represents loss, a metric that indicates how well the model's predictions align with the actual target values. Lower loss values signify better model performance during training and testing as shown in Fig. 3.

The training loss (red line) generally decreases across epochs, suggesting the model is progressively learning from the training data and minimizing its prediction errors. The testing loss (orange line) follows a similar trend as the training loss, but it fluctuates more and stays consistently higher than the training loss.

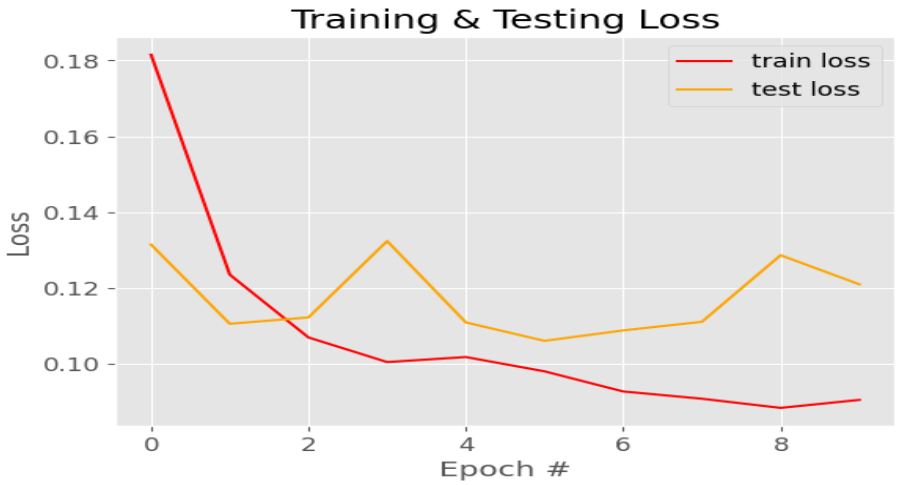

Fig. 3. Training and testing loss of CNN algorithm

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C. Result in comparison with the state-of-the-art solutions

In addition to comparing and evaluating the performance of the ML algorithms deployed in this work, the authors also compared such algorithms with the existing related works, as shown in Table V.

Table V: Result comparison from the related works

Author	Title	Methods used	Result %
[11]	Detection of SQL Injection Attacks: A Machine Learning Approach	Ensembled bagged tree	93.8%
[15, 16]	A deep learning approach for detection of SQL injection attacks using convolutional neural networks.	CNN	94.84%
[5]	A Machine Learning Methodology for Detecting SQL Injection Attacks.	CNN	92.7%
Ours	SQL Injection Attacks Detection: Performance Comparisons on Multiple Classification Models	CNN	96.55%

V. CONCLUSION AND RECOMMENDATION

In conclusion, the performance evaluation of multiple classification models for detecting SQL injection attacks provides valuable insights into the efficacy of different approaches in safeguarding web applications against malicious intrusions. Through comprehensive analysis and comparison of various machine learning algorithms, including K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Decision Tree (DT), Naive Bayes (NB), and Convolutional Neural Network (CNN) valuable experimental results are obtained. The findings of this evaluation provide valuable insights for organizations tasked with securing web applications against SQL injection attacks. By leveraging advanced machine learning techniques such as CNN and DT, institutions can enhance their ability to detect and mitigate security threats effectively.

Additionally, the performance evaluation highlights the importance of considering factors such as interpretability, computational resources, and the balance between different performance metrics when selecting an appropriate detection model.

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Among the evaluated models (KNN, SVM, DT, NB, CNN), CNN achieved the highest overall accuracy (96.55%) in correctly classifying both malicious and legitimate SQL queries. It also maintained an acceptable balance between precision (98.92%) and recall (91.71%), indicating it effectively identified malicious queries while minimizing false alarms.

By evaluating and comparing the performance of different classification models, the study can help enhance the security measures of web applications against SQL injection attacks. The comparative analysis of multiple classification models contributes to advancing research in the field of cybersecurity and machine learning. strengthening cybersecurity practices, empowering organizations to proactively defend against evolving threats, and fostering a more secure digital environment for web applications and databases.

Based on the analysis of various machine learning models for detecting SQL injection attacks, the author recommends the exploration of additional models beyond KNN, SVM, DT, NB, and CNN. Recurrent Neural Networks (RNNs) or Long Short-Term Memory (LSTM) networks might be suitable for capturing sequential patterns in SQL queries using ensemble methods like Random Forests or Gradient Boosting that combine multiple models and optimize hyperparameters (e.g., learning rate, number of filters in CNN) for each model to improve its performance.

Declaration of Conflicts of Interest

All authors declare that there are no conflicts of interest.

Data Availability

All the necessary data will be found from the corresponding author for a reasonable request.

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EXPERIMENTAL STUDY ON STEEL FIBRE-REINFORCED NATURAL AGGREGATE CONCRETE

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Abstract

The rising volume of pollution is a significant threat to achieving the United Nations' goal for a sustainable society. Various approaches have been used to tackle pollution, including recycling wastes into completely new products or utilizing them to improve other materials. In this respect, this article presents the results of an experimental study conducted on waste steel fiber sourced from waste tyres in concrete production. The fibers measuring 2, 4, and 6 cm were utilized using dosages of 0.5, 1, and 1.5% by mass of cement. The natural aggregate which is a bya -a product of the Precambrian deposits of the Bida trough was utilized as coarse aggregate. Iron moulds measuring 150 x 150 x 150mm were used for concrete production and were demoulded after 24 hours and cured. The optimum 28-day compressive strength of 27.19 N/mm^2 was recorded with a 4 cm fiber length and 0.5% fiber content. This represented a 36.36% gain in the 28-day compressive strength of the concrete when compared to the control.

Keywords: ***Compressive Strength, Natural aggregate, Reinforced Concrete, Steel Fibre.***

I. INTRODUCTION

The global increase in the number of waste tyres poses a great threat to the sustainability of the environment. Reports from countries in the European Union (EU), China, the United Kingdom (UK), and Nigeria reveal that the increase in the amount of available waste tyres is a major hurdle to achieving the goals of the United Nations for a green environment [1]. According to a study [2] more than a billion tyres are used for replacement every year globally with more than half of this figure being abandoned and waiting to be disposed of. Over a billion discarded tyres are produced worldwide. The accumulation of these tyres is a significant problem because tyre component materials are exceedingly complex and make natural degradation impossible. This necessitates the

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careful management of this massive quantity of trash. Waste tyres can be managed using various methods, including material recovery, energy recovery, retreating, export, and landfill disposal [2]. In Nigeria, the automobile sector generates about 10 million tyres each year. Of this Fig. 2 million wastes are generated. These wastes pose health challenges and are environmentally unfriendly [3]. This situation is aggravated by the absence of a scrap tyre waste collecting system as well as designated specially constructed landfill sites in the country for tyre wastes. This further highlights the need for a comprehensive national solid waste management policy that would incorporate this present scrap tyre menace. Recycling is still a nascent concept in Nigeria and as such has not received much attention from the government [4].

Aggregates occupy about 60-80% of the volume of normal-weight concrete; hence, their characteristics influence the properties of concrete. As opined by a study [5], the compressive strength of concrete depends on the aggregates' proportion used for production in addition to other factors. Aggregates used in concrete production are obtained either from natural sources or by crushing large-sized rocks. Coarse aggregate bonds with cement paste during the hydration process to form cement concrete, whereas fine aggregates are utilized to fill the gaps between the coarse aggregate particles. Some of the constituents of concrete have become very expensive because of high demand and are gradually becoming scarce. This reality has led engineers and researchers to seek the use of alternative materials. Several researches with different materials have been conducted with several recorded successes [6].

Natural Aggregates (NA) occur in the middle of the Niger basin of Nigeria in several Million metric tons. The Natural deposit of aggregates in Bida is generally located in and around the Bida area, Niger State, Nigeria. Located about 250km northeast of Bida inland from the federal capital city of Abuja. The natural deposit aggregates are extensively used in Bida for building constructions and domestic dwelling units.

The use of this NA sourced from Bida for concrete production has gained wide acceptance with the dwellers of the Bida basin the expenses in the production of crushed granite and its labor-intensive nature [7]. Against this background, investigating the potential application of waste tyre components in the production of NA concrete to encourage waste tyre recycling in Nigeria is timely and justifiable.

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II. CONSTITUENTS OF STEEL FIBRE-REINFORCED NATURAL AGGREGATE CONCRETE (SFRNAC)

Traditionally, concrete is made of cement, fine and coarse aggregates, and water. But, in the case of steel, fiber-reinforced natural aggregate concrete production, the constituents are cement, fine and coarse aggregate (NA), steel fiber reinforcement (extracted from waste tyres), and water. Fine and coarse aggregates are bonded with the cement paste during the hydration process to form cement concrete. The fine aggregate is utilized to fill the gap between the natural aggregate particles. Water is also an important component in concrete because it allows the other constituents to mix properly. Reinforced steel fiber adds strength and durability.

III. MATERIALS AND METHODS

A. Cement

Ordinary Portland Cement (OPC) Dangote brand was used throughout the production of the steel fiber-reinforced natural aggregate concrete. The cement was stored on a raised wooden platform at room temperature to prevent damage.

B. Fine Aggregate

A fine aggregate that is free from dirt and deleterious substances was obtained from a river bank in Kpakungu, Minna, Niger state, Nigeria. This fine aggregate was transported to the Civil Engineering departmental laboratory of the Federal University of Technology, Minna, Niger state, Nigeria. The fine aggregate conformed to the requirements for fine aggregate as specified in BS 882 (1992).

C. Coarse/Natural Aggregate

The Natural aggregate (NA) used in this research was sourced from Bida in Niger State, Nigeria. The particle size ranged between 5 to 20mm. It conformed to the specification for natural aggregate as specified in BS 882 (1992). The Natural aggregate (NA) is presented in Fig. 1.

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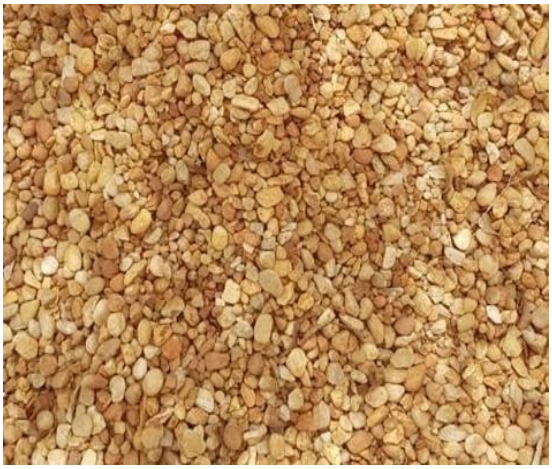

Fig. 1. Natural aggregate

D. Water

The water used was sourced from the borehole at the departmental laboratory of Civil Engineering, Federal University of Technology, Minna, Nigeria. It was ensured that the water was potable and clean. It satisfied the requirements stipulated in BS EN 1008 (2002).

E. Steel Fibre

The steel fiber used in this research work was obtained by the Pyrolysis process (burning of the waste tyre). The steel fiber had a diameter of 0.89 mm and was cut into lengths of 2, 4, and 6cm. Three steel fiber volume fractions were used: 0.5, 1.0, and 1.5% by weight of cement. The steel fiber is presented in Fig. 2.

Fig. 2. Steel fibre

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Fig. 3.: Fresh properties test in progress

F. Methods

Table I presents the breakdown of the proportions of the constituent materials used for concrete production.

Table I: Mix quantities of SFRNAC constituents

S/N	% Replacement Steel Fibres	Water (kg)	Cement (kg)	Sand (kg)	Gravels (kg)	Steel Fibres (g)
Control	0%	4.50	10.00	15.32	26.92	0.00
2cm	0.50%	4.50	9.95	15.32	26.92	50.00
	1%	4.50	9.90	15.32	26.92	100.0
	1.50%	4.50	9.85	15.32	26.92	150.0
4cm	0.50%	4.50	9.95	15.32	26.92	50.00
	1%	4.50	9.90	15.32	26.92	100.0

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	1.50%	4.50	9.85	15.32	26.92	150.0
6cm	0.50%	4.50	9.95	15.32	26.92	50.00
	1%	4.50	9.90	15.32	26.92	100.0
	1.50%	4.50	9.85	15.32	26.92	150.0

G. Compressive Strength Test of SFRNAC

This test provides us with an idea about all the characteristics of concrete. Compressive strength is the ability of a material or structure to carry the loads on its surface without any crack or deflection. A material under compression tends to reduce the size; while in tension, size elongates. The test was performed according to BS EN 12390-3 (2019). Concrete cubes measuring 150×150 × 150 mm were cast and utilized for this research. Each cube was placed on the universal testing machine and subjected to loading until failure occurred, the load at failure for each cube was noted and concrete compressive strengths were obtained using Equation (1).

Area of the specimen = 22,500 mm^2

$$\text{Compressive Strength} = \frac{Load}{Area} \ (N/mm^2) \quad (1)$$

IV. RESULTS AND DISCUSSION

A. Specific Gravity of Fine Aggregate BNA and Cement

The results of the specific gravity of fine aggregate and Natural aggregate (NA) are presented in Tables II and III. The specific gravities obtained for fine aggregate and NA were 2.65 and 2.60, respectively. These values fall within the 2.6 - 2.7 limits for Natural aggregates [8]. This implies that the fine aggregate and NA can be conveniently used for concrete production.

Table II: Specific gravity of fine aggregate

Trial Number	**1**	**2**	**3**
Wt. of empty jar (W1)	46.00	43.60	69.00
Wt. of jar + sample (W2)	84.22	85.72	96.21
Wt. of jar + sample + water (W3)	168.53	168.18	185.25
Wt. of jar + Water (W4)	144.80	142.00	168.20
Specific Gravity	2.64	2.64	2.68
Average Specific Gravity		2.65	

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Table III: Specific gravity of Natural Aggregate (NA)

Trial Number	**1**	**2**	**3**
Wt. of empty jar (W1)	46.00	43.60	69.00
Wt. of jar + sample (W2)	93.20	84.20	95.00
Wt. of jar + sample + water (W3)	173.80	167.10	184.10
Wt. of jar + Water (W4)	144.80	142.00	168.20
Specific Gravity	2.59	2.62	2.57
Average Specific Gravity		2.60	

B. Sieve Analysis of Fine Aggregate

The result of percentage passing sieves (BS 410) complied with the grading limit of fine aggregate in zone II, NIS 87:2004; therefore, the aggregate is suitable for concrete production. From the curve (Fig.4), the fine aggregate coefficient of uniformity (CU) is 7.42 which is greater than 6, hence the soil is considered as well graded. Also, the coefficient of concavity (CC) is 2.15, which is between 1 and 3; this means that the aggregate is well-graded.

C. Sieve Analysis of Natural Aggregate

Fig. 5 reveals the curve for the NA is steep, which is an indication that the aggregate contains particles of almost the same sizes and is deemed to be poorly graded aggregate. The coefficient of uniformity (CU) of this aggregate is 1.93 which i s less than 6. Hence the NA is considered poorly graded [9].

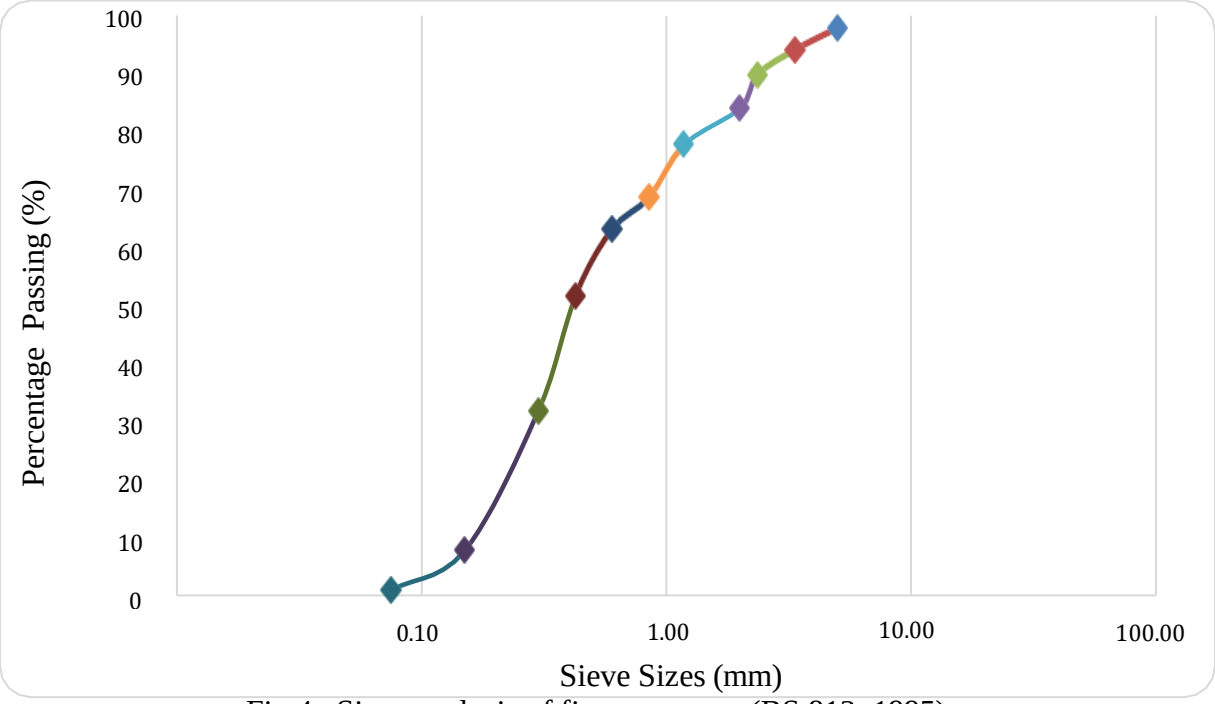

Fig.4. Sieve analysis of fine aggregate (BS 812: 1995)

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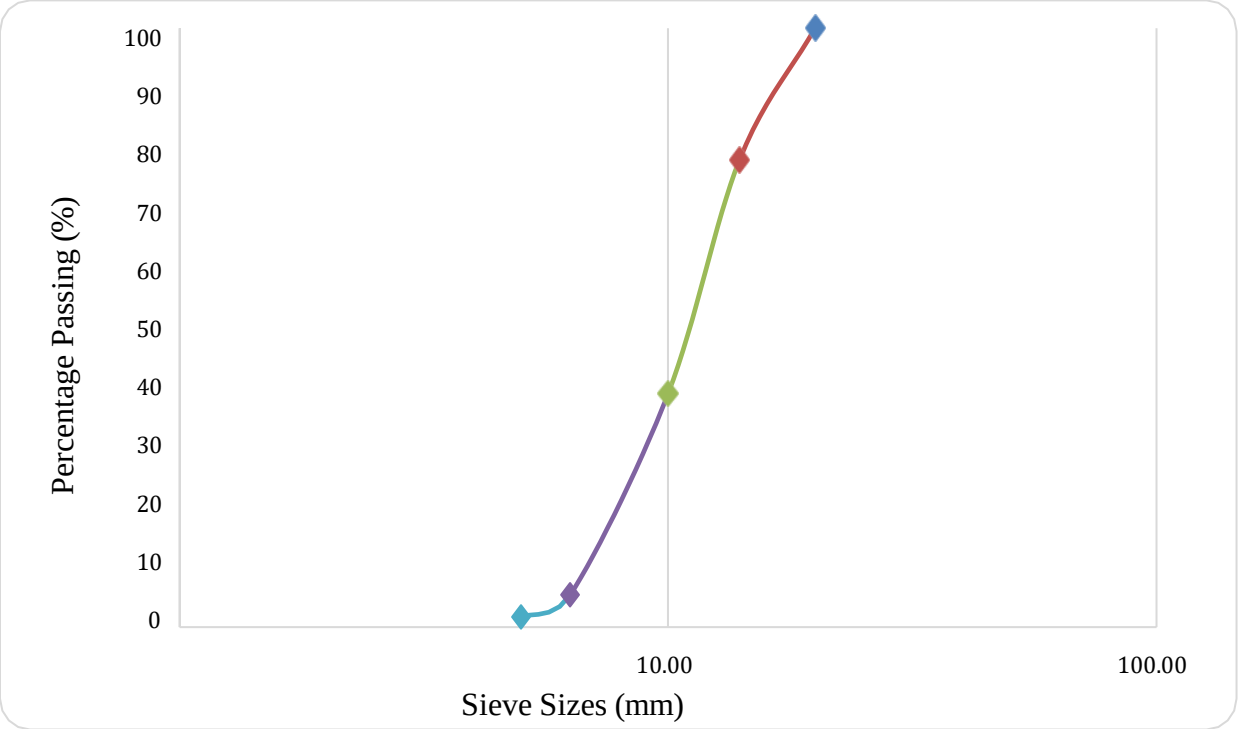

Fig. 5. Sieve analysis of NA (BS 812:1995)

D. Aggregate Impact Value (AIV) of NA

The average result of AIV of NA following BS 812 (1995) is 18.6%. BS-EN 13043 (2002) identified that the AIV of material for concrete pavement must not exceed 30% and must be less than 45% for concrete wearing surface. Therefore, this aggregate with an AIV of 18.6, which is less than 30%, is suitable for concrete-wearing surfaces.

E. Compressive Strength Test of SFRNAC

The 7 and 28-day compressive strength of the SFRNAC were obtained in accordance with BS EN 12390 – 3 (2019) and are presented in Fig. 6 and 7, respectively. The 7-day results show that the mix containing a 4cm length of steel fiber at 1% volume returned the highest compressive strength value of 19.20N/mm^2 while the control mix returned a compressive strength value of 16.39 N/mm^2. Furthermore, the 28 days compressive strength of SFRNAC shows that mix with 4cm length of steel fiber at 0.5% fiber content returned the highest compressive strength value of 27.19N/mm^2 with the percentage increase of 27.8% when compared with control which had a 28 days compressive strength of 19.64N/mm^2.

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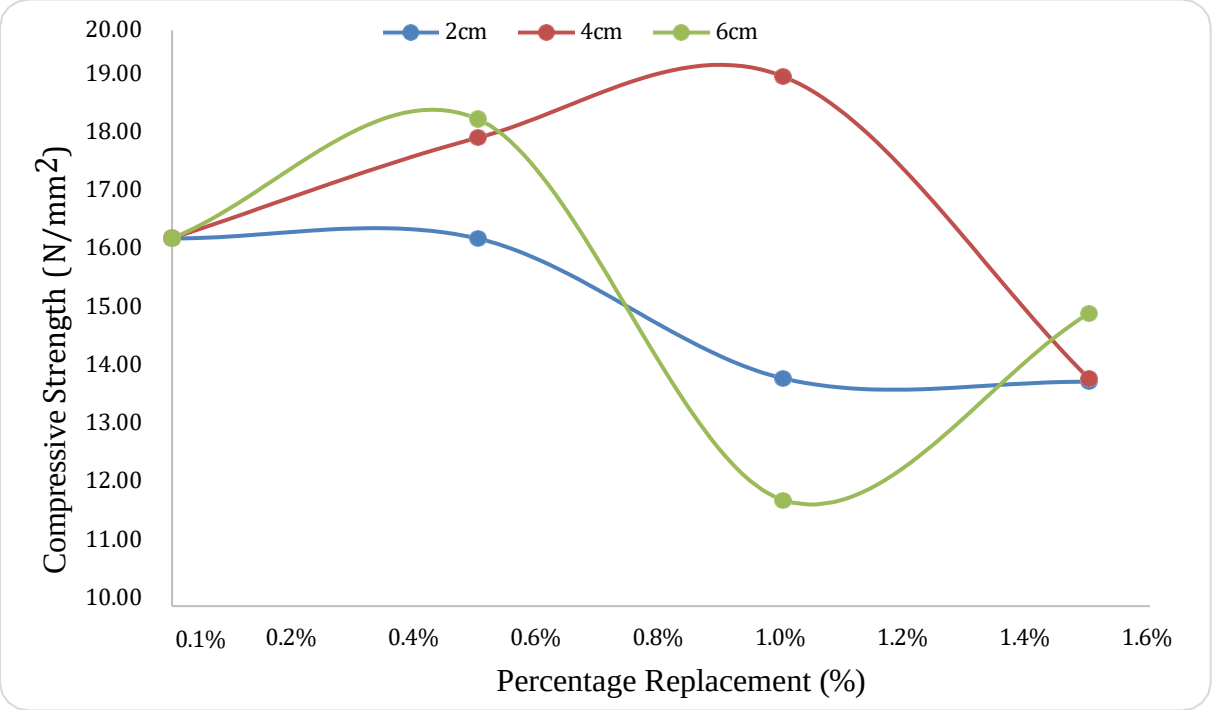

Fig. 6. 7 days compressive strength of SFRNAC

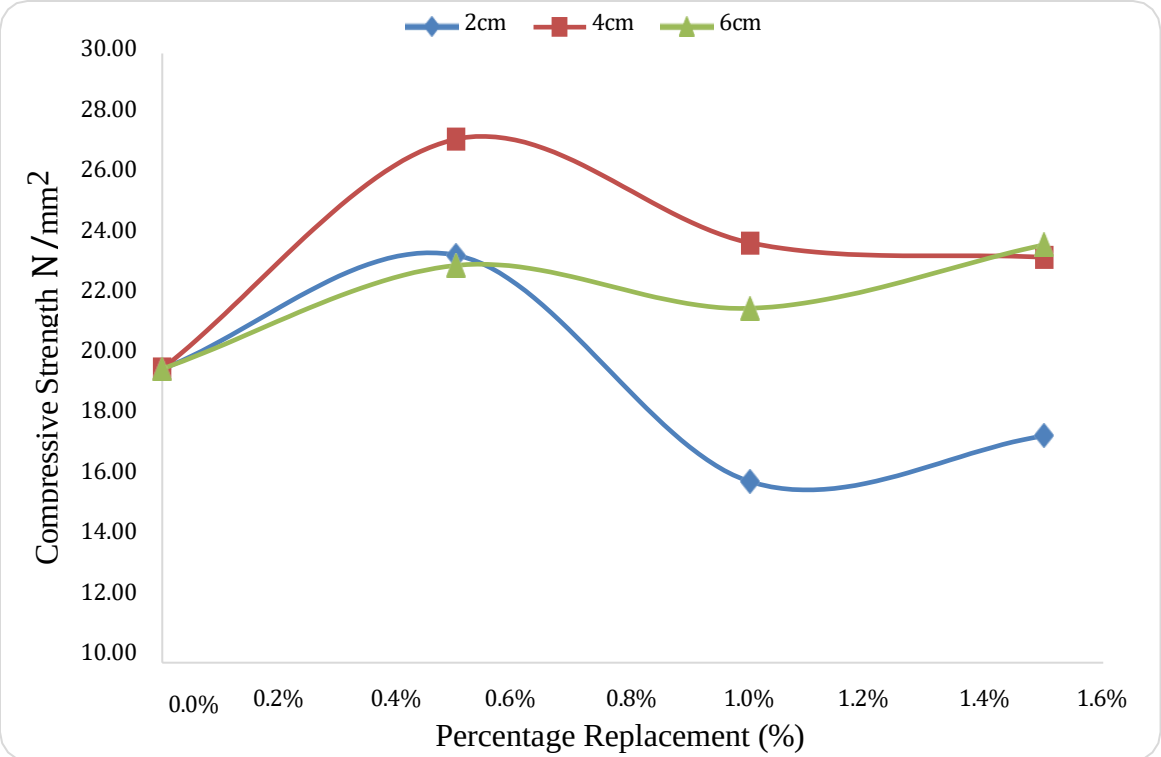

Fig. 7. 28 days compressive strength of SFRNAC

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V. CONCLUSION

Based on the results of this research, the following conclusion is drawn. The physical properties of constituent materials show that they have satisfactory properties and can be used in concrete production. The average compressive strengths of concrete with 0% volume of steel fibers (control mix) of curing ages of 7 and 28 days were determined to be 16.39 N/mm^2 and 19.64 N/mm^{2,} respectively. The highest compressive strengths at curing ages of 7 and 28 days were determined to be 19.20 N/mm^2 at 4cm length of steel fibers and 1% volume replacement with cement, and 27.19 N/mm^2 at 4cm length of steel fibers and 0.5% volume replacement with cement, respectively. From the experimental study, the use of steel fibers as reinforcement improved the compressive strength of concrete by 36.36%.

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Conflict of Interest: Authors have claimed no conflict of Interest

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ASSESSMENT OF TRAFFIC CONGESTION AND ITS IMPACT ON ROAD CAPACITY IN URBAN AREAS UNDER MIXED TRAFFIC CONDITIONS USING MULTIPLE REGRESSION ANALYSIS - A CASE STUDY OFADDIS ABABA CITY

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Abstract

Traffic congestion is a complex phenomenon that is connected to several vehicle movements on the road. The major reasons behind this problem are the various continuous activities in the urban areas such as education, employment, recreation, business, political, social, and cultural. In addition to these activities, floating and migration, increase congestion on city roads. This will affect the traffic stream characteristics and reduce the road capacity and level of service. The present study aims to evaluate and analyze traffic congestion and its effect on road capacity and level of service at Mebrathail's mid-block location in Addis Ababa city. To achieve the objective, the Mebrathail mid-block was divided into four segments appropriately, and the traffic volume and speed studies were conducted at each segment for 10 hours a day at 15-minute consecutive intervals. The necessary traffic data including road geometry at each segment was recorded. The congestion levels at each segment were then measured by estimating the reduced speed between each segment. The volume-to-capacity ratio (v/c ratio) was then estimated and found to be exceeding 1 in most of the hours of the day, resulting in a poor level of service F. Various Multiple Regression Models were developed correlating the reduced speed with traffic volume, composition, and road geometry. The results from the analysis indicate that traffic congestion on urban roads has an impact on urban characteristics.

Keywords: ***Road Capacity, Level of Service, Reduction in Speed, Traffic congestion, V/C ratio***

I. INTRODUCTION

Traffic congestion is a critical problem in urban areas and probably become a challenge for designers and administrators to control vehicles on the roads. Road congestion cannot be simply solved by improving infrastructure facilities but also needs a technological system for

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transportation management. The traffic control system has direct influence on traffic problems and traffic jams that occur due to various incidents, maintenance works, and other activities on roads. The transportation system should satisfy the perceived social and economic needs of users. The transportation system evolves itself to accommodate users' demand change and problems occur if it becomes inadequate [1]. In addition, improper transportation systems are one of the main causes of traffic congestion in many countries. Traffic has grown proportionate to urbanization in almost all countries in recent years [2].

Traffic congestion is currently high in Addis Ababa city due to the increase in the number of vehicles and pedestrian users concerning economic and social development. Traffic congestion is also influenced by long queues and excessive delays during peak hours in the city and has become a major problem in different sections of the road especially at road mid-blocks. The increasing traffic volume creates a reduction in the speed of vehicles and affects the road capacity resulting poor level of service. This needs the attention of administrators and transport planners to evaluate and mitigate congestion levels by proper management techniques, geometric design, road markings, street lights, traffic signals, construction of flyovers, by-pass roads, outer ring roads, etc. Many cities in various regional states of Ethiopia have developed different ways to implement various measures for reducing the degree of congestion [7]. The traffic volume has been increasing rapidly from time to time in Addis Ababa city. And, as a result, transportation-related problems are getting worse day to day. The increase in traffic volume results in growing congestion levels with associated environmental pollution and a high risk of accidents and wastage of time during travel. This needs alternative intelligent transport management systems and the implementation of new technologies from the transportation planners in the city transportation to smoothen the traffic flow in Addis Ababa city.

II. LITERATURE REVIEW

Traffic congestion has been one of the major issues that most metropolises are facing. Due to this, many measures have been taken to mitigate congestion. It is believed that the identification of congestion characteristics is the first step for such efforts since it is an essential guide for selecting appropriate measures [3]. Traffic congestion can have significant adverse economic, social, and environmental impacts within densely populated urban areas. One of the major factors contributing to traffic congestion is traffic incidents. Traffic incident refers to any event that degrades safety

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and slows traffic, including disabled vehicles, accidents, debris on the roadway, and hazardous material spills; it temporarily reduces the roadway capacity [4]. Different researchers and reports identified many interrelated factors that cause traffic congestion in developed and developing countries where the road network and road users' behavior are different [1]. For instance, many reports show that road network was the main cause of traffic congestion in various developing countries. A research study [8] identified the major traffic congestion causes in Lagos Metropolitan. Accordingly, another study [5] results showed that the cause and their percentage share contribution to traffic congestion in the United States of America are: bottleneck (40%), traffic incidents (25%), work zone (10%), bad weather (15%), poor signal timing (5%), and special events (5%). It indicates that there is no consistent congestion measure used by transport engineers and planners to monitor system congestion [5]. In addition, a good set of congestion measures has the potential to improve not only the quality and consistency of public transportation policy but also public understanding about the congestion phenomenon, leading to political support for policy improvements and more rational behavior by individual travelers.

Accordingly, most literature agrees that the travel time approach for quantifying congestion gives a better opportunity for the public and policymakers to understand the level of congestion. According to a study [6], and other researchers, LOS is the best empirical indicator of congestion in transport systems. Moreover, the road user's perception as a measure for "acceptable" or "Unacceptable" congestion can be taken as an indicator or a demarcation for classifying a road section or an intersection as congested or not.

The current study identified a research gap in evaluating traffic congestion and its effect on road capacity and level of service by measuring the percentage of speed reduction at each segment in the selected mid-block in Addis Ababa. It, therefore, aims to assess the traffic congestion at the selected location and to observe the reduction of traffic speed at each segment in the selected mid-block in Addis Ababa city under variable roadway and traffic conditions.

III. MATERIALS AND METHODS

The research methodology selected the required materials and methods for selecting the study area, location, study design, methods of data collection, the variables for investigation, and the analysis.

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A. Study Area and Study Location

As depicted in Fig.1, Addis Ababa city is considered the study area in the present study, which is the capital city of Ethiopia and is located at a Latitude of 8°58'N and a Longitude of 38°47'E. The city is located at an altitude of 2324 m above mean sea level covering a total area of 527 sq. km. The city has a population of 3,384,569 as per the 2007 population census with a yearly growth rate of 3.8%. As depicted in Fig.2, the Mebrathail mid-block in Addis Ababa city was selected as a study location to evaluate the traffic congestion and its effect on road capacity and level of service.

Fig. 1. Addis Ababa study area aerial view (Courtesy: Google-earth)

Fig. 2. Mabrathail's zoomed mid-block

B. Study Design

The study was organized in two stages. The first stage involves the collection of traffic and roadway data by proper traffic surveys in the selected location of the study area. This includes the division of the selected location into four segments appropriately and collecting traffic volume and speed data with field studies at a time at each segment, for 10 hours at every 15-minute consecutive intervals. The measurement of road geometry at each segment was also part of the study.

The second stage involves the evaluation of traffic congestion levels and their impact on road capacity and level of service. This includes the estimation of road capacity at each segment by plotting respective capacity curves and the estimation of the level of service by measuring the degree of freedom (v/c ratio). The study design also includes the modeling of traffic congestion by considering the responsible factors. The study has considered that the congestion on the road is a

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function of traffic volume, its corresponding speed, and the existing road width. The other factors such as environmental and roadside effects are not considered because their influence in the selected location is found to be negligible.

C. Traffic Data Collection

The traffic data was collected by conducting traffic volume and speed studies at a time at Mebrathaile mid-block in Addis Ababa. Traffic volume data was collected by manual method for 10 hours at every 15-minute consecutive intervals and by counting the number of vehicles with a composition that crosses the reference line at each segment in the study location. Similarly, traffic speed data was also collected by manual method for 10 hours at every 15 minutes consecutive intervals. To collect traffic speed data, two reference lines were drawn at a distance of 30 meters at the study location. Then, the travel time taken for each vehicle to cross the two reference lines was measured. After knowing the distance and travel time, the traffic speed was calculated for different categories of vehicles. Later, the average speed was evaluated. Road geometry at each segment in the study location was also measured and recorded. The traffic data was collected on weekdays during the summer season. Table I and Fig. 3 indicate the traffic volume and speed data collected at the study location.

IV. ANALYSIS AND DISCUSSION

A. Evaluation of Reduced Speed

Traffic Speed on a road is the symbol of driving comfort that indicates the level of service of the road. The present research aims to observe the variation of traffic speed for a particular traffic volume and composition under variable traffic and roadway conditions. The reduction of traffic speed (km/hr) at each segment in the study location was then calculated by taking the difference of traffic speed at segment 1 with the traffic speeds at other consecutive segments. The congestion levels measured on the selected mid-block were the result of the traffic speed variation (speed reduction) along each segment, which was considered one of the major parameters to cause traffic congestion.

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Table I: Mebrathail Mid-Block – Traffic Volume and Speed Data

Time	Segment 1		Segment 2			Segment 3			Segment 4		
	Volume, Veh/hr	Speed, Km/hr	Volume, Veh/hr	Speed, Km/hr	Reduced Speed	Volume, Veh/hr	Speed, Km/hr	Reduced Speed	Volume, Veh/hr	Speed, Km/hr	Reduced Speed
8-8.15	1976	25.72	2040	18.12	7.6	1704	25.69	0.03	2168	18.62	7.1
8.15-8.30	1804	28.94	1116	20.25	8.69	2196	28.5	0.44	2368	21.3	7.64
8.30-8.45	2256	25.56	2096	18.03	7.53	2272	25.31	0.25	2416	18.46	7.1
8.45-9	1684	26.09	1832	21.08	5.01	1972	15.36	10.73	1928	18.68	7.41
9-9.15	2212	29.23	2008	23.4	5.83	2220	24.99	4.24	2100	27.13	2.1
9.15-9.30	2396	27.4	1636	17.86	9.54	1752	21.42	5.98	1976	26.3	1.1
9.30-9.45	2224	26.27	1748	17.09	9.18	1812	21.91	4.36	1960	25.74	0.53
9.45-10	1708	28.91	1496	20.39	8.52	1508	28	0.91	2000	20.85	8.06
10-10.15	2024	29.95	1652	20.34	9.61	1844	28.3	1.65	2028	20.61	9.34
10.15-10.30	1920	34.88	1932	21.15	13.73	1924	21.78	13.1	1980	33\.87	1.01
10.30-10.45	1944	27.9	1896	21.38	6.52	1896	19.68	8.22	1923	22.2	5.7
10.45-11	1888	34.31	1876	30.46	3.85	1876	22.12	12.19	1964	33.12	1.19
11-11.15	1748	32.55	1992	30.73	1.82	1992	21.93	10.62	2212	24.08	8.47
11.15-11.30	1864	28.34	1852	19.39	8.95	1840	25.24	3.1	2008	27.67	0.67
11.30-11.45	2108	26.65	1960	25.84	0.81	2100	26.21	0.44	1948	26.27	0.38
11.45-12	1844	28.06	1772	21.59	6.47	1776	21.71	6.35	2092	27.87	0.19
1-1.15	1800	28.91	1648	21.46	7.45	1760	24.69	4.22	1932	26.33	2.58
1.15-1.30	1860	39.15	1744	31.62	7.53	1820	38.34	0.81	1828	31.23	7.92
1.30-1.45	1840	37.77	1800	28.36	8.41	1840	32.96	4.81	1808	24.12	13.65
1.45-2	1716	30.36	1736	22.36	8	1776	28.06	2.3	1748	28.14	2.22
2-2.15	1672	26.33	1544	30.72	-4.39	1544	22.86	3.47	1648	31.17	-4.84
2.15-2.30	1636	26.24	1492	30.61	-4.37	1492	22.55	3.69	1552	28.35	-2.11
2.30-2.45	1576	28.94	1592	27.29	1.65	1592	20.1	8.84	1704	25.87	3.07
2.45-3	1592	31.37	1676	29.48	1.89	1704	21.51	9.86	1664	27.48	3.89
3-3.15	1680	29.91	1764	11	18.91	1764	29.4	0.51	1792	11	18.91
3.15-3.30	1620	32.38	2092	30.58	1.8	2032	22.06	10.32	1852	26.58	5.8
3.30-3.45	1636	26.42	1960	13.38	13.04	1960	25.81	0.61	1888	20.14	6.28
3.45-4	1756	34.93	2232	30.56	4.37	1912	22.85	12.08	1912	25.28	9.65
4-4.15	1744	33.58	1928	32.31	1.27	1928	23.74	9.84	1940	25.85	7.73
4.15-4.30	1752	29.19	2364	27.76	1.43	1920	21.95	7.24	1916	25.05	4.14
4.30-4.45	1896	28	2336	26.5	1.5	2044	21.23	6.77	1920	21.13	6.87
4.45-5	1892	29.03	2176	24.88	4.15	2176	20.77	8.26	2304	22.88	6.15
5-5.15	1928	27.49	2380	17.34	10.15	1964	21.71	5.78	2236	26.26	1.23
5.15-5.30	2212	32.41	2168	26.67	5.74	2168	30.53	1.88	2372	26.67	5.74
5.30-5.45	2016	27.73	2216	20.69	7.04	2320	26.74	0.99	2384	20.14	7.59
5.45-6	2012	28.27	2320	27.25	1.02	2346	24.65	3.62	2352	18.09	10.18
6-6.15	2144	31.77	2272	30.1	1.67	2400	22.1	9.67	2288	28.2	3.57
6.15-6.30	2288	29.95	2252	29.89	0.06	2252	26.9	3.05	2264	19.44	10.51
6.30-6.45	2188	28.13	2568	18.45	9.68	2384	27.61	0.52	2340	20.05	8.08
6.45-7	2164	23.05	2520	16.15	6.9	2309	16.67	6.38	2440	16.76	6.29

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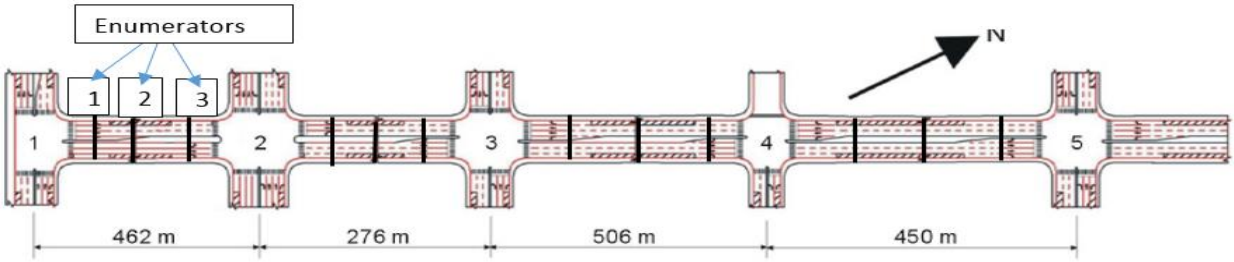

Fig. 3. Example of segment division at the selected location during data collection

B. Determination of Road Capacity and Level of Service

Road capacity is the function of traffic volume and speed. Thus, the variation of stream characteristics on the road will affect the road capacity and its level of service. To measure the effect of traffic volume and speed, capacity curves were drawn by plotting the graphs between traffic volume (vehicle/hour) on the x-axis and corresponding traffic speed (km/hour) on the y-axis at each segment of the selected mid-block. The road capacity at each segment of the mid-block was then evaluated from the plotted graphs. The degree of freedom (v/c ratio) for each 15-minute consecutive interval was then determined for each segment of the selected mid-block, as shown in Table II. Later, by considering the Highway Capacity Manual (2000) guidelines for degree of freedom, the level of service of the road was evaluated at each segment for every 15-minute consecutive interval. The results obtained from the evaluations indicate that the level of service was very poor with the level of service F at each segment during peak hours for the majority of the peak period. It was also observed to be average to poor levels of service D and E during the majority of non-peak hours. This indicates that the impact of traffic congestion is high during peak hours in the study area and is normal during half-peak hours.

Table II: Mabrathail mid-block – road capacity and level of service

	Segment 1				Segment 2				Segment 3				Segment 4			
Time	**volume**	**capacity**	**v/c**	**Los**	**Volume**	**capacity**	**v/c**	**Los**	**volume**	**Capacity**	**v/c**	**Los**	**volume**	**capacity**	**v/c**	**Los**
8-8.15	**1976**	**2410**	**0.8**	**E**	**1240**	**2565**	**0.4**	**C**	**1704**	**1815**	**0.9**	**E**	**2168**	**1790**	**1**	**F**
8.15-8.30	**1804**	**2410**	**0.7**	**D**	**1116**	**2565**	**o.4**	**C**	**2196**	**1815**	**1**	**F**	**2364**	**1790**	**1**	**F**
8.30-8.45	**2256**	**2410**	**0.9**	**E**	**2096**	**2565**	**0.8**	**E**	**2272**	**1815**	**1**	**F**	**2410**	**1790**	**1**	**F**
8.45-9.00	**1684**	**2410**	**0.7**	**D**	**1832**	**2565**	**0.7**	**D**	**1972**	**1815**	**1**	**F**	**1928**	**1790**	**1**	**F**
9-9.15	**2212**	**2410**	**0.9**	**E**	**2008**	**2565**	**0.7**	**D**	**2220**	**1815**	**1**	**F**	**2100**	**1790**	**1**	**F**
9.15-9.30	**2396**	**2410**	**0.9**	**E**	**1636**	**2565**	**0.6**	**D**	**1752**	**1815**	**0.9**	**E**	**1976**	**1790**	**1**	**F**
9.30-9.45	**2224**	**2410**	**0.9**	**E**	**1748**	**2565**	**0.6**	**D**	**1812**	**1815**	**1**	**F**	**1900**	**1790**	**1**	**F**
9.45-10	**1708**	**2410**	**0.7**	**D**	**1496**	**2565**	**0.5**	**C**	**1508**	**1815**	**0.8**	**E**	**2000**	**1790**	**1**	**F**
10-10.15	**2024**	**2410**	**0.8**	**E**	**1602**	**2565**	**0.6**	**D**	**1844**	**1815**	**1**	**F**	**2028**	**1790**	**1**	**F**
10.15-10.30	**1920**	**2410**	**0.8**	**E**	**1932**	**2565**	**0.7**	**D**	**1924**	**1815**	**1**	**F**	**1980**	**1790**	**1**	**F**

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10.30-10.45	1944	2410	0.8	E	1896	2565	0.7	D	1996	1815	1	F	1976	1790	1	F
10.45-11	1888	2410	0.7	D	1874	2565	0.7	D	1870	1815	1	F	1964	1790	1	F
11-11.15	1748	2410	0.7	D	1912	2565	0.7	D	1992	1815	1	F	2212	1790	1	F
11.15-11.30	1814	2410	0.7	D	1822	2565	0.7	D	1840	1815	1	F	2008	1790	1	F
11.30-11.45	2108	2410	0.8	E	1960	2565	0.7	D	2100	1815	0.9	E	1948	1790	1	F
11.45-12	1844	2410	0.7	D	1772	2565	0.6	D	1796	1815	1	F	2092	1790	1	F
12-12.15	1800	2410	0.7	D	1648	2565	0.6	D	1960	1815	1	F	1932	1790	1	F
12.15-12.30	1860	2410	0.7	D	1744	2565	0.7	D	1820	1815	1	F	1828	1790	1	F
12.30-12.45	1840	2410	0.7	D	1800	2565	0.7	D	1840	1815	1	F	1808	1790	1	F
12.45-1	1716	2410	0.7	D	1736	2565	0.6	D	1776	1815	1	F	1745	1790	0.9	E
1-1.15	1672	2410	0.6	C	1544	2565	0.5	C	1544	1815	0.9	E	1648	1790	0.9	E
1.15-1.30	1630	2410	0.6	C	1492	2565	0.6	D	1492	1815	0.8	E	1562	1790	0.8	E
1.30-1.45	1576	2410	0.6	C	1582	2565	0.6	D	1582	1815	0.8	E	1904	1790	1	F
1.45-2	1542	2410	0.6	C	1676	2565	0.6	D	1904	1815	0.8	E	1896	1790	1	F
2-2.15	1680	2410	0.7	D	1714	2565	0.6	D	1764	1815	1	F	1912	1790	1	F
2.15-2.30	1620	2410	0.6	C	2012	2565	0.7	D	2012	1815	0.9	E	1940	1790	1	F
2.30-2.45	1660	2410	0.6	C	1960	2565	0.7	D	1905	1815	1	F	1990	1790	1	F
2.45-3	1756	2410	0.7	D	2212	2565	0.8	E	1912	1815	1	F	1925	1790	1	F
3-3.15	1744	2410	0.7	D	1928	2565	0.7	D	1928	1815	1	F	2304	1790	1	F
3.15-3.30	1709	2410	0.7	D	2313	2565	0.9	E	1920	1815	1	F	2230	1790	1	F
3.30-3.45	1806	2410	0.7	D	2416	2565	0.9	E	2044	1815	1	F	2352	1790	1	F
3.45-4	1890	2410	0.7	D	2176	2565	0.8	E	2176	1815	1	F	2288	1790	1	F
4-4.15	1926	2410	0.8	E	2280	2565	0.9	E	1963	1815	1	F	2364	1790	1	F
4.15-4.30	2313	2410	0.9	E	2360	2565	0.9	E	2168	1815	1	F	2260	1790	1	F
4.30-4.45	2016	2410	0.8	E	2218	2565	0.8	E	2320	1815	1	F	2380	1790	1	F
4.45-5	2012	2410	0.8	E	2230	2565	0.8	E	2006	1815	1	F	2215	1790	1	F
5-5.15	2144	2410	0.8	E	2315	2565	0.9	E	2252	1815	1	F	2136	1790	1	F
5.15-5.30	2089	2410	0.8	E	2342	2565	0.9	E	2182	1815	1	F	2340	1790	1	F
5.30-5.45	2165	2410	0.9	E	2416	2565	0.9	E	2265	1815	1	F	2280	1790	1	F
5.45-6	2124	2410	0.8	E	2268	2565	0.8	E	2259	1815	1	F	2278	1790	1	F
6-6.15	2235	2410	0.9	E	2170	2565	0.8	E	2176	1815	1	F	2310	1790	1	F
6.15-6.30	2436	2410	1	F	2269	2565	0.8	E	2180	1815	1	F	2308	1790	1	F
6.30-6.45	2098	2410	0.8	E	2315	2565	0.9	E	2207	1815	1	F	2293	1790	1	F
6.45-7	2385	2410	0.9	E	2287	2565	0.9	E	2182	1815	1	F	2284	1790	1	F

C. Analysis of the level of Congestion

According to the Tomtom's Traffic Index, Congestion levels can be divided into four forms:

i. No congestion: <15% reduction in traffic speed
ii. Low congestion : 15%-25% of reduction of speed
iii. Medium congestion : 25%-50% of reduction of speed
iv. High congestion : >50% of reduction in speed

In the present study, traffic indices in accordance with Tomtom's were calculated to assess and analyze the traffic congestion at the selected mid-block location.

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D. Multiple Regression Models

Different Multiple Regression Models were developed by considering the percentage of reduced speed as the dependent variable and the factors associated with traffic congestion such as traffic volume with composition and road geometry as independent variables by using SPSS Software. Multiple regression models were developed for Medium Congestion level and Heavy Congestion level at each segment of the selected Mid-block and are as given below.

1) For Reduction in Speed between Segment 1 to Segment 2

a) Medium Congestion Situation

Model 1:

$$\%\ of\ Reduction\ in\ Speed\ (\%\ of\ RS) = 40.025 + 0.006\ (Volume) - 2.227\ (Road\ width) \quad (1)$$

R Square = 0.807, F Value = 7.919, Significance Value = .003

b) High Congestion Situation

Model 2:

$$\%\ of\ Reduction\ in\ Speed\ (\%\ of\ RS) = 78.086 + 0.003\ (Volume) - 4.055\ (Road\ width) \quad (2)$$

R Square= 0.782, F Value = 3.859, Significance Value =.007

2) For Reduction in Speed between Segment 1 to Segment 3

a) Medium Congestion Situation

Model 3:

$$\%\ of\ Reduction\ in\ Speed\ (\%\ of\ RS) = 52.959 + 0.004\ (Volume) - 3.486\ (Road\ width) \quad (3)$$

R Square = 0.786, F Value = 3.654, Significance value = 0.001

b) High Congestion Situation

Model 4:

$$\%\ of\ Reduction\ in\ Speed\ (\%\ of\ RS) = 76.105 + 0.003\ (Volume) - 4.989\ (Road\ width) \quad (4)$$

R Square = 0.985, F Value = 66.086, Significance Value = 0.005

3) For Reduction in Speed between Segment 1 to Segment 4

a) Medium Congestion Situation

Model 5:

$$\%\ of\ Reduction\ in\ Speed\ (\%\ of\ RS) = 32.689 + 0.008\ (Volume) - 2.430\ (Road\ width) \quad (5)$$

R Square = 0.821, F Value = 9.143, Significance Value = 0.012

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b) High Congestion Situation

Model 6:

$$\%\ of\ Reduction\ in\ Speed\ (\%\ of\ RS) = 55.649 + 0.003\ (Volume) - 1.510\ (Road\ width) \quad (6)$$

R Square = 0.965, F Value = 34.961, Significance Value = 0.002

E. Development of Graphs for Medium and High Congestion Situations

Different graphs were plotted from the above models for both medium -and high-congestion situations. The graphs were plotted by considering Traffic Volume on the x-axis and the percentage of Reduction in Speed on the y-axis. The outcomes of the above models indicate that for a given traffic situation on the road, a relationship exists between Traffic Volume, Road width, and percentage of Reduction in Speed. The results indicate that for a given traffic volume, the % of speed reduction decreases as the road width increases. Similarly, for a given road width, the percentage of speed reduction increases as the traffic volume increases. Fig. 4 to 9 and Table III show the variation of deceleration for different traffic situations and road widths.

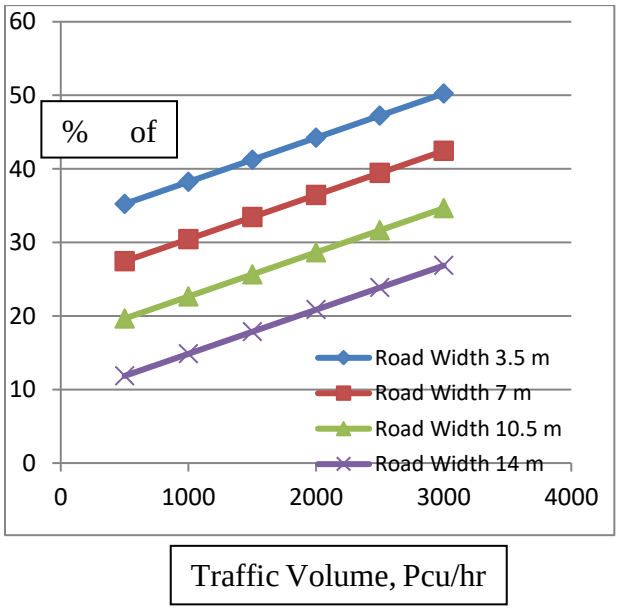

Fig. 4. Segment 1 to 2 – Medium Congestion

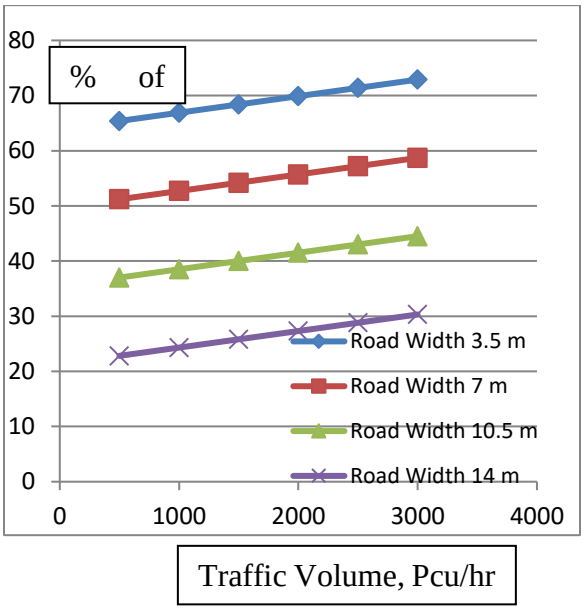

Fig. 5. Segment 1 to 2 – High Congestion

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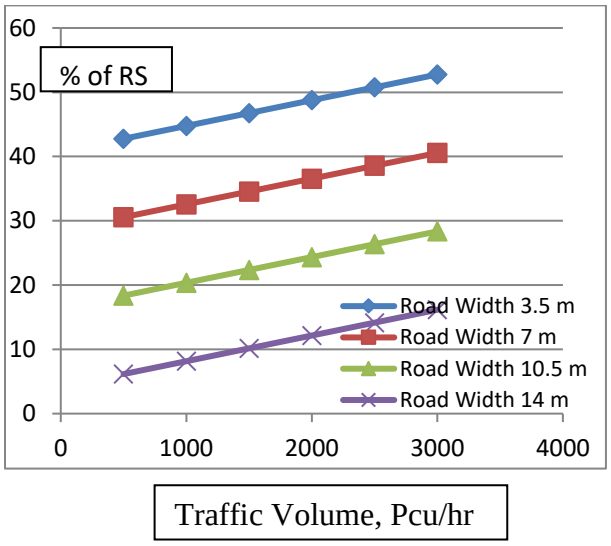

Fig. 6. Segment 1 to 3 – Medium Congestion

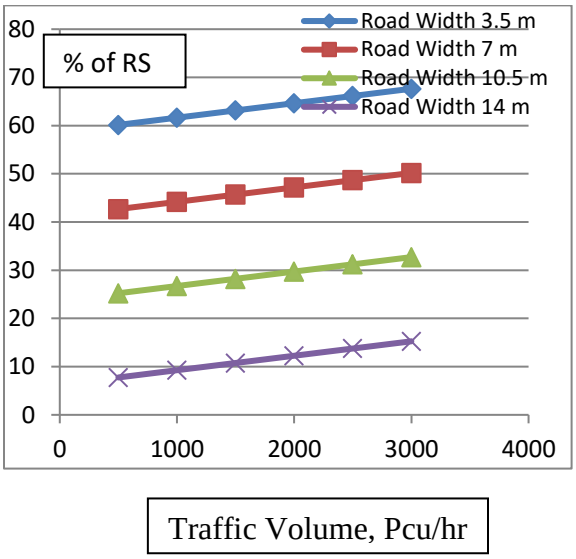

Fig. 7. Segment 1 to 3 – High Congestion

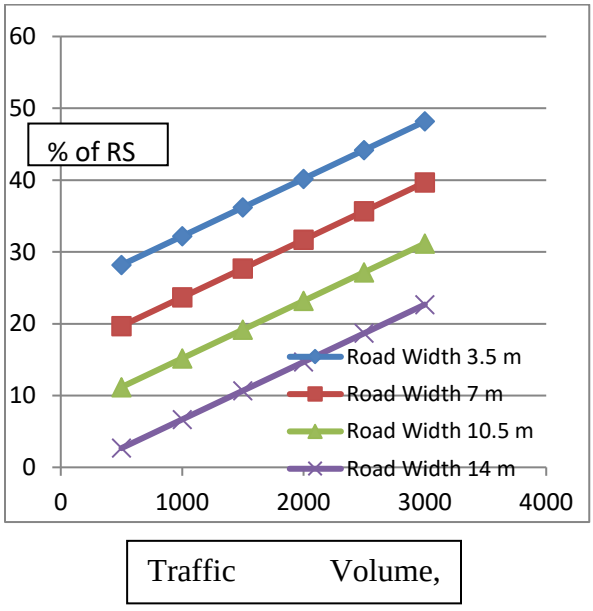

Fig. 8. Segment 1 to 4 – Medium Congestion

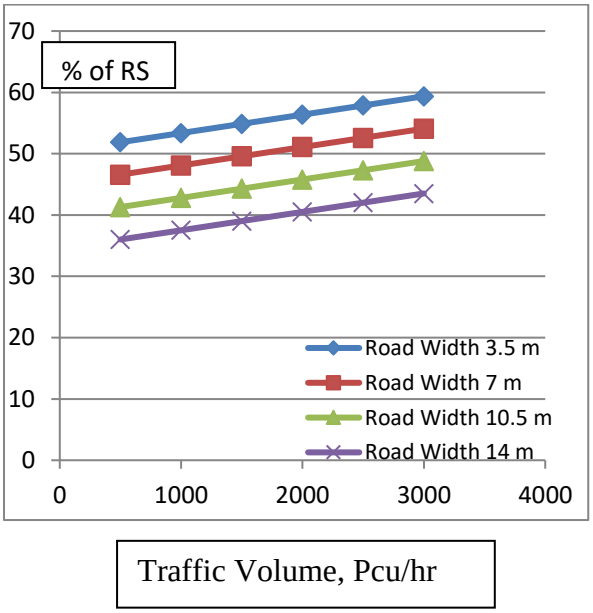

Fig. 9. Segment 1 to 4 – High Congestion

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Table III: % of reduction in speed under different traffic situations & road widths–from models

Segment / Situation	% of RS - Road width 7 m	% of RS - Road width 10.5 m	% of RS- Road width 14 m
For a Traffic Volume: 2000 Pcu/hr			
1 to 2 – Medium Congestion (Model 1)	37	28	21
1 to 2 – High Congestion (Model 2)	56	41	27
1 to 3 – Medium Congestion (Model 3)	35	24	12
1 to 3 – High Congestion (Model 4)	48	30	16
1 to 4 – Medium Congestion (Model 5)	31	23	15
1 to 4 – High Congestion (Model 6)	51	45	40

V. CONCLUSION

Traffic congestion is a complex situation in Addis Ababa city that makes the traffic volume decline on the road. Due to this effect, the speed of the vehicles, road capacity, and level of service decrease correspondingly, whereas travel time, travel cost, and traffic delay increase harmoniously. The acceleration and deceleration of the vehicles change due to congestion levels in the city which accelerate air pollution on roads. The present study was conducted to analyze the effect of traffic congestion on traffic stream characteristics in Addis Ababa city. The traffic data was collected at four different segments on the selected Mebrathail mid-block, at every 15-minute consecutive interval, for 10 hours. The percentage of reduction in speed at different segments was evaluated by considering the speed variations at each segment in the selected midblock. Different Multiple Linear Regression models were developed for each segment by considering the % of reduction in speed as the dependent variable and the traffic volume and road width as independent variables. The results indicate that for a road width of 7 m to 14 m with a traffic volume of 2000 Pcu/hr, the percentage of speed reduction varies between 12% to 37% for medium congestion levels and between 16 % to 56% for high congestion levels.

VI. RECOMMENDATIONS

- For a road width of 6m having a traffic speed of 50 km/hr, the traffic volume shall be limited to 1750 pcu/hr and is 2900 pcu/hr for a road width of 8m and for the same speed
- Restrict on-street parking at all the segments in the study location to reduce further the effect of traffic congestion level

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Conflict of Interest: Authors have claimed the no conflict of interest among contributors.

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A CUSTOM INTEGRATED KNOWLEDGE MANAGEMENT SYSTEM FRAMEWORK OVER THE CLOUD FOR ARBA MINCH UNIVERSITY STAFF

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Abstract

Effective knowledge management is crucial for universities like Arba Minch University (AMU) to maintain a competitive edge. However, the efficient management and dissemination of knowledge within university communities pose significant challenges. As one of Ethiopia's eight research universities, AMU must establish robust knowledge management (KM) conditions to facilitate staff knowledge-sharing practices, making existing knowledge accessible, and generating new knowledge. AMU lacks adequate mechanisms for staff to share knowledge and collaborate on various tasks virtually. In response to this, our research introduces a custom integrated KM system deployed over the cloud to enhance collaboration and knowledge sharing among AMU staff. Utilizing a design science approach and a mixed research methodology, we investigated collaboration and knowledge sharing among AMU staff. The analysis revealed that 81% of respondents were dissatisfied with the current environment regarding the accessibility of knowledge sharing, indicating that knowledge within the institution is not easily accessible at any time and from any location. Additionally, 73% of respondents acknowledged the importance of Knowledge Management Systems. Based on these findings and the needs of the staff, we developed a cloud-based integrative KM framework designed to capture, represent, and share knowledge among AMU staff. The study concludes that the implementation of the developed KM framework in the institution can significantly improve the accessibility, sharing, and preservation of knowledge among AMU staff, ultimately enhancing the university's competitiveness and knowledge-sharing capabilities.

Keywords: ***Cloud-based, Integrative Knowledge Management System, Knowledge Sharing, Collaboration, Explicit knowledge, Tacit knowledge***

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I. INTRODUCTION

Every higher education (HE) institution in Ethiopia has three major responsibilities, i.e., teaching, research, and community engagement. To carry out these responsibilities, higher education institutions (HEI) should organize teaching and learning activities, do scientific research, and support students and lecturers to implement the knowledge they obtained in the community. Furthermore, HEIs consist of people with different educational backgrounds, cultures, and experiences[1], and everyone has the knowledge to contribute to the organization. Those differences lead to different approaches in their contributions to real-world problem-solving. Individuals' knowledge is not sufficient to be applied to solving the organization's challenges and problems[2][3]. In today's competitive atmosphere, the development, and productivity of institutions are dependent on several factors such as knowledge-sharing capabilities for sustainable competitive advantages. This means that organizations must have the means to create, manage, and share knowledge to be competitive and profitable. Currently, the ability of institutions to innovate depends on the way they manage the knowledge used for the exchange of facts between people[4][5]. However, the implementation of KM is a prerequisite for understanding and developing the necessary infrastructural elements that support the creation and management of knowledge [6].

In our country, research universities play fundamental roles in promoting knowledge production by focusing on cultivating high-quality graduates with analytical, problem-solving, and interpersonal understanding skills, thereby contributing to Ethiopia's goal of building a knowledge-based society. The university's strategic focus on knowledge management can bring further progress and growth advantages of knowledge sharing. This is because research cooperation is the basis for the cultivation of existing knowledge and the production of new knowledge. To achieve this goal, one of the key steps the government has identified is implementing knowledge management to improve the performance of universities. This requires every researcher and faculty member to practice appropriate and effective knowledge management by successfully creating, acquiring, storing, and distributing knowledge in teaching and research activities [7][6].

Thus, developing a cloud-based integrative knowledge management framework for universities is an important step toward improving collaboration, knowledge sharing, and decision-making

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within the institutions. The framework enables stakeholders to capture, store, retrieve, share, and apply knowledge and information securely and efficiently, and it can help support the institution's research, teaching, and administrative missions. The academic institutions have different fields of knowledge and experience which must be shared among employees[8]. This shows that KS is necessary for the universities, especially for the professional development, reputation, and self-empowerment of faculty and staff. AMU is one of the eight research universities in Ethiopia, understanding and providing the essential environment for knowledge management. This is necessary to encourage researchers and faculty to trust each other, collaborate, and be motivated to share ideas and participate in discussions through different communication methods for sharing information and knowledge to generate new knowledge[7][9].

In the literature, different conditions have been proposed as prerequisites by many researchers allowing to enable the sharing of knowledge to support and strengthen cooperation between researchers in research universities. These are called knowledge management enablers and are divided into individuals (lack of trust, motivation, and lack of commitment), organizations (lack of guidance, lack of support, and participation in senior management), technology (lack of compatibility between various information technology systems) and communication structure (poor and limited communication of knowledge sharing) which are essential for knowledge sharing to happen[10][11]. Most of the staff conduct research at AMU and participate in many community services. However, based on the inaccurate view that “knowledge is power”, they tend to retain knowledge for personal academic achievements rather than share. This is because they believe that if knowledge is made public, it may endanger and threaten the status of researchers’ and teachers’ recognition and power[12]. In addition, due to the absence of knowledge management tools to support the exchange of knowledge between staff, all scholars cannot fully access and use the knowledge within the organization.

Therefore, to overcome the above problems, this research set out to develop an appropriate cloud-based integrative knowledge management method to virtually increase the research collaboration and knowledge sharing between AMU staff.

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II. LITERATURE REVIEW

Many academic members failed to realize that effective research collaboration among members would increase their effectiveness and contribute to the generation of institutional capabilities that are vital to the university's performance. The study [13] expressed the concern that faculty members lack the sharing of mutual visions in accomplishing their university's goals and objectives by somehow placing greater importance on their scholarly achievement.

As discussed in a study [2] the main goal of knowledge management is to store knowledge in a repository so that the knowledge can be used and/or updated later in the future. The researcher developed the knowledge management framework for Indonesian higher education institutions. As discussed, HEI's knowledge can be gathered from daily activities done in the organization like business processes and activities such as learning in classes, student mentoring, scientific research, information sharing, and management meetings. During these activities, knowledge is captured and then managed in a structured process called the KM cycle (capturing, structuring, storing, disseminating, and implementing). They also expressed different factors that are necessary to successfully run the explained knowledge management cycle. This model is good and relevant to this study; however, some components must be explored to make it suitable for any kind of knowledge-producing sector[2]. The potential of cloud-based technologies in enhancing knowledge management and sharing within organizations has been widely recognized in prior research studies. Cloud-based knowledge management (KM) frameworks can significantly improve the accessibility and availability of information for employees. By allowing users to access and share knowledge from any location with an internet connection, these cloud-based systems break down geographical barriers and enable collaboration across the globe [14]. In addition to improved accessibility, cloud-based KM systems offer enhanced scalability and flexibility. These platforms can easily scale up or down to accommodate changing organizational needs and user demands, providing the necessary infrastructure to manage increasing volumes of knowledge and users [15]. The flexibility of cloud-based platforms also enables the easy integration of new features and functionalities as required by the organization, ensuring the KM system evolves with the changing needs of the business. These platforms enable users to create, share, and discuss content, fostering a culture of knowledge exchange and peer-to-peer learning.

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The cloud-based nature of these platforms ensures that knowledge is centrally stored and accessible to all authorized users with a minimum latency which can further reduce carbon emissions. This promotes cross-functional collaboration and green knowledge management and sharing. The role of IT and cloud computing in supporting the overall knowledge management processes, including knowledge capture, storage, and distribution, has been widely recognized[16][17]. Cloud-based KM systems can automate and optimize various knowledge management tasks such as knowledge capture, indexing, and retrieval. This improves the efficiency and effectiveness of the overall KM lifecycle. The cloud infrastructure also ensures the secure storage and backup of organizational knowledge protecting it from local system failures or data loss.

Knowledge management is vital to HEIs because it brings crucial benefits to educational institution processes such as research, curriculum development, student and alumni services, administrative services, and strategic planning. It is necessary to point out the valuable knowledge, create a methodology for receiving and consolidating knowledge, perform the spread of knowledge among the students and staff, and generate new knowledge and innovation through knowledge sharing. In a study, the researchers present a framework that increases knowledge sharing and collaboration in higher education institutions. The developed framework has four main components: knowledge acquisitions, knowledge repository, knowledge sharing, and knowledge storage along with different sub-activities[3]. However, the researcher has failed to come up with a framework evaluation and testing to check whether it is improving collaboration within higher education institutions [18].

III. RESEARCH METHODOLOGY

This section explains the research methodology used for conducting the study in the selected domain. The study used design science research.

In this study, design science (DS) was selected to conduct this study. DS develops an artifact for IK capturing, representing, and sharing, and its performance can be determined through prototypical demonstration. As shown in Fig. 1 design science research methodology has six basic activities[19].

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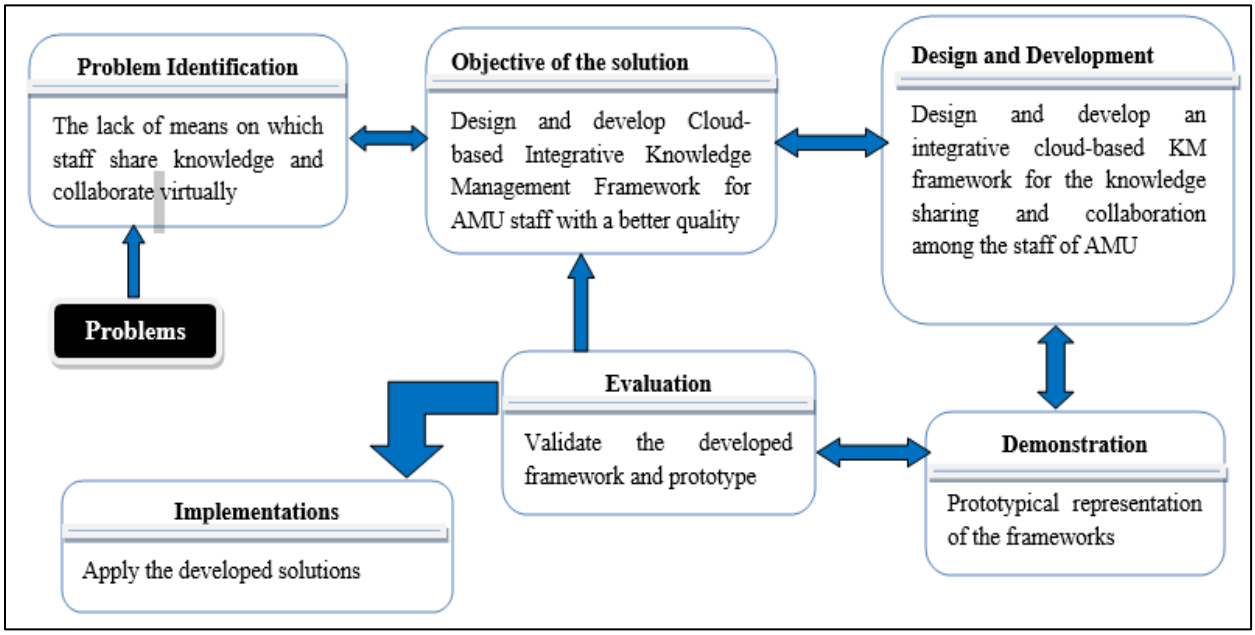

Fig. 1. DS model of knowledge management system (KMS in HEIs Activities)

A. Research Framework

In this research study, a baseline Information Systems Research Framework is used as presented in Fig. 2.

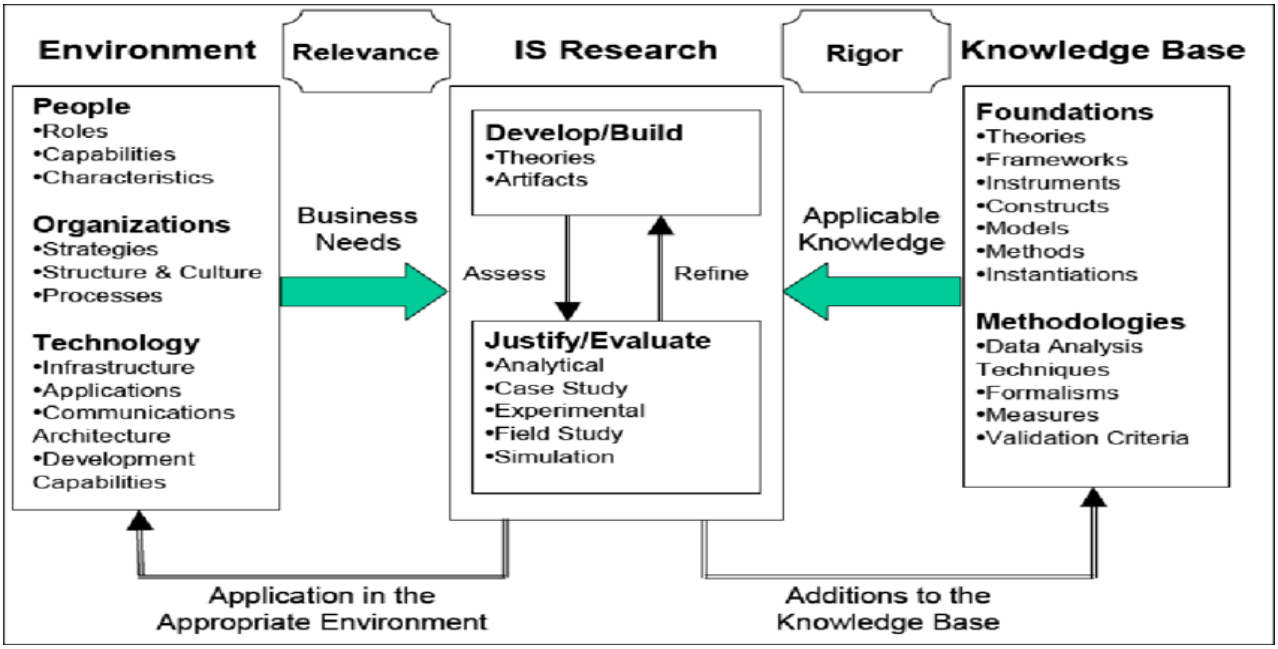

Fig. 2. Information systems research framework

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The Information Systems Research Framework is essential in the field of Knowledge Management (KM) because it provides a structured and comprehensive approach to understanding and addressing the complexities involved in managing and sharing knowledge within organizations. Information Systems Research Framework facilitates the integration of technological, human, and organizational aspects to ensure that KM systems are both innovative and practically relevant. By guiding the development, implementation, and evaluation of KM systems, the Information Systems Research Framework ensures that these systems are not only theoretically sound but also effective in real-world applications. This framework helps capture, represent, and disseminate knowledge efficiently, thereby enhancing collaboration and knowledge sharing among stakeholders. The importance of the Information Systems Research Framework in KM emphasizes the inability of continuous improvement and adaptation of KM systems to meet evolving organizational needs[20].

B. Research Approach

Fig. 3 presents the details of major data and knowledge-gathering approaches used in this study.

C. Sampling Design

In this study, the sampling techniques employed were purposive and stratified sampling methods. The purposive sample size was 342 individuals, consisting of AMU staff from five campuses: Main, Abaya, Nech-sar, Kulfo, and Chamo. The survey questionnaire was administered to 332 participants, and interviews were conducted with 10 participants to gather primary data.

D. Data Collection Methods

The data collection methods and data sources used in this study are clearly described in Fig. 3.

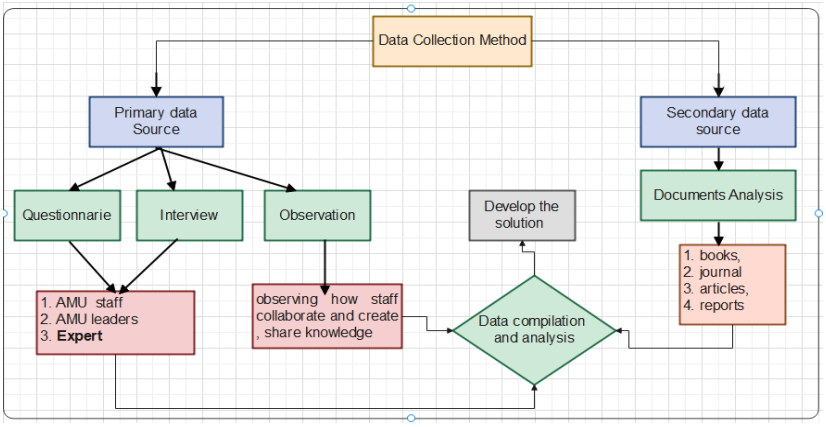

Fig. 3. Data collection method

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E. Data Analysis and Tools Selections

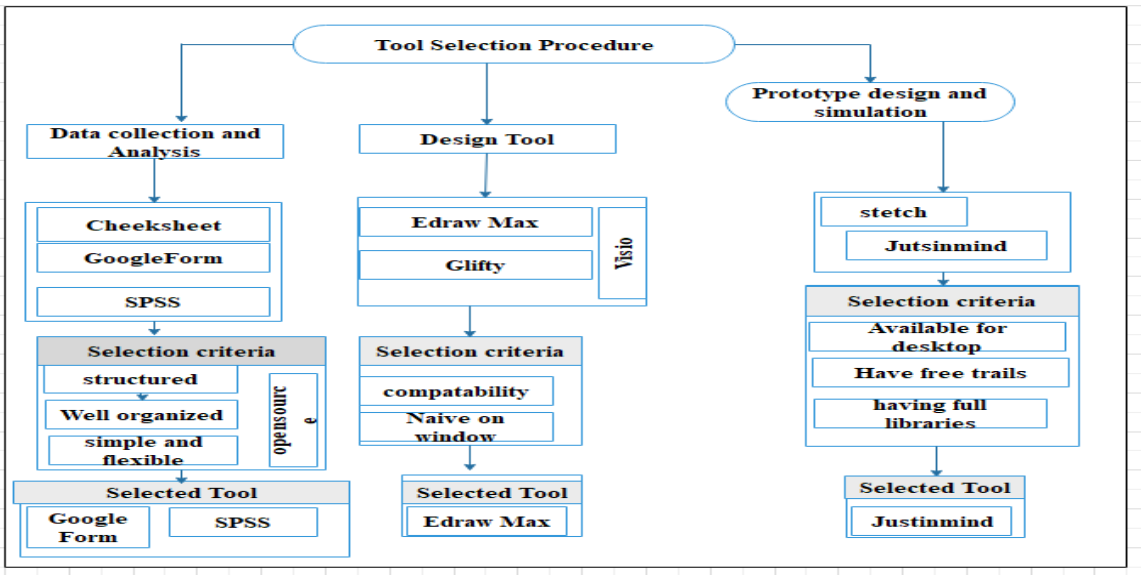

Fig. 4. Tool selection

IV. DATA ANALYSIS AND DISCUSSION

Among the distributed questionnaires, 322 were adequately filled and returned, yielding a response rate of 95.3 %.

A. Demographic Composition of the Respondents

70% of the respondents are male while 30% are female. Regarding the age of respondents, very few are in the age category of 51 and above while the majority are between 24 and 30. 180 respondents are between 24 and 30, 100 between 31 and 40, 25 between 41 and 51, and the remaining below 20 and above 51 years of age as shown in Fig. 5 below.

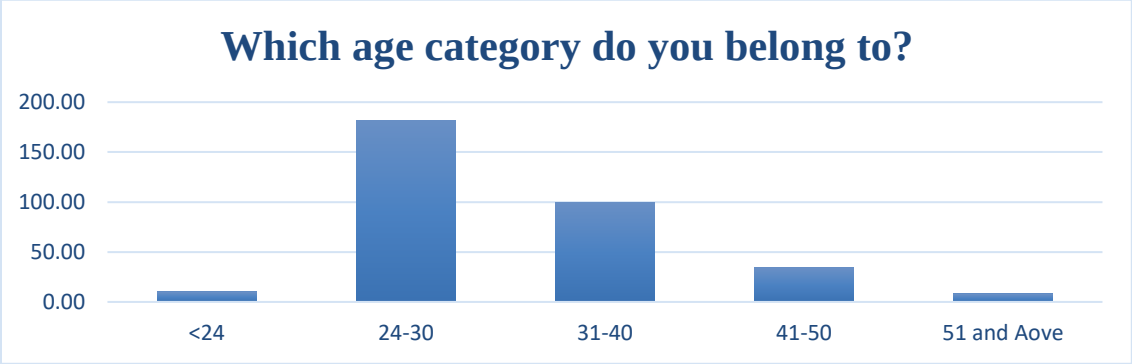

Fig. 5. Respondents distribution by age

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When it comes to their level of education, 60% of the respondents are MSc holders. Around 30% of them are with a PhD and above qualification, while 10% of them are BSc degree holders.

The majority of respondents, 54%, have the academic rank of lecturer. Assistant professors without PhD and assistant professors with PhD constitute 15%, and the fewest are Associate professors and full professors which constitute 9% and 7% of respondents, respectively.

The majority of the respondents, 40%, have a work experience of 1-5 years. 30% of them have work experience of 6-10 years, 21% of them have 11-15 years, and the remaining 9% have 16 years and above work experience.

B. Knowledge Sharing Practices

According to the respondents' response results, the majority, i.e., 60% of respondents had a low level of awareness regarding the importance of knowledge management in their organization, while 30% of respondents had a medium level of understanding of the importance of knowledge management. The remaining 10% of responses had a high level of understanding of the importance of knowledge management.

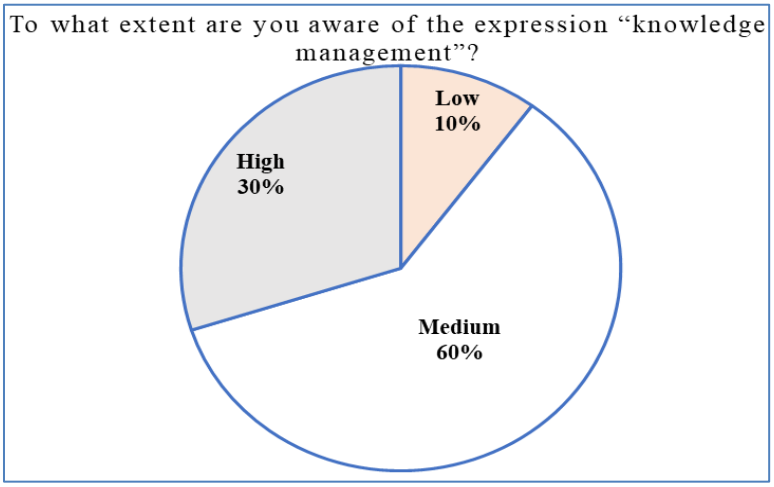

Fig. 6. Awareness of the expression "knowledge management"

According to the result shown in Fig.6 above regarding the awareness of the respondents about the expression "knowledge management", the majority of respondents (60%) reported their awareness as medium level, 30% as high level, and the remaining 10% of the respondents had a low level of awareness about the expression "knowledge management".

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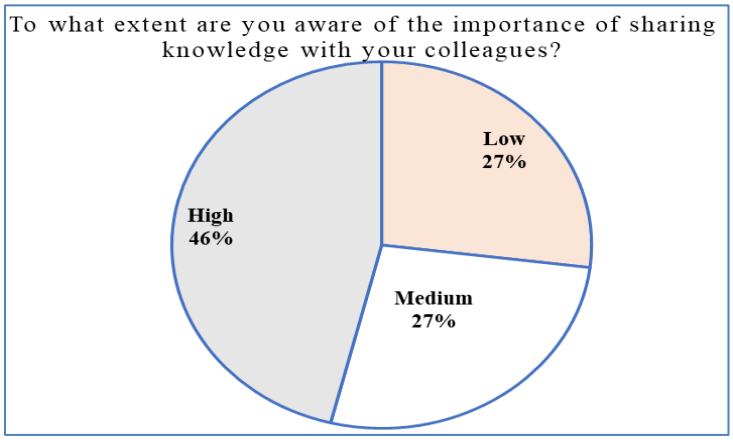

Fig. 7. Awareness of knowledge sharing

Fig. 7 above shows that the majority of respondents, 46%, confirmed that they are aware of the importance of sharing knowledge with their colleagues. Those who reported low and medium level of awareness about this constituted 27% each.

According to the respondents' responses, the majority of the respondents, 73%, reported high belief in the value of KM for the success of their organizations, 24% of respondents reported medium-level belief, and 3% of respondents had low belief.

Similarly, during our interview, we asked this same question and they answered they highly believed KM is valuable for the success of organizations.

C. KM Barriers

There are many barriers in the institution that we had identified. According to the respondents' responses, the majority of the respondents, 60% agreed that there are KM barriers in the organization, 30% of respondents consider maybe there are, and 10% of respondents do not think that there are KM barriers in the organization. Based on the presented question, the majority of respondents confirmed that there were many KM barriers in the organization like no platform (which takes the lion's share) lack of communication media, lack of training, lack of motivation, lack of encouragement, lack of support, and lack of trust between them. So, this finding encourages the researchers to propose a new knowledge-based KM System for AMU.

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D. Organization Support

Fig. 8 to 10 show the responses from questions offered with YES, MAYBE, and NO answers as levels of measurement.

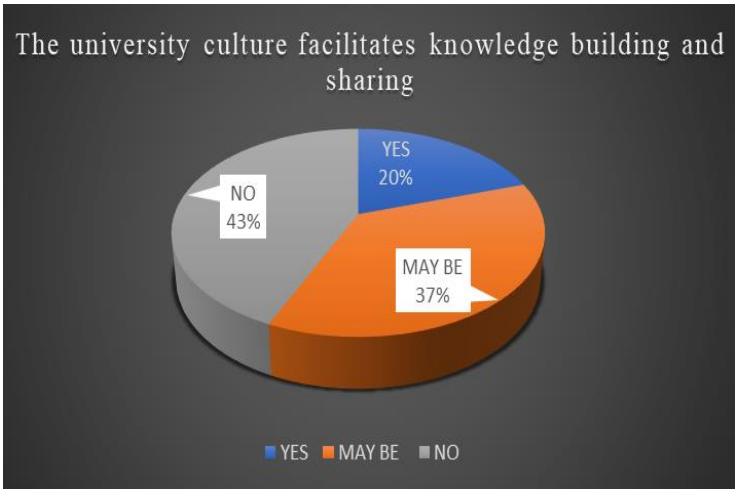

Fig. 8 Culture of the university on knowledge sharing

According to the respondents' responses shown in Fig. 8 above majority of the respondents, 43%, responded ‘no’ confirming that there is no facilitation from the university on knowledge sharing. 37% of respondents responded with a ‘maybe’ and 20% responded ‘yes’ approving that the university facilitates knowledge sharing.

In the university, 43% of the respondents agreed that there are conducive environments for enhancing knowledge-sharing attitudes. 35% responded with uncertainty, while 22% disagreed that there is a supportive working environment that fosters knowledge-sharing attitudes.

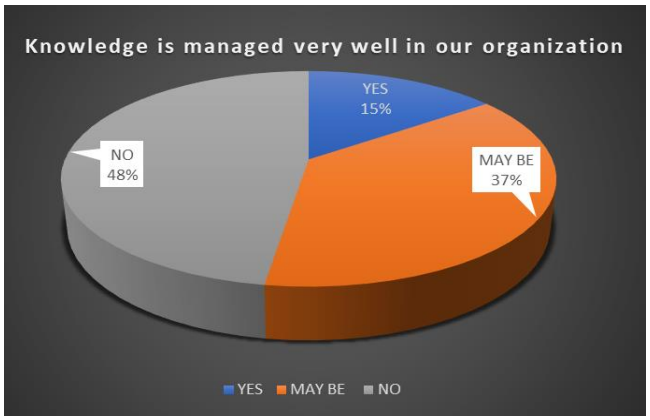

Fig. 9. Knowledge management in the university

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According to the respondents' responses as shown in Fig. 9 the majority of the respondents i.e., 48%, do not agree that there is good knowledge management in university, 37% of respondents responded with 'maybe' and 15% agreed that knowledge is managed very well in the university.

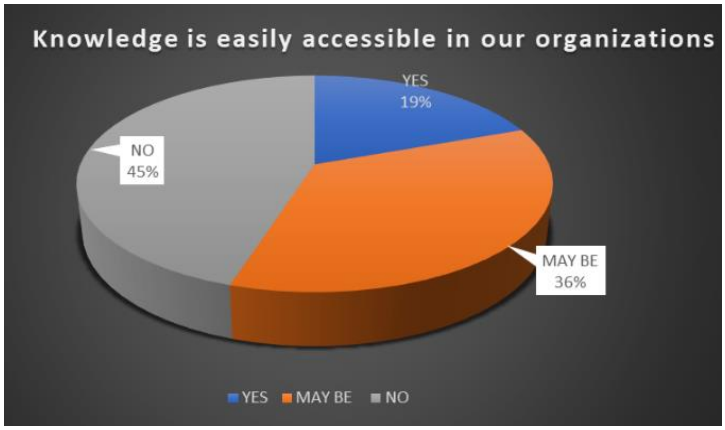

Fig.10. Knowledge accessibility in the university

According to the respondents' responses as shown in Fig. 10 above, the majority of the respondents i.e., 45%, do not agree that knowledge is easily accessible in university, 36% think it may be easily accessible, and 19% agree that it is easily accessible.

E. Infrastructure

The purpose of this section is to assess and identify the infrastructure of the institution toward KM practices. The responses are presented in Fig. 11-13.

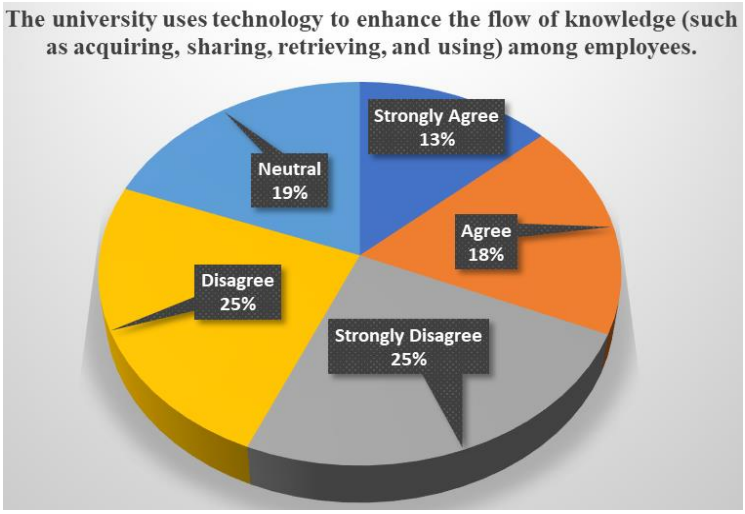

Fig. 11. Technology enhances the flow of knowledge in the university

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As shown in Fig.11 the majority of respondents disagreed and strongly disagreed with the statement of the existence of technology that enhances the flow of knowledge among staff in the institution with 25% responses each while 19% are neutral about this statement. On another hand, 18% of respondents agreed and 13% of the respondents strongly disagreed with this statement.

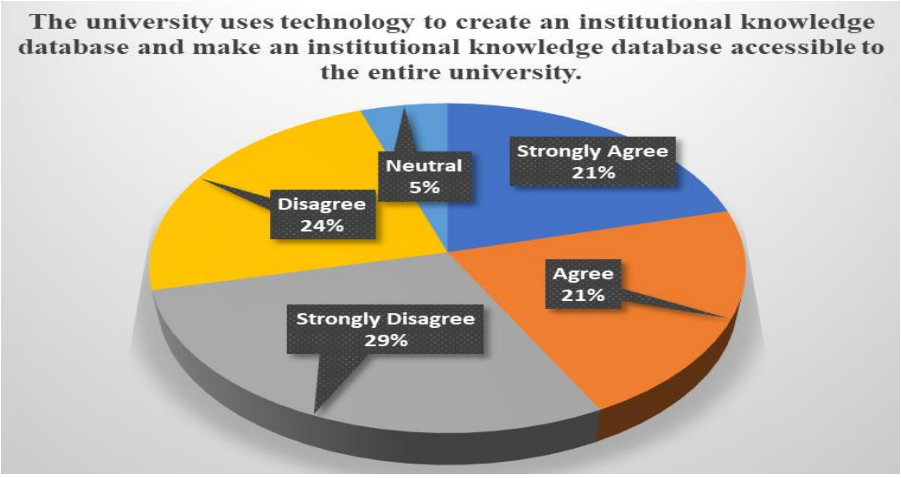

Fig. 12. Existence of accessible knowledge DB in the university

As shown in Fig. 12 above, the majority of respondents strongly disagreed with the statement on the existence of a knowledge database accessible to staff in the institution which is 29% of the responses, and also 24% disagreed with this statement. But 21% of respondents agreed and strongly agreed, whereas 5% of respondents were neutral on this statement.

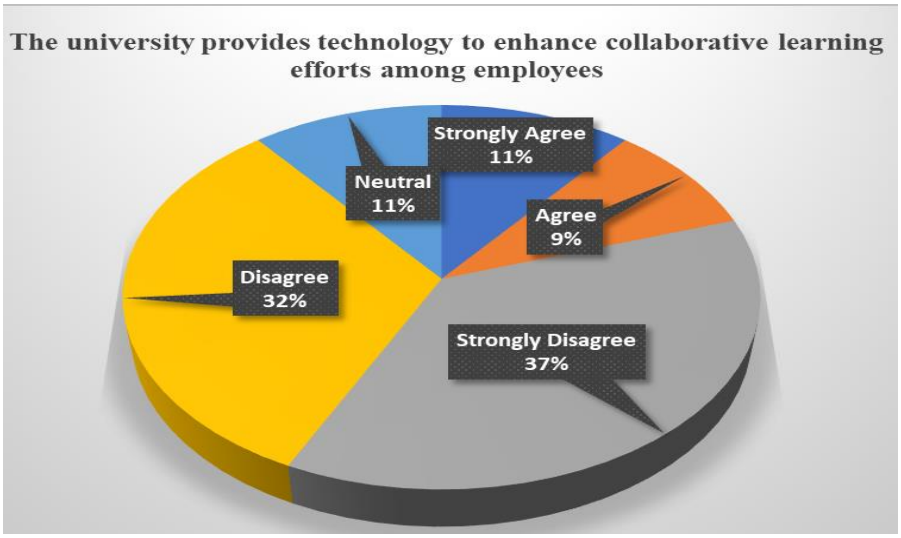

Fig. 13. Existence of accessible knowledge DB in the university

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As shown in Fig. 13, the majority of respondents strongly disagreed with the statement that technology enhances collaboration among staff in the institution which is 37% of responses, and 32% disagreed with this statement while 11% were neutral. Those that agreed and strongly agreed were 9% and 11%, respectively.

V. Summary of Fact-Findings

The survey and interview data analysis indicates that existing state-of-the-art knowledge management and sharing practices in HEIs of Ethiopia in general and Arba Minch University as a case typically lagging. These fact findings provide a new knowledge thrust towards the need for an alternative knowledge management system that can facilitate the knowledge creation, sharing, and collaboration among the staff.

Several emerging technologies can provide a platform for creating knowledge management systems. Cloud computing plays a pivotal role in overcoming the challenges faced by Knowledge Management (KM) and knowledge sharing in institutions like Arba Minch University (AMU) and other similar institutions. Since Cloud-based solutions offer scalable, flexible, and cost-effective platforms that enable seamless access to information and collaborative tools from any location at any time and therefore it was selected for developing a new knowledge-based KM System Framework. Cloud computing was primarily perceived to facilitate new KM systems that can offer low maintenance costs, high accessibility, and unified data silos that facilitate effective knowledge sharing and collaboration. A study [21] underscores the transformative impact of cloud-based KM systems by noting that they significantly enhance organizational agility and knowledge dissemination capabilities.

After rigorous technical observations, it was reveled that a cloud-based integrative Knowledge Management (KM) framework needs to be designed and tested for Arba Minch University (AMU) to fix the several critical reasons pinpointed in survey and technical observations. It was postulated that such a framework can address the current challenges of knowledge accessibility and sharing among AMU staff. With 81% of respondents expressing dissatisfaction with the ease of accessing

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knowledge, a cloud-based solution can ensure that information is available anytime and anywhere, thus enhancing overall knowledge dissemination and accessibility.

Creating a custom cloud-based Knowledge Management (KM) system for Arba Minch University (AMU) is crucial to meet the university's unique needs such as its specific workflow and collaboration requirements. While existing solutions like Microsoft SharePoint or Google Workspace are powerful, they often require expensive and complicated customization to fit perfectly. A custom system can be more cost-effective over time, as it avoids ongoing licensing fees and extensive modifications. It would also integrate smoothly with AMU's existing systems, making it easier to use. Additionally, a tailor-made solution could likely have higher user adoption because it would be designed with AMU staff in mind, reducing the need for extensive training. It can also allow AMU to implement precise security measures and compliance protocols tailored to their specific requirements. In the long run, a custom KM system can provide AMU full control over future updates and improvements, ensuring it remains effective and relevant[22].

A. Proposed Solution and its Functionalities

The proposed KM framework as depicted in Fig. 14 has three components that are required to fit the requirement of AMU contexts, those are organizational, technological, and infrastructural which are discussed below.

1) ***Organizational Component*** As depicted in Fig. 14, the organizational component contains a knowledge capture module. The knowledge capture module is responsible for capturing and organizing knowledge both (tacit and explicit) and information from various sources such as research papers, reports, and data sets. It can help the organization's culture in knowledge building, sharing, and trust and encourage the staff members to improve the working environment with proper guidance and experts in the area. The second attribute of the organizational component identified is the top management (with a leadership commitment) that should provide different types of reward and recognition (such as monetary, and non-monetary) as well as motivations based on the guidelines and policies otherwise the reward can be biased leading to improper KM practices within the organization with a detrimental effect on knowledge creation, sharing, and building the collaboration among the staff members. The third attribute of the organizational

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component identified is the KM Team's involvement which is the most important to create awareness about KM and provide training on the platform for the staff members as well as supporting the users as needed promptly in addition to managing the platform account.

2) ***Technological Component****:* The second component as depicted in Fig. 14 of the proposed framework is the technological component and, in this component, the technology adopted has four characteristics, those are simplicity, accessibility, trust, compatibility, and integration. Those characteristics can help the users' perception of the KM system as easy to use, with accessibility in needed time (24/7), not biased for rewarding (in retrieving the right users who highly contribute towards the KS), as operating in available users' devices for KM practices, and as integrative to other institutions' systems as indicated in a similar study[23]**.**

3) ***Environmental Component****:* As depicted in Fig. 14, the last component of the proposed framework is the environmental or infrastructural component. The infrastructural component indicates the factors that are considered for the competitiveness of the institution. So, to be able to work with their partners that are more advanced in technology, AMU should use modern technologies such as cloud computing technology services. In the infrastructure component, the major factors that were identified as influential for successful KM are well-updated ICT infrastructure (that supports the current state of the art) and resource support to be a competitive global university. So, the proposed framework is designed to meet the current state of the art.

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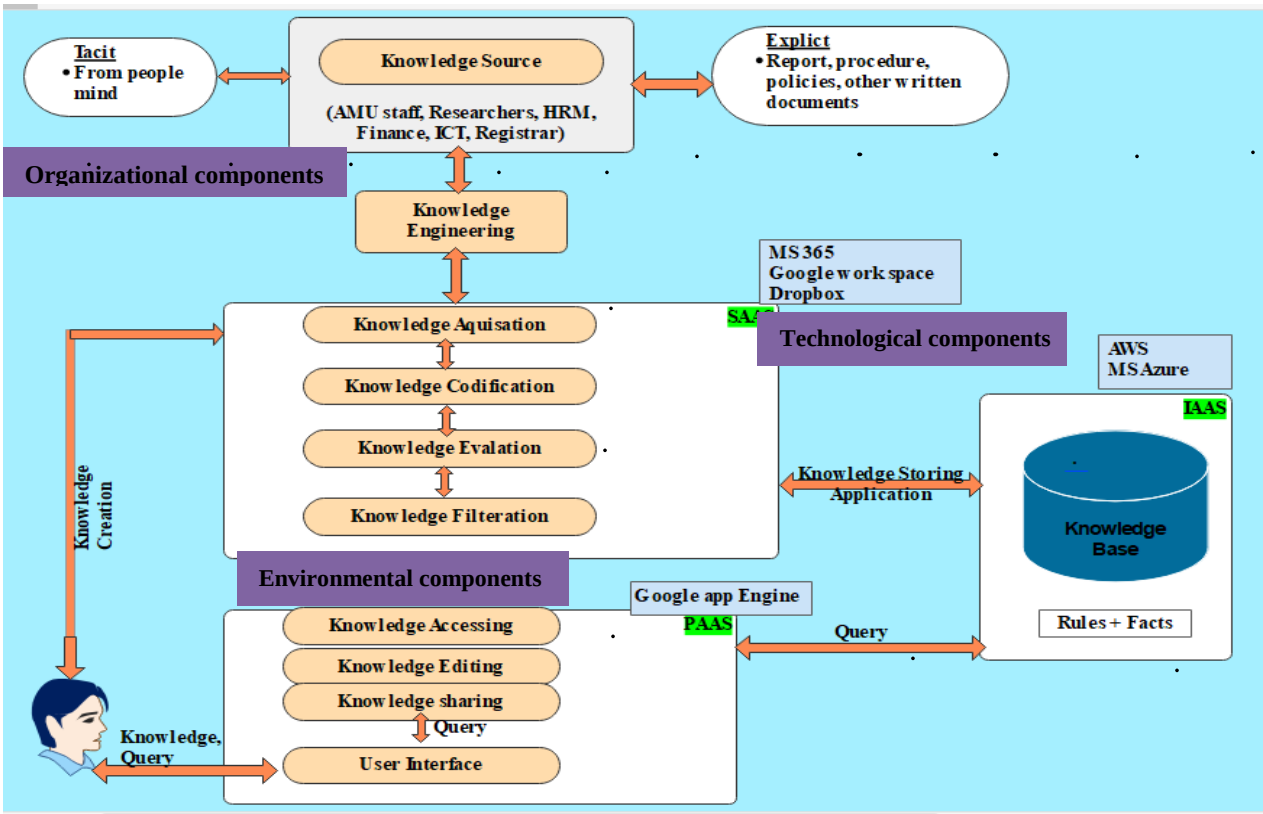

Fig. 14. Proposed cloud-based KM framework for AMU staff (CBKMF-AMU)

VI. CONCLUSIONS

In the fourth industrial revolution (digital age), every HEI needs to have judicious adoption of emerging technologies such as cloud to ensure the survival and competency with other organizations to become more relevant and impactful. To obtain local and global recognition as top universities, they must include digital technology in their process. To be the best universities, they should be able to withstand the changes brought upon by modernization. This is impossible without sufficient knowledge and expertise. The objective of this study was to design and develop an integrative cloud-based knowledge management framework for AMU that will facilitate knowledge-sharing practices between and/or among academic staff members and make the university competitive and more efficient.

By implementing this cloud-based KM framework, AMU can improve its ability to create, share, and apply knowledge, and can enhance its reputation as a center of excellence for teaching,

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research, and innovation. This KM framework can help AMU to better leverage its knowledge and expertise in a variety of ways by enhancing collaboration and knowledge sharing. The university can use these KM tools and techniques to foster collaboration and knowledge sharing among faculty, staff, and students.

The framework ensures that employees have access to the expertise held within the organization, reduces mistakes to a minimum, and helps people make smarter, informed decisions. Moreover, it builds a more efficient workplace, enables faster decision-making, increases team collaboration, optimizes the employee onboarding and training process, and reduces turnover. It also aids in assessing, curating, and documenting knowledge; identifying where and in what form the knowledge exists; ensuring the captured knowledge is accessible to everyone in a company; creating a culture of knowledge sharing and continuous improvement; finding ways to generate new, relevant knowledge; preventing knowledge loss by storing important information when experienced employees leave; centralizing information and helping employees not to waste time trying to figure out answers; accumulating best practices, and boosting productivity and efficiency amongst employees as well as at the organizational level.

RECOMMENDATIONS

In future, the researchers can focus their attention on thinking that the findings can be based on other sampling methods by increasing the sample size that generalizes for the whole staff of AMU. This research focused only on internal KM barriers; thus, future researchers may also incorporate external barriers to the KM framework.

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Conflict of Interest: Authors have not claimed and reported any conflict of interest among the contributors.

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