AFRICAN JOURNAL OF SCIENCE, TECHNOLOGY AND ENGINEERING (AJSTE)

Volume 6, Issue 1 2025

KIRINYAGA UNIVERSITY

KIRINYAGA UNIVERSITY

AFRICAN JOURNAL OF SCIENCE, TECHNOLOGY AND ENGINEERING (AJSTE)

Volume 6(1) 2025

KIRINYAGA UNIVERSITY, KENYA

ISO 9001: 2015 Certified

AFRICAN JOURNAL OF SCIENCE, TECHNOLOGY AND ENGINEERING (AJSTE)

AFRICAN JOURNAL OF SCIENCE, TECHNOLOGY AND ENGINEERING (AJSTE)

Email: journals@kyu.ac.ke

ISSN 1356-6282

KIRINYAGA UNIVERSITY
P.O Box 10500
NAIROBI, KENYA

Forward

It is with great pleasure that I present Volume 6 of the *African Journal of Science, Technology and Engineering*. This volume marks another significant step forward in our mission to foster innovative research and knowledge dissemination across the African continent and beyond.

This edition features a rich collection of peer-reviewed articles addressing current and emerging issues in various fields—ranging from emerging technologies, sustainable infrastructure, and advanced materials, to data-driven innovations and engineering applications tailored to local and global needs. The diversity and depth of contributions reflect the growing capacity and commitment of African scholars and practitioners in addressing complex scientific and technological challenges through locally relevant and globally informed solutions.

As Africa continues to assert its place in the global knowledge economy, it is vital that platforms like this journal provide visibility and support for homegrown research and innovations. Volume 6 not only celebrates intellectual achievement but also encourages collaboration, cross-disciplinary engagement, and practical application of science and technology to improve lives.

I commend the authors, reviewers, editorial board, and supporting institutions whose dedication and scholarly rigor have made realization of this volume possible. May this edition inspire further inquiry, innovation, and impactful solutions throughout Africa and the global scientific community.

Chief Editor

Table of Contents

Contents

NURSES AND MIDWIVES KNOWLEDGE ASSESSMENT ON COMPLETION OF THE PATOGRAPH WITHIN SELECTED FACILITIES IN KENYA.

Odhiambo R.

Kirinyaga University, KENYA

Correspondence : *odhiamboroselyne01@gmail.com*

Abstract

Globally, the top five causes of maternal mortality in women of all ages include hemorrhage, hypertensive disorders, abortions and sepsis, accounting for over 75% of all maternal fatalities. The partograph is a simple, low-cost tool recommended by the World Health Organization (WHO) for monitoring labor and identifying potential complications. The World Health Organization (WHO) recommends universal use of the partograph during labor to support decision-making in diagnosing and managing prolonged or obstructed labor. Despite its simplicity and low cost, studies conducted in many developing countries have shown that the use of the partograph remains limited. This study aimed to assess the knowledge of nurses and midwives regarding completion and use of the partograph in managing labor. The study was conducted in maternity units within selected facilities in Meru County, Kenya. This study employed a mixed-methods approach, incorporating both qualitative and quantitative techniques. A case study design was used to evaluate the knowledge and skills of participants during the intrapartum period, through completion of partographs. The sample consisted of 78 nurses and midwives. Data was collected using case-based partograph scenarios, with quantitative data analyzed using SPSS version 26 to generate descriptive statistics, while qualitative data was analyzed thematically. Despite availability of Basic Emergency Obstetric and Newborn Care (BEmONC) guidelines, significant gaps were identified in the accuracy of completing the partograph (mean score = 1.7). Participants demonstrated limited knowledge and skills, as evidenced by incorrect charting of fetal parameters and inaccurate documentation. A number of participants experienced difficulty in using the partograph, citing challenges such as staff shortages. One participant stated, "We are very few staff during the shifts, so I don't think it will be possible to fill this partograph." Other reported barriers included lack of training, inadequate staffing, and unavailability of partographs. Although efforts have been made to maintain clinical competence, the study revealed persistent gaps in correct use and completion of the partograph. There is need for continuous training and capacity-building initiatives to improve quality of care and strengthen clinical practice among nurses and midwives.

Keywords: Patograph, Completion, Nurses and Midwives.

Introduction

The top five causes of maternal mortality in women of all ages globally include hemorrhage, hypertensive disorders, abortions and sepsis, accounting for over 75% of all maternal fatalities [1]. The Maternal Mortality Rate (MMR was 223 for every 100, 000 live births in 2021 globally for every 100000 live births in Sub-Saharan Africa and 378 for every 100, 000 live births in Kenya greatly exceed the SDG goal of 70 maternal mortalities for every 100,000 live births. The global Neonatal Mortality rate (NMR) was 17 for every 1000 live births; In Sub-Saharan Africa, the neonatal mortality rate (NMR) was 24 per 1,000 live births. In Kenya, the NMR stood at 16 per 1,000 live births in Kenya, well above the Sustainable Development Goal (SDG) target of 12 per 1,000 live births by 2030. The "Three Delays" model continues to be a major contributor to these outcomes. These outcomes result from delays in deciding to seek care, reaching appropriate healthcare facility, and delays in receiving adequate care upon arrival. In this context, timely and accurate interpretation of labor progress is critical, and nurses and midwives play a vital role in this process.

The partograph is a simple, low-cost tool endorsed by the World Health Organization (WHO), designed to monitor labor and detect complications such as prolonged or obstructed labor. WHO recommends its use universally to support better informed clinical decision-making during labor. However, despite its proven benefits, studies from many developing countries have reported limited use of the partograph in routine practice[2]. The partograph serves as a vital tool that visually tracks the progress of labor and monitors the health status of both the mother and the fetus. It is structured into four main sections: maternal information, fetal well-being, labor progression, and maternal condition. The fetal well-being section includes monitoring of the fetal heart rate, the condition of the amniotic fluid, and the presence of cranial molding. Labor progress is documented through cervical dilation and fetal head descent, which are assessed in relation to the "alert" and "action" lines to guide timely interventions. The maternal condition section records key indicators such as uterine contractions, blood pressure, pulse, urine output, temperature, and any medications given, including those used to stimulate labor [3].

The partograph can significantly improve birth outcomes by enabling early detection and management of labor complications. Although, its consistent use remains low in many developing countries across Africa, strengthening routine use for labor monitoring at a national level is crucial to reducing perinatal mortality and enhancing quality of maternal care[4]. It has been reported that 50% of midwives do not regularly use partographs, citing the challenges of monitoring them, as they find it time-consuming and difficult. They also believe that identifying labor complications requires experience, leading them to view partograph use as a time-wasting activity that does not impact their responsibilities or professional growth[5].

In Kenya, an estimated 140 million births occur each year, and more qualified nursing staff are needed to provide skilled care [6]. Baloyi and Jarvis [7] asserted that healthcare consumers have a right to excellent, timely healthcare by qualified nurses and midwives in accordance with the Sustainable Development Goal number three [8]. The objective of this study was to assess the nurses and midwives' knowledge on completion of the patograph. Delivery of essential obstetric care to women continues to be one of the crucial initiatives that must be carefully adopted to meet the third Sustainable Development Goal by 2030 [9]. This study will guide the Ministry of Health, Nursing Council of Kenya (NCK), Midwifery Regulators and Ministry of Education on the knowledge and clinical skills gaps existing among nurses and midwives pertaining management during labour.

Methods

The study was conducted in maternity units in selected facilities in Meru County, Kenya. The study used both qualitative and quantitative techniques (Mixed methods). A case study design was used to assess participants' level of knowledge and skills during the intrapartum period, through completion of a patograph case scenario. The target population comprised 98 nurses and midwives, who consented to participate in the study and had minimum working experience of at least 6 months within the maternity units.

The formula for Taro Yamane (Yamane, 2019) was used to compute the sample size, as follows,

$$n = \frac{N}{1 + Ne^2}$$

n – The sample size

N – The target population size: 98

e – The acceptable margin of error or level of precision= 0.05.

Therefore:

$$n = \frac{98}{1 + 98(0.05)^2}$$

n=78 respondents.

Table 1: Target & Sample Population of Different Hospitals.

No.	Hospital Name	N- Target population Reference. (Maternity Units staff database records.)	n- Sample size
1	Kanyakine Sub-county Hospital	23	18
2	Githongo Sub-county hospital	27	21
3	Muthara Sub-County Hospital	18	15
4	Nyambene sub County Hospital	30	24
	Total	98	78

Purposive sampling, which targets a specific group depending on the rationale for conducting the study [10], was used to select facilities within Meru County, which recorded high maternal mortality rate (291/100000 live births). Systematic random sampling technique was used to select participants from the facilities using the formula i=N/n, to obtain the sampling interval. The justification for using this method was to ensure statistical generalization and data representation, ensuring valid conclusions about the population under study. [10]

The patograph, was administered and completed as a case scenario, using the case study design, which is analytical and provides in-depth exploration of the intrapartum mother. Through the monitoring and follow-up period of using a patograph, the nurses and midwives were able to make diagnoses through identification of abnormal findings and to take appropriate actions or decisions to manage the client, noting that active phase of labour should be less than 18 hours.

A pre-test study was performed to strengthen the quality of the research with particular emphasis placed on its significance for boosting the study's reliability and validity [11]. All the consenting nurses and midwives were taken through the data collection process, which involved completion of the patographs.

Data was revised, coded, and uploaded on excel spreadsheets for computation before analysis commenced. Data was cleaned to remove any inaccuracies, then both qualitative and quantitative analysis was performed. SPSS version 26 was used to analyse quantitative data [12], with use of descriptive statistics. Thematic analysis was employed for qualitative data, after which the information was grouped into themes for easy analysis.

The study was approved by the Chuka University research, Ethics and Review Committee. The ethics committee number is **NACOSTI/NBC/AC-0812.** Permission was also sought from the specific Sub-County hospitals and from the Meru County Government. Potential participants were taken through informed consent procedures. Participation in the study was voluntary and confidentiality, privacy, and participants right to withdraw from the study assured. The researcher linked to coded data only on a paper participant tracking form which was stored in a locked file cabinet at the study site accessible only by study investigators and study clinician,

after which they were transferred to the research office. After instruments were checked for precision and comprehensiveness, data was prepared for upload. Reserve copies, including electronic sets of all data files were safely stored, and any extra information saved in hard disk drives.

Results

A total of 70 participants completed the data collection process, resulting in a 90% response rate. The sample consisted of 77.1% females (n=54) and 22.9% males (n=16). 42.9% (n=30) of participants were aged between 32 and 36 years. 72.9% (n=5l) of nurses and midwives were KRCHNs, and the labor ward was the most common deployment area (37.1%, n=26).

Knowledge on Complete Documentation of the Patograph

To assess the knowledge on chatting the patograph, respondents were required to complete a patograph case scenario. A clear case scenario of a mother in labour was given, who was admitted in first stage of labour for monitoring; these included chatting the general baseline information, fetal parameters, maternal parameters and other details. Results were presented in form of mean and standard deviation in the Table below.

Table 2: Knowledge on completing the patograph

	N	Mean	Std. Deviation
knowledge on charting baseline data	70	1.20	.403
knowledge on starting the partogram_active phase	70	1.31	.468
outline priority care during active phase	70	1.56	.500
advice during active phase	70	1.51	.503
expected results at 1 pm	70	1.77	.423
knowledge on charting FHR	70	1.29	.455
knowledge on charting amniotic fluid	70	1.37	.487
knowledge on charting molding	70	1.36	.483
knowledge on charting decent	70	1.70	.462
cervical diletation	70	1.29	.455
knowledge on charting time	70	1.24	.432
knowledge on charting contractions	70	1.37	.487
knowledge on charting Maternal pulse & BP	70	1.43	.498
knowledge on chatting temperature	70	1.51	.503
knowledge on charting urinalysis parameters	70	1.41	.496
describe the care that will be given at 1pm	69	1.55	.501
what was the duration during active phase of the first stage	69	1.32	.469

what was the duration during the second stage	69	1.38	.488
impressions derived from the plotted patograph	69	1.54	.502

Results on Table 10 shows the mean scores ranging from 1.20 to 1.77 across different aspects of knowledge related to charting the patograph. Regarding the knowledge on charting the patograph the data was coded using 1 and 2, where 1 was yes and 2 represented no. Higher mean scores suggested a lower level of understanding regarding the specific knowledge area. For instance, a lower mean of 1.2 indicated that most respondents demonstrated knowledge on charting baseline data. However, the highest mean score of 1.77 was observed for expected results at 1 pm, indicating a relatively weak understanding in this aspect. Further knowledge on charting decent had a mean of 1.70 which gave an impression of inadequate knowledge.

Gaps were observed in the process of accurately completing the parameters on the patograph. It was observed that some respondents were not keen to correctly fill the fetal parameters, while many more respondents were not sure how to complete it.

Qualitative Findings: Positive Perspectives of the Patograph

The nurses and midwives demonstrated basic knowledge in using the patograph. They were able to chart the baseline data and clearly understood how to interpret the duration of active phase of labor.

"*The duration of first stage of labour is 4hours while the duration of second stage of labour is 20minutes*"- ***nurses and midwives***

Negative Perspectives of the Patograph

Six themes were identified as negative observations in utilization of the patograph. Some themes identified during analysis of data from the patograph included, documentation on completeness and accuracy, timely charting and interpretation, impact on clinical decision-making, challenges and barriers to effective use, communication and collaboration. Figures 1-4 below show information as filled on the respondent's patograph. Although Figure 1 demonstrates satisfactory completion with all parameters correctly displayed, figures 2, 3 and 4 were incorrectly completed by some of the respondents.

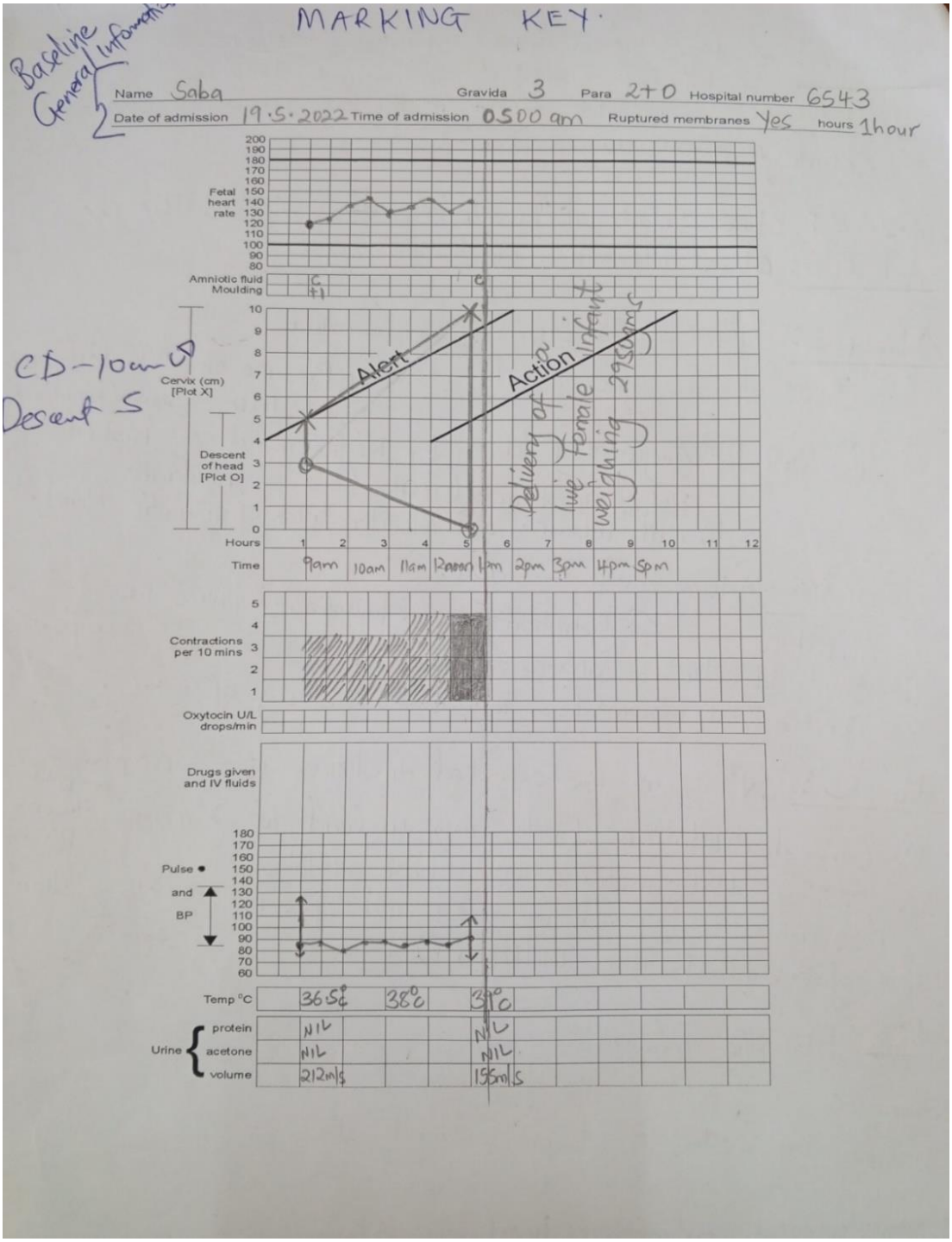


Figure 1: Complete patograph

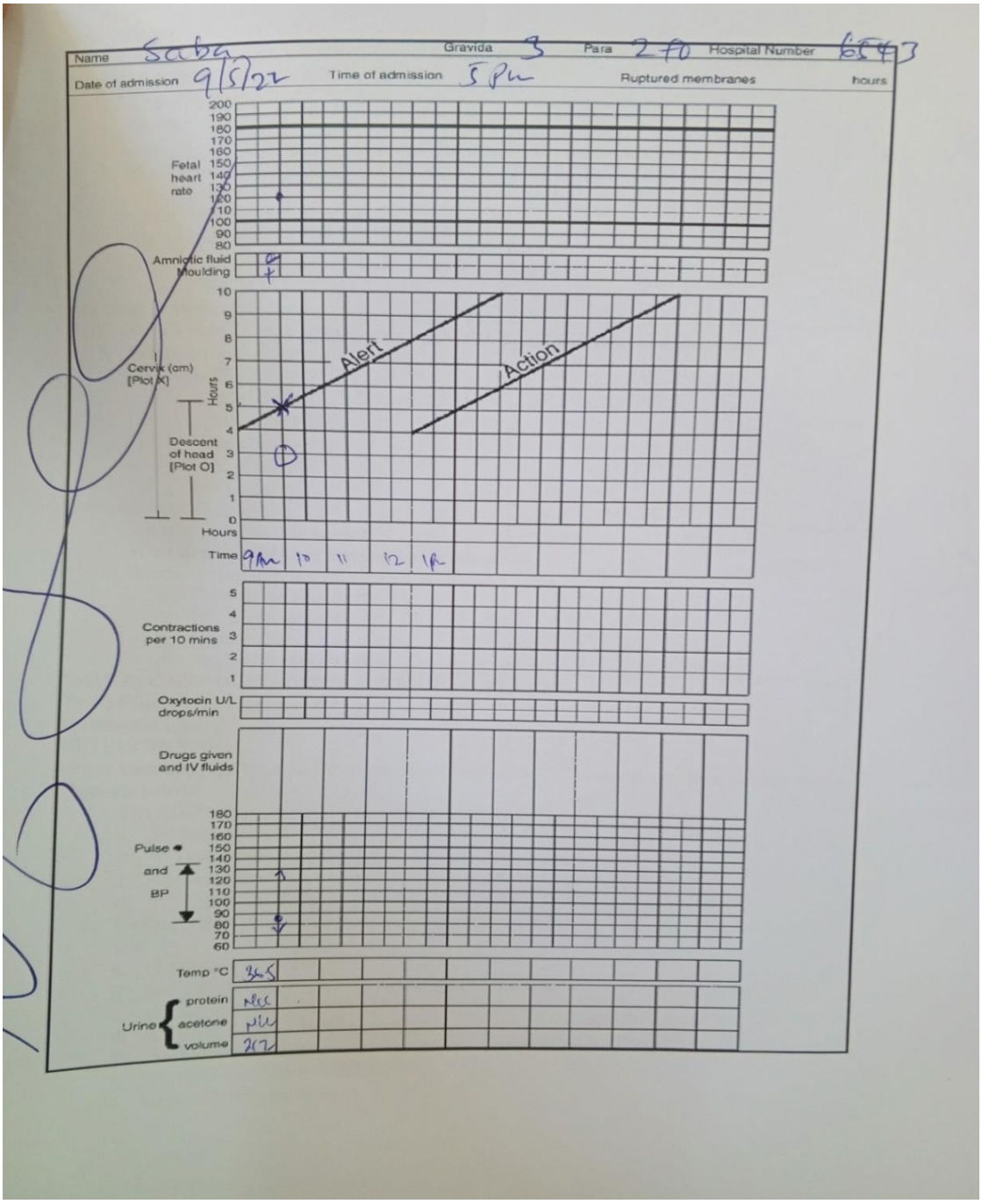


Figure 2: Incomplete patograph 1

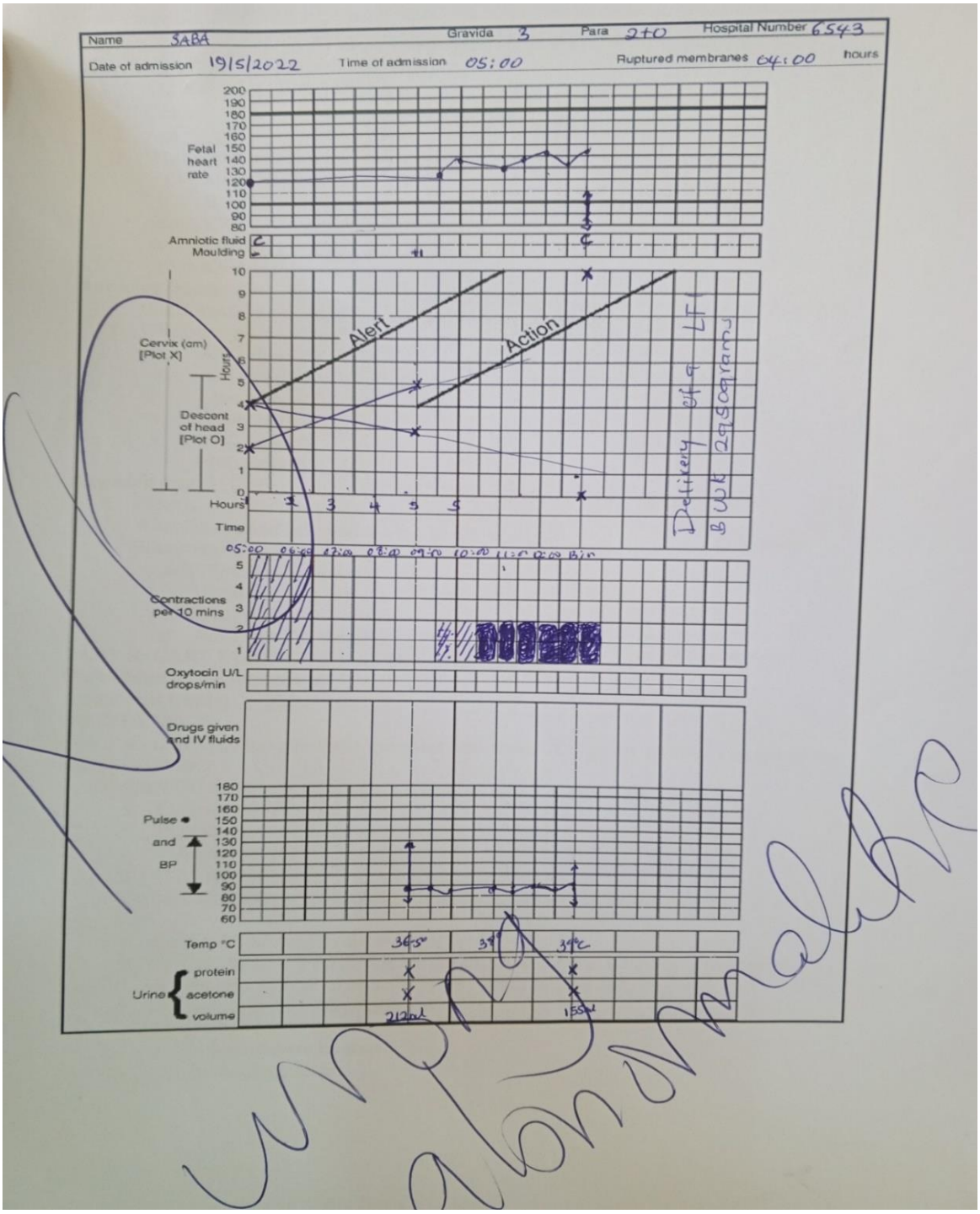


Figure 3: Incomplete patograph 2

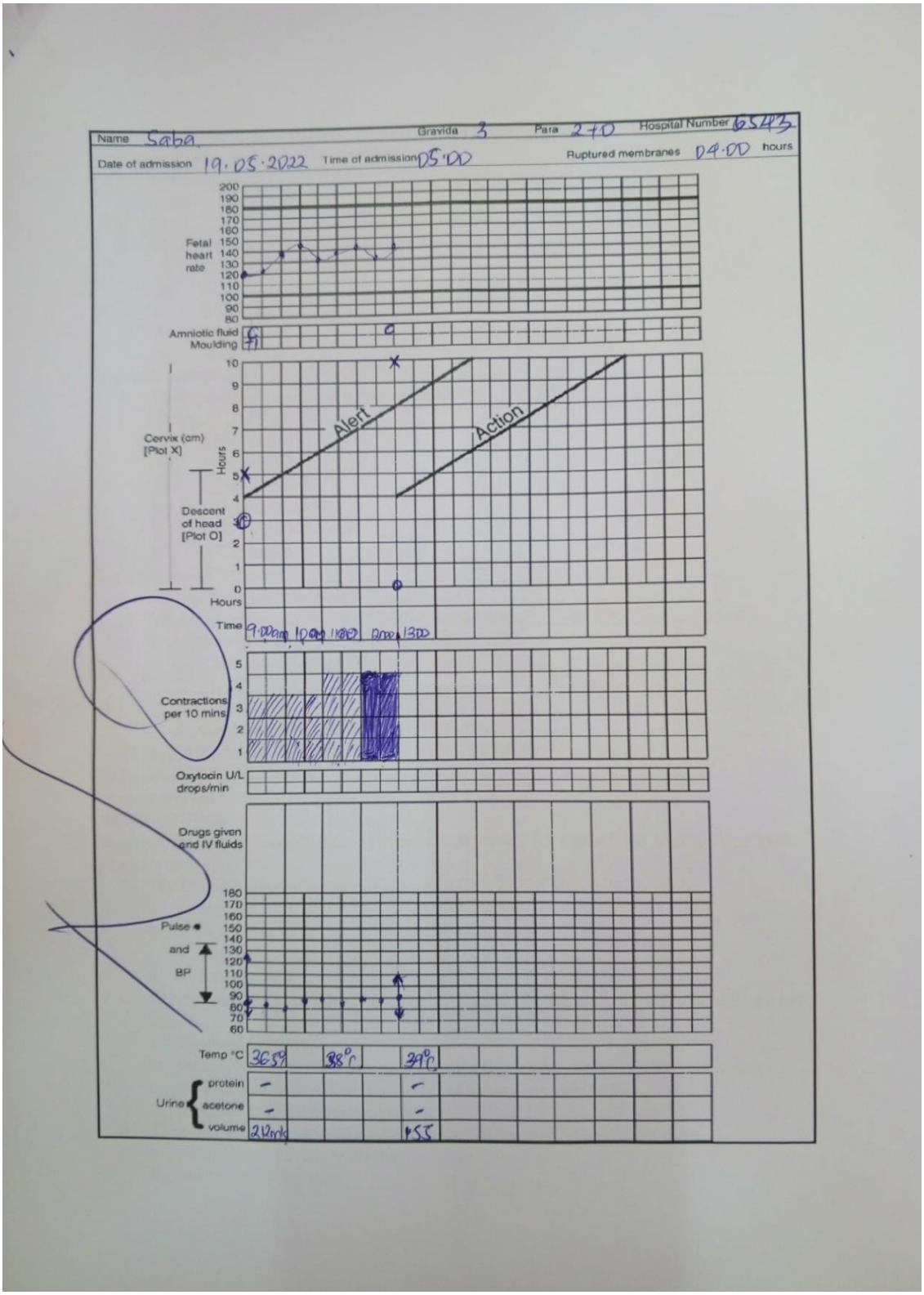


Figure 4: Incomplete patograph 3

i. Documentation on Completeness and Accuracy

The gaps identified in completeness and accuracy through observation included; patograph halfway filled; lack of knowledge in the initial charting especially of the cervical dilatation and tie allocation; inconsistency in charting the different parameters; wrong chatting of the different parameters i.e. descent is charted using an 'X' instead of 'O'. Uncertainty was depicted in charting the contractions where mild contractions were charted together with moderate contractions. These inconsistencies demonstrated lack of knowledge in completing the patograph making the information hard to interpret and make conclusive decision as pertaining to management of women in labour.

i. Timely Charting and Interpretation

There were gaps identified through observation in the timeliness of charting the patograph which affected the interpretation. The gaps include; wrong allocation of time when starting the patograph, this lead to wrong interpretation of all the available information documented on the patograph. Hence, timing of when to perform vaginal examination was a great concern.

ii. Impact on Clinical Decision-Making

Inconsistencies observed in some of the patograph filled by the respondents made the interpretation difficult hence lack of proper decision making on the next course of action in management of the mother in labor. This implies that the nurses and midwives could easily make a wrong diagnosis for the client, which will lead to wrong management actions, for example, deciding on the mode of delivery where no clear complication is observed, the respondents were asked, in one of the poorly done questions, to give the expected results at 1pm. Most of the respondents did not answer this question, while those who answered did not give conclusive responses enough to guide in the next course of action for management of the woman. Below are a few sampled responses.

*"Mother is far from second stage of labour"- **nurses and midwives***

*"Contractions are not good"- **nurses and midwives***

*"Mother needs more time before birth"-**nurses and midwives***

The responses above are not very clear, because at 1pm, the mother should be approaching second stage of labour, cervical dilatation and descent should also be progressive hence birth is imminent. The information charted on the patograph is so crucial, because it gives direction on the next course of action to be taken, this must be a serious activity for the staff.

iii. Challenges and Barriers to Effective Use

The case study completion by the respondents presented various challenges. For the participants who were unable to either complete its documentation stated;

*"I have no time to fill the patograph"- **nurses and midwives***

*"There is too much work I don't think I can complete this work" - **nurses and midwives***
*"We are very few staff during the shifts so I don't think it will be possible to fill this patograph" - **nurses and midwives***
*"Filling the patograph is very tedious, as long as the mother delivered well, I can just complete them at the last minute, I don't have to give a lot of details" - **nurses and midwives***

*"Iam not sure I know how to complete this tool, if we were trained on how to do it, maybe I will have more confidence, we shall ask thos who understand better to do it instead" - **nurses and midwives***
This being the reason for some of the nurses and midwives handing in incomplete sections of the patograph.

iv. Communication and Collaboration

There are respondents who left the patograph blank, while others started filling and did not complete the whole process of documenting the information, from observation, this could suggest that they were neither keen nor interested to consult on how to do it.

Discussion

The partograph, which is a visual tool designed to track labour progress and monitor maternal and fetal conditions over time, is majorly used to offer a visual overview of labour and to notify obstetric care providers of any changes in maternal or fetal conditions or deviations in labour progress [13]. The World Health Organization (WHO) recommends universal use of the partograph during labour. Its routine use aids in making informed decisions for diagnosing and managing prolonged or obstructed labour [14]. Worldwide, prolonged and obstructed labour contributes to 8% of maternal deaths, which can be mitigated through the appropriate use of partographs. Employing the partograph effectively during labour is a crucial intervention for decreasing both maternal and perinatal morbidity and mortality [13].

In this study, major inconsistencies were observed in charting the various parameters, to include; baseline data, fetal and maternal parameters. Evidently, most respondents did not correctly chart the fetal descent (mean 1.70). The lack of knowledge here is what could lead to complication during labour. These findings are consistent with other reports which indicate that prolonged and obstructed labour, along with delays in decision-making, are significant contributors to maternal and fetal mortality. These complications encompass severe hemorrhage, infections, hypertensive disorders, and obstructed labour[15]. Hence, effective use of the partograph positively influences maternal and neonatal delivery outcomes. This underscores the importance of proficiently in using the partograph to monitor labour progress.

The thematic areas developed also expounded further on the realized gaps. Hence, the qualitative perspectives from the study outlined negative aspects of the patograph revealing gaps in completeness and accuracy through observation which included; patograph halfway filled; lack of knowledge in the initial charting especially of the cervical dilatation and tie allocation; inconsistency in charting the different parameters; wrong chatting of the different parameters for instance, descent is charted using an 'X' instead of 'O', unclear charting of the contractions was observed where mild contractions are charted together with moderate contractions. Similarly, another study[16] addressed the same gap in knowledge of correctly charting and interpreting the information on the patograph.

Additional themes explaining the gaps included wrong timing and interpretation during charting hence a good number (mean 1.31), still were unable to initiate the patograph during the active phase of labour. The expectation of the respondents was for them to have a basic understanding on using the patograph bearing in mind that they must have the least standard knowledge to operate and offer up-to-date services for the pregnant mothers. Another setback observed was indicated by the highest mean score of 1.77 theoretical interpretation for expected results at 1 pm, this indicated a relatively weak understanding in interpretation. This finding is similar to another study[17] that emphasized on the need for correct interpretation and prompt action taken in order to minimize unnecessary interventions to the mother.

Evidently, the inconsistencies in correct charting would impact on prompt clinical decision making, because incorrect diagnoses are likely to be derived. Weakness was also observed from the theme developed on communication and collaboration among the nurses and midwives. This could imply that the nurses and midwives are either not keen, or may be disinterested, or they have a negative attitude towards completion of the patograph. Compounding this fact is also the fact that the nurses and midwives did not seem to attach importance to communicate difficulties and consult on the correct way to complete the process. This explains why some of the patograph were incomplete. Agreeably, study [18] done in Dar-es-Salaam found that only slightly over 40% of the WHO standard Partograph parameters were completed, a finding consistent with similar studies in Kenya and Western Uganda. In Nigeria and the Southwest Region of Cameroon, some midwives viewed completing the partograph as a time-consuming task and did not fully understand its life-saving potential, leading to negative attitudes. This discrepancy may have been due to staff shortages, increased workloads, or a lack of awareness about the partograph's benefits [19]. These findings align with observations in another study [20] that reported that only 24.6% (88/355) of partographs were fully completed with all three parameters (fetal, maternal, and labour monitoring), indicating that over 60% of the reviewed partographs were inadequate.

The participants were issued with the patographs to complete, though some of them stated that they had challenges in completing the process. Some of the statements were as follows:
"There is too much work I don't think I can complete this work" - ***nurses and midwives***
"We are very few staff during the shifts so I don't think it will be possible to fill this patograph" - ***nurses and midwives***

"Filling the patograh is very tedious, as long as the mother delivered well, I can just complete them at the last minute, I don't have to give a lot of details" - ***nurses and midwives***

"Iam not sure I know how to complete this tool, if we were trained on how to do it, maybe I will have more confidence, we shall ask thos who understand better to do it instead" - ***nurses and midwives***

These statements are consistent with a study [15] that was conducted which identified several constraints that hindered the effective use of the partograph during labour, including staff shortages, lack of training, inadequate skills, and insufficient knowledge about the partograph itself. These challenges compromised the quality of care provided. Similar findings were observed at Mulago Referral Hospital, where healthcare workers cited a heavy workload due to understaffing, the unavailability of partographs in patient charts, lack of equipment, insufficient skills, and poor attitudes towards using the partograph as reasons for its low completion rate. A related study conducted in Malawi [16] also highlighted key factors contributing to the underutilization of the partograph, such as staff shortages, negligence, a lack of appreciation for the partograph's importance, ineffective and inadequate supervision, lack of recognition or motivation, and skill incompetency. The statement from the study's phase one addressing the need for further training is in line with other studies that focused on creating awareness on patograph utilization [15]. Accordingly, a similar study [13] found that healthcare providers had low awareness on utilization of the partograph, along with significant skill and knowledge gaps in maternity care. Additional barriers to using the partograph included negative attitudes among health providers, limited confidence, inconsistent commitment, and poor interaction with the delivering mother.

Conclusion

This study highlights significant gaps in the knowledge and use of the partograph among nurses and midwives, which can adversely impact maternal and fetal outcomes during labor. Inconsistencies in charting, lack of training, poor communication, and inadequate staffing were identified as key barriers to effective partograph utilization. These issues contribute to delays in decision-making, incorrect diagnoses, and negative attitudes toward the tool, which undermine its potential to improve clinical outcomes. Addressing these challenges through enhanced training, better staffing, and fostering positive attitudes toward the partograph is essential to ensuring its effective use, especially through participation in CPD. Ultimately, this will lead to improvement of maternal and neonatal care. Considering the gaps identified, effectiveness of CPD in clinical practice for the nurses and midwives is still wanting. Hence the need for continuous training.

References

1. Davidson K.W., Terry M.B., Braveman P., Reis P.J., Timmermans S., Epling Jr J.W. (2022). Maternal mortality: National Institutes of Health pathways to prevention panel report. Obstetrics & Gynecology. 5:10-97.
2. Bedada K.E., Huluka T.K., Bulto G.A. Ephrem Y.R. (2020). Low Utilization of Partograph and Its Associated Factors among Obstetric Care Providers in Governmental Health Facilities at West Shoa Zone, Central Ethiopia. International Journal of Reproductive Medicine. 1-9.
3. Ayehubizu L.M., Tibebeu A.T., Fetene M.T., Yohannes S.H., Yadita Z.S. (2022). Partograph utilization and associated factors among obstetric care givers in governmental health institutions of Jigjiga and Degehabur towns, Somali region, Ethiopia: A cross-sectional study. PloS one. 9;17(3):e0264373.
4. Yeshitila Y.G., Daniel B., Desta M., Kassa G.M. (2022). Obstructed labor and its effect on adverse maternal and fetal outcomes in Ethiopia: a systematic review and meta-analysis. PLoS One. 30;17(9):e0275400.
5. Kusumawati E., Istiana S.(2025). Factors That Influence Midwives' Compliance in Completing the Partograph. In proceedings of International Conference on Health Science, Practice, and Education. 106-115).

6. World Health Organization. Strengthening quality midwifery education for universal health coverage 2030. In Strengthening quality midwifery education for universal health coverage 2030 2019.
7. Baloyi O.B., Jarvis M.A(2020). Continuing professional development status in the World Health Organisation, Afro-region member states. International Journal of Africa Nursing Sciences. 13:100258.
8. Albu D. (2021). The sustainable development goals report 2021. Drepturile Omului. 115.
9. Ingwu J.A., Efekalam J., Nwaneri A., Ohaeri B., Israel C., Chikeme P., Madu O., Opara H., Omotola N. (2019). Perception towards mandatory continuing professional development programme among nurses working at University of Nigeria Teaching Hospital, Enugu-Nigeria. International Journal of Africa Nursing Sciences.11:100169.
10. Nikolopoulou K. What is Non-Probability sampling? | Types & Examples. 2023
11. Bujang M.A., Omar E.D., Foo D.H., Hon Y.K(2024). Sample size determination for conducting a pilot study to assess reliability of a questionnaire. Restorative dentistry & endodontics. 10;49(1).
12. Lai J., Lortie C.J., Muenchen R.A., Yang J., Ma K. (2019). Evaluating the popularity of R in ecology. Ecosphere. (1): e02567.
13. Jamuna N., Thayumanavan M. (2023). Utilization of Partograph for Labor Management Among Healthcare Providers in Healthcare Facilities in India: A Systematic Review. Cureus. 28;15(8).
14. WHO Guidelines Approved by the Guidelines Review Committee. WHO recommendations: Uterotonics for the prevention of postpartum haemorrhage. Geneva: World Health Organization. 2018.Zellew, A, & Tegegne, T. (2016). Level of partograph utilization and its associated factors among obstetric care givers at public health facilities in East Gojam. East African Journal 2016;13(7):1–13
15. Zellew, A, Tegegne, T. (2016). Level of partograph utilization and its associated factors among obstetric care givers at public health facilities in East Gojam. East African Journal 13(7):1–13
16. Mezmur H., Semahegn A., Tegegne B.S. (2017). Health professional's knowledge and use of the partograph in public health institutions in eastern Ethiopia: a cross-sectional study. BMC pregnancy and childbirth.17:1-7.
17. Say L., Chou D., Gemmill A., Tunçalp Ö., Moller A.B., Daniels J., Gülmezoglu A.M, Temmerman M., Alkema L. (2014). Global causes of maternal death: a WHO systematic analysis. The Lancet global health.2(6):e323-33.
18. Mukisa J., Grant I., Magala J., Ssemata A.S., Lumala P.Z., Byamugisha J. (2019). Level of Partograph completion and healthcare workers' perspectives on its use in Mulago National Referral and teaching hospital, Kampala, Uganda. BMC Health Services Research. 19:1-8.

19. Melese K.G., Weji B.G., Berheto T.M., Bekru E.T. (2020). Utilization of partograph during labour: A case of Wolaita Zone, Southern Ethiopia. Heliyon. 6(12).
20. Nwaneri A., Ndie E.C., Ehiemere O.E., Ezenduka P.O., Emeh A.(2017). Evaluation of factors affecting the utilization of partograph by nurses/midwives in primary/secondary health facilities in Enugu Metropolis. Gynecol Obstet (Sunnyvale). 7(8):3.

DEVELOPING A STRATEGIC MODEL TO ENHANCE UPTAKE AND EFFECTIVENESS OF CPD IN CLINICAL PRACTICE AMONG NURSES AND MIDWIVES IN KENYA.

Odhiambo R.

Kirinyaga University, KENYA

Correspondence : odhiamboroselyne01@gmail.com

ABSTRACT

The global Maternal Mortality Rate (MMR) is 223 per 100,000 live births, with hemorrhage being the leading cause of death. In Sub-Saharan Africa, the need for nurses and midwives is increasing. Incidentally, only 3.5% of the world's health staff are accountable for 27% of the disease burden. The depicted heavy workloads have largely contributed to poor participation in Continuous Professional Development activities among nurses and midwives. Kenyas MMR burden exceeds the global MMR, which is a great concern. However, the Nursing Council of Kenya stipulates a total of 20 CPD hours to be met annually for all nurses and midwives. The aim of the study was to develop a strategic CPD uptake model for the nurses and midwives. This study seeks to inform the public on the gaps in the uptake and implementation of CPD, and provide recommendations to improve its effectiveness. The study used both qualitative and the quantitative techniques, and adopted a Randomized Clinical Trial design. A sample of 78 nurses and midwives was obtained from a target population of 98. Quantitative data was collected using questionnaires and completion of patograph case studies. Data was analysed using SPSS version 26, to derive descriptive statistics, while qualitative data was collected through interview schedules and observation checklists, which were analysed thematically. Pearson's chi square tested the relationship between knowledge and CPD uptake in clinical practice($p=0.00$) at 95%CI. Paired t-test compared means within the control and intervention groups($t=1.000$). Despite the provision and use of BEmONC guidelines, major gaps were observed in Active Management of Third stage of labour (17.9%)and also in completion of the patograph(mean=1.7). Despite the efforts to maintain competence levels in clinical practice, gaps pertaining to structuring and organization still exist. Theere is therefore need for continuous training to bridge quality gaps and development of a CPD uptake model that can be adopted for use by the nurses and midwives.

Key words: Continuous Professional Development, Nurses and Midwives, Model, Clinical practice.

Introduction

Continuous Professional Development (CPD) is a process through which professionals maintain, expand, and enhance their knowledge, skills, and expertise [1]. In view of nurses and midwives, CPD is essential in reducing maternal and neonatal morbidities and mortalities by equipping them with the knowledge and skills to manage obstetric emergencies effectively.

Maternal and neonatal mortality remain significant challenges, particularly in Sub-Saharan Africa, where maternal mortality rates (MMR) and neonatal mortality rates (NMR) are alarmingly high. In Kenya, for instance, the MMR stands at 378 per 100,000 live births, significantly surpassing the SDG target of 70 maternal deaths per 100,000 live births by 2030[2]. The leading causes of maternal fatalities, such as hemorrhage, hypertensive disorders, abortions, and sepsis, are preventable with timely, skilled interventions, underscoring the need for nurses and midwives, to continually update their skills and knowledge, hence, addressing obstetric emergencies.

The Nursing Council of Kenya (NCK) mandates that all nurses and midwives complete 20 hours of CPD annually, with a focus on maternal and child health. This ensures that healthcare professionals continue to provide safe, ethical, and high-quality care. However, despite this requirement, participation in CPD activities remains irregular and unstructured, often hindered by factors such as staff shortages, heavy workloads, and lack of well-structured CPD programs within healthcare facilities [3].

The lack of structured CPD programs for midwives has led to inconsistencies in clinical practice and a deficiency in critical skills necessary for the management of obstetric complications [4]. Moreover, variations in midwifery training programs, despite the International Confederation of Midwives' (ICM) established Essential Competencies for Basic Midwifery Practice, exacerbates this issue. The need for a structured CPD model that aligns with the ICM's competencies is urgent, as it would ensure adequately equipped staff with the skills to manage maternal and neonatal emergencies, improve patient outcomes, and ultimately contribute to reduction of maternal and neonatal mortality rates [5, 6].

Objectives:

i. To assess nurses and mid-wives factors influencing effectiveness of CPD activities.
ii. To develop a CPD uptake model.

Methodology

This study that used both qualitative and quantitative techniques. Participants included nurses and midwives from selected Hospitals in Kenya. Purposive and stratified random sampling methods were used to select four facilities and the 78 sampled participants respectively.

Data was collected using questionnaires, structured interviews and case study follow-up. Quantitative data was analysed using SPSS version 26 while qualitative data was analysed using the themes that emerged. Pearson's chi square was used to test association between the nurses and midwife's knowledge and CPD effectiveness in clinical practice.

The study was approved by the Chuka University research, Ethics and Review Committee (ethics committee number **NACOSTI/NBC/AC-0812).** Permission was also sought from the specific Sub-County hospitals and from Meru County Government. Potential participants were taken through informed consent procedures. Participant took part in the study voluntarily and were assured of confidentiality, privacy, and their right to withdraw from the study as and when they wish. Coded data was linked only on a paper participant tracking form which was stored in a locked file cabinet at the study site accessible only to study investigators and study clinician, after which they were transferred to research office. Instruments were checked for precision and comprehensiveness then prepared for upload. Reserve copies, including electronic sets of all data files were safely stored, and any extra information saved in hard disk drives.

Results

Results showed low participation in Continuing Professional Development (CPD) activities among nurses and midwives, alongside significant gaps in midwifery knowledge and clinical skills.

Table 1 presents results on participation in CPD activities. 68.6% of respondents had participated in professional development activities within the last 6 months while 12.8% had not engaged in professional development activities for more than 2 years implying that that there may be differences in knowledge based on levels of CPD uptake.

Table 1: Nurses and midwives last participation in CPD

Participate in professional development activity	Frequency	Percent
less than a month ago	6	8.6
1-6 months ago	42	60
7-11 months ago	5	7.1
1-2 years ago	8	11.4
more than 2 years	9	12.8
Total	70	100

Statistical analysis showed a strong association between CPD effectiveness and improved knowledge levels ($p < 0.001$), emphasizing the importance of CPD in enhancing clinical competencies.

Figure 1: Respondents Key job roles.

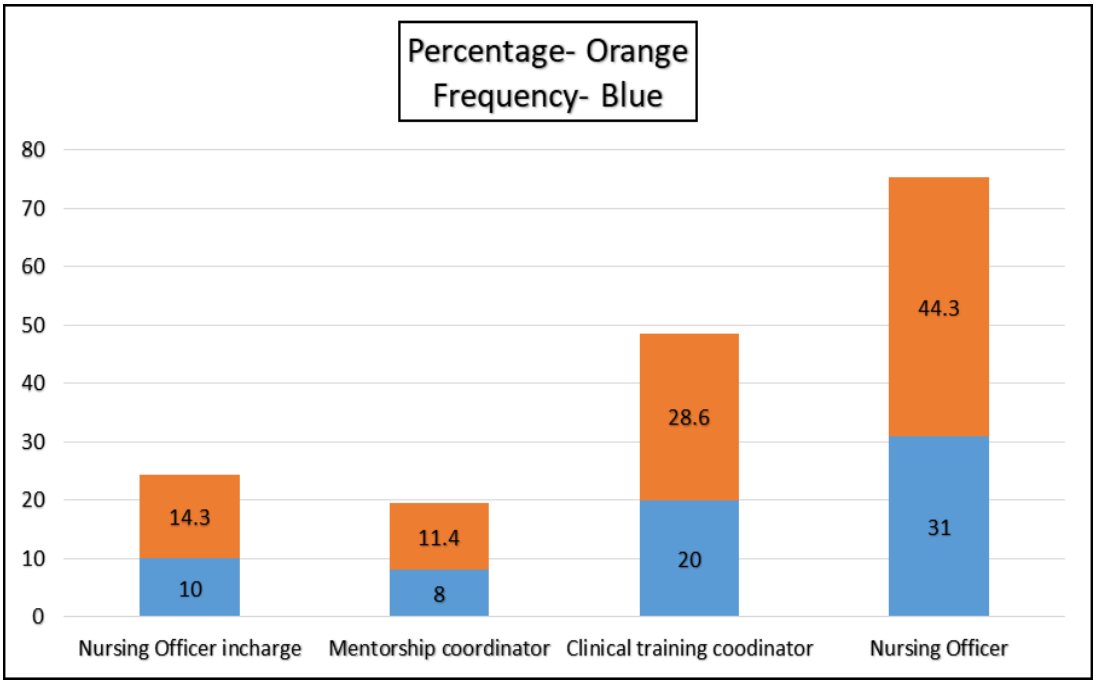


Figure 1 above shows that mentorship coordinators, comprising 11.4% played a key role in continuous learning. This is a team that is meant to take charge in mentoring and orienting young staff into developing holistically as professionals. They ensure that learning takes place in liaison with the Continuous medical education coordinator and the nursing officer in charge. However, results showed that these personnel were few across the different facilities nonetheless suggesting that this role is relevant and was actively employed within the continuing education context.

Table 2: Respondents Engagement in CPD Activities

CPD Activity	Never	Less Often	Often	More Often	Always
	Freq(%)	Freq (%)	Freq(%)	Freq (%)	Freq (%)
Weekly CPD	10(14.3)	19 (27.1)	9 (12.9)	26 (37.1)	5 (7.1)
Upgrading Program	19(27.1)	14 (20.0)	26(37.1)	6 (8.6)	4 (5.7)
Workshops	20(28.6)	35 (50.0)	7 (10.0)	0 (0.0)	7 (10.0)
Seminars	16(22.9)	31 (44.3)	9 (12.9)	5 (7.1)	7 (10.0)
Research	40(57.1)	20 (28.6)	4 (5.7)	0 (0.0)	5 (7.1)

Journaling	54(77.1)	7 (10.0)	4 (5.7)	1 (1.4)	3 (4.3)
Scientific Conferences	38(54.3)	25 (35.7)	3 (4.3)	0 (0.0)	3 (4.3)
Online Courses by NCK	12 (17.1)	9 (12.9)	14(20.)	12 (17.1)	22(31.4)

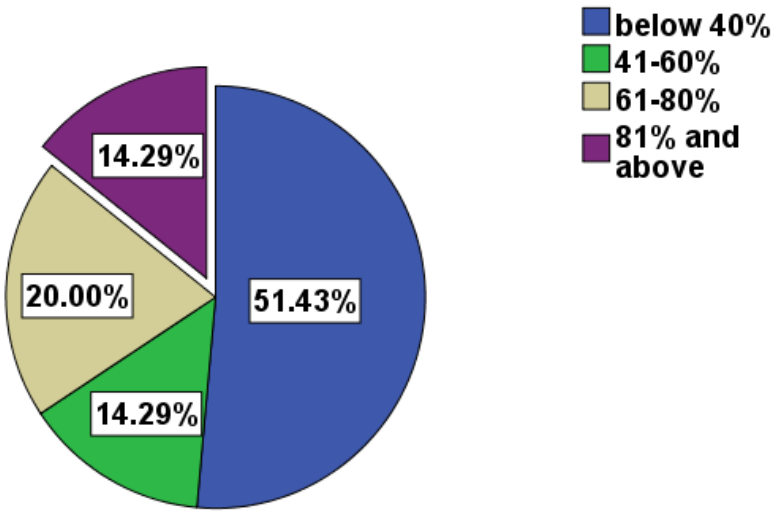
Results of this study showed that online courses by NCK seem to have a higher engagement level, with a notable portion of respondents indicating they engage in them often (20%) or always (31.4%), while scientific conferences also show a balanced distribution. This interpretation suggests a varying degree of engagement in different CPD activities among nurses and midwives.

Table 3: Respondents facilitation for CPD activities attended

Facilitation for most CPD activities attended	Self	15	21.4
	Hospital	16	22.8
	training agency	34	48.6
	Others	5	7.1

Respondents indicated that CPD activities (48.6%) were facilitated by training agencies. This highlights the reliance on external organizations specialized in providing professional development training.

Figur 2: Weekly competent time used in care, training and clinical instruction



Results showed that 14.3% of respondents spent between 41% and 60% of their weekly competent time on patient care, clinical training, and clinical instruction. This reflects a moderate level of engagement in these activities for this group.

Table 4: Utilization of midwifery clinical competency guidelines

Variable	Frequency	Percent
Facility Utilize WHO Patograph		
Yes	42	60.00%
No	26	37.10%
Don't know	2	2.90%
Updated MOH Document Available		
Yes	26	37.10%
No	17	24.30%
Don't know	27	38.60%
Usage of Manual as Reference Material		
Not at all	16	22.90%
Less often	44	62.90%
Monthly	3	4.30%

Weekly	2	2.90%
Everyday	5	7.10%
Do you have any Program on Safe Motherhood Concerns		
Yes	11	15.70%
No	51	72.90%
Don't know	8	11.40%

The study sought to find out the hospital's frequency in utilization of the manuals for reference. Responses were presented in frequencies and percentages. 62.9% of respondents indicated that they less often used manuals as reference materials which should be tied to evidence-based information to support informed decision-making in midwifery practices.

Table 5: Number of clients attended by the Nurses and midwives per week.

Number of clients attended by the Nurses and midwives/week	N	Mean	Std. Deviation
Number of antenatal clients served per week	64	47.64	35.665
Births attended per week	62	16.55	21.825
Estimate number of postpartum clients Seen per week	65	25.03	15.546
Number of newborns you attend to per week	52	20.31	15.362
Valid N (listwise)	51		

Notably, the number of births attended per week was compiled from respondents. Responses are presented in frequencies, percentages and on table 6 below. A mean of 16.55 births are attended per week, with a standard deviation of 21.825. This indicates substantial variability in the number of births attended per week. This shows that nurses and midwives play a critical role in attending births. However, the variation in workload may stem from factors such as facility size, geographic location, and patient population characteristics.

Table 6: Relationship between the nurses and midwives' knowledge and CPD uptake in clinical practice.

Chi-Square Tests			
	Value	Df	Asymptotic Significance (2-sided)
Pearson Chi-Square	17.716[a]	2	.000
Likelihood Ratio	17.301	2	.000
Linear-by-Linear Association	13.505	1	.000
N of Valid Cases	70		
Chi-square value=17.716, P=0.000 df=2			

Notably, interview results indicated a marked improvement in participants' performance following training interventions. Mean scores increased from 79.30% to 91.34%, and paired sample tests confirmed a significant 35.81% improvement in clinical skills after training ($df = 24$, $p < 0.001$). These findings highlight the positive impact of structured CPD programs on clinical outcomes.

Despite these improvements, serious gaps were observed in the practice of Active Management of the Third Stage of Labour (AMTSL), with only 17.9% of participants applying this essential intervention correctly. This indicates persistent weaknesses in prevention of postpartum haemorrhage, a leading cause of maternal mortality.

Pertaining antenatal care competencies, nurses and midwives demonstrated good understanding of the Expected Date of Delivery (EDD) based on the Last Menstrual Period (LMP). However, areas with poor responses, where improvement is needed, included counseling on formulation of an individual birth plan and recognizing danger signs. Competencies on normal labor demonstrated that nurses and midwives generally have a good understanding of practices during normal labor, However, there are instances where immediate actions during labor, such as active management of the third stage of labor 12(17.9%), require more attention.

In regard to immediate newborn care, there is need for improvement in areas such as assessing the APGAR score 18(26.9%) and performing parts of the newborn resuscitation procedure 55(82.2%), where correct responses are lower compared to other aspects. Nurses and midwives demonstrated good understanding of counseling on postpartum danger signs and prevention of breast engorgement. However, the need for improvement in areas such as achieving proper breast attachment to minimize nipple cracking 22(32.8%).

Many participants demonstrated limited ability to accurately complete and interpret partographs, particularly in monitoring critical fetal parameters such as descent and cervical dilation. These skill gaps pose risks to effective labour monitoring and timely intervention.

The challenges faced by respondents in the completion of the patograph was depicted thematically in the following quotations:

"I have no time to fill the patograph"- nurses and midwives

"There is too much work I don't think I can complete this work" - nurses and midwives

"We are very few staff during the shifts so I don't think it will be possible to fill this patograph" - nurses and midwives

There was low engagement in CPD programs. More than half of the participants (54.3%) described the sessions as uninteresting, while 57.1% reported attending CPD activities mainly due to employer pressure rather than personal motivation. This lack of intrinsic motivation suggests the need for more engaging and relevant training approaches.

Barriers to CPD participation were included staff shortages (35.7%), difficulties balancing work and personal life (40%), high workload stress (52.9%), fear of competency assessments (35.7%), and unsupportive work environments (45.7%). These challenges highlight the need for systemic solutions to improve CPD accessibility and participation among nurses and midwives.

Discussion

12.8% of respondents had not engaged in professional development activities for more than 2 years. This observation is consistent with findings of a previous study [7].

The varied timing of last participation in CPD from this study highlights the need to design a

a variety of CPD options, including workshops, online courses, and conferences to accommodate different learning styles and preferences. Continuous professional development (CPD) for nurses could include involvement in workshops, seminars, conferences, research, and formal training [8]. Additionally, CPD is often a requirement for the renewal of licenses for practicing nurses [10]. Results of this study demonstrate that online courses by NCK have a higher engagement level, with a notable portion of respondents indicating they engage in them often (20%) or always (31.4%). This trend reveals the actual behaviour of nurses and midwives when they are due for renewal of their practice requiring them to have acquired 20 hours of CPD courses from programs approved by NCK. There is need to ensure that online courses offered by NCK are accessible and cover a diverse range of topics to cater for different interests and learning needs. In addition, identifying preferred workshop topics can enhance engagement, tailoring seminar topics to address a broader range of interests may boost participation since varied participation levels suggested diverse preferences[3]. Mentorship coordination team liase with education department and the nursing officer in charge in identifying and addressing knowledge and skills gaps through continuous education. However, the small representation of mentorship coordinators (11.4%) means that CPD participation is low. These findings are consistent with previous reports citing importance of providing conducive work environment and guidance for staff to enable them perceive CPD as an opportunity to advance their competence.

The observation that up to 48.6% of respondents depended heavily on training agencies to acquire CPD points to a great risk that most probably touches on lack of initiative to participate in CPD activities in a more structured, consistent and organized way. Low enrolment for CPD activities is due to poor program communication and understanding of the value of the CPD programs, lack of time and pessimistic attitude towards participation in continuous education[10, 11]

That 14.3% of the respondents spent 81% of their weekly competent time on patient care, clinical training and clinical instruction highlights inadequate time for CPDs leading to major gaps in essential competencies. Seemingly, CPD participation has not been a priority for many

participants having great implication on level of knowledge and skills in essential competencies [10].

The study results revealed major gaps in patient to staff ratio as evidenced by the number of clients attended to in one week by the nurses and midwives. This translates to serious staff workloads that contributes to poor participation of the respondents in CPD activities, eventually this leads to poor patient outcomes. Notably, inadequate healthcare workforce, limited funding, lack of self-motivation and poor CPD standardization were major barriers to engagement in CPD activities [12].

62.9% of respondents stated that the tools were less utilized demonstrating a gap to continuous updating of knowledge and skills to improve clinical practice and patient outcomes. This observation agrees with findings from another study that highlighted the importance of using clinical practice guidelines to enhance standard practices and to boost knowledge and skills [13]. Accordingly, emphasis is placed on Evidence Based Practice to ensure that knowledge and skills are improved overtime [14]. Arguably, nurses and midwives acknowledge the need of having reference materials as an important sources of information in practice [15] to evidence-based informed decision-making in midwifery practices. Thus utilization of manuals would enhance knowledge dissemination and standardization of practices across different settings.

Global statistics show that more than half of maternal deaths are attributed to hemorrhage, hypertensive disorders, and sepsis. Addressing these issues necessitates several interventions identified as the "signal functions" for Basic Emergency Obstetric and Newborn Care (BEmONC), as recommended by the United Nations [16]. Postpartum Hemorrhage remains a major burden and a leading cause of deaths in pregnant women. Women with prolonged labor (≥24 hours) were 3.4 times more likely to experience postpartum hemorrhage (PPH) compared to those with labour lasting less than 24 hours [17,18]. Effective management of the third stage of labour relies entirely on proper application of Active Management of the Third Stage of Labour (AMTSL) skills.

Respondents indicated that unplanned work schedule changes, (40%) and lack of adequate staff (35.7%) impeded engagement in CPD for many. Furthermore, balancing CPD with caretaking duties (32.9%) and duty periods (31.4%), personal activities (40%), feeling overloaded (52.9%),

lack of financial support (31.4%), affordability of sessions (30.0%), language barriers (31.4%), lack of courage for competency assessment (35.7%), and unsupportive work environment (45.7%) were cited as major barriers to participation in CPD activities. Elsewhere, heavy and fixed workloads, lack of time and unavailability of co-workers to cover for those attending CPDs [19], technology related challenges [20], unsupportive work environment [21], inadequate staffing levels, limited time available for study, lack of organizational support due to negative cultural practices, issues with CPD design and delivery, and a restricted range of CPD activities. [22]

have also been cited as major impediments to participation in CPD activities.

The partograph, which is a visual tool designed to track labour progress and monitor maternal and fetal conditions over time, is majorly used to offer a visual overview of labour and to notify obstetric care providers of any changes in maternal or fetal conditions or deviations in labour progress [23]. The World Health Organization (WHO) recommends universal use of the partograph during labour. Its routine use aids in making informed decisions for diagnosis and management of prolonged or obstructed labour [19] which contributes to 8% of maternal deaths if not appropriately managed. Effective use of the patograph is a crucial intervention for decreasing both maternal and perinatal morbidity and mortality [23].

In this study, major inconsistencies were observed in charting the various parameters, to include; baseline data, fetal and maternal parameters. These findings are consistent with previous reports indicating that prolonged and obstructed labour, along with delays in decision-making, are significant contributors to maternal and fetal mortality. These complications lead to severe hemorrhage, infections, hypertensive disorders [24].

This study highlights gaps in completeness and accuracy through observation which included; patograph halfway filled; lack of knowledge in the initial charting especially of the cervical dilatation and tie allocation; inconsistency in charting the different parameters; wrong chatting of the different parameters for instance, descent is charted using an 'X' instead of 'O', unclear charting of the contractions was observed where mild contractions are charted together with moderate contractions. These gaps have been highlighted in previous reports [25].

Participants were issued with the patographs to complete, though some of them stated that they had challenges in completing the process. Some of the statements were as follows:

"There is too much work I don't think I can complete this work" - ***nurses and midwives***

"We are very few staff during the shifts so I don't think it will be possible to fill this patograph" - ***nurses and midwives***

"Filling the patograh is very tedious, as long as the mother delivered well, I can just complete them at the last minute, I don't have to give a lot of details" - ***nurses and midwives***

"Iam not sure I know how to complete this tool, if we were trained on how to do it, maybe I will have more confidence, we shall ask thos who understand better to do it instead" - ***nurses and midwives***

These statements are consistent with previous reports that highlighted several constraints that hindered effective use of the partograph during labour namely staff shortages, lack of training, inadequate skills, and insufficient knowledge about the partograph itself [24]. These challenges compromised the quality of care provided. Similar findings were observed at Mulago Referral Hospital, where healthcare workers cited heavy workloads due to understaffing, unavailability of partographs in patient charts, lack of equipment, insufficient skills, and poor attitudes towards using the partograph as reasons for its low completion rate. A related study conducted in Malawi also highlighted key factors contributing to the underutilization of the partograph, such as staff shortages, negligence, a lack of appreciation for the partograph's importance, ineffective and inadequate supervision, lack of recognition or motivation, and skill incompetency [25].

Effectiveness of CPD is totally dependent on continuous training. This study revealed low CPD effectiveness based on the poor performance of participants in the baseline survey that assessed their knowledge and skills. However, CPD effectiveness can be improved if proper strategies are employed to ensure a more structured and organized way of ensuring knowledge and skills acquisition in clinical practice.

CPD Model: Continuous Professional Development Uptake Model on Midwifery Clinical Competencies for Nurses and Midwives (Adopted from ICM Guidelines, 2019)

The primary purpose of a CPD Framework is rooted in the principle of lifelong learning, which requires healthcare professionals to continuously engage in both formal and informal education to maintain clinical competence and acquire new knowledge and skills to enable

them expand their professional roles. One of the major objectives of this study was to develop a model on CPD uptake for nurses and midwives for adoption, as an annex to the CPD framework developed by the Nursing Council of Kenya.

Usually, nurses sign up for courses that lead to attainment of different levels of nursing practice recognized by NCK. For example, an enrolled community nurse (ECN) engaging in a full-time, part-time, or distance learning program may be upgraded to a higher rank such as a registered nurse (RN) [9]. However, CPD activities are occasionally planned for. The employer, a training agent, or sometimes the nurses and midwives individually pay for CPD activities [26]. Therefore, the significance of nurses and midwives participating in CPD as a means of ensuring ongoing expertise and being current in practice is fully acknowledged and appreciated by NCK, although, CPD programs remain typically irregular, without defined structures within hospitals. There is therefore a need to develop a standardized guideline to be accommodated in the main CPD framework provided by the nursing council of Kenya and be considered for adoption for use across the country. The proposed guideline is intended for adoption by NCK to; i) establishes minimum guidelines for all stakeholders involved in CPD, ii) standardize, regulate, strengthen, and harmonize CPD programs and activities. iii. Enhance processes and linkages within the CPD framework, iv) ensure equal access to CPD programs for nursing professionals, v) identify key areas where nursing professionals need CPD training and vi) be used by the Council to compare against international best practices, accredit CPD providers, and advocate for support in developing and training nursing professionals with a view to providing safe, ethical, competent, and high-quality care to the public.

This study seeks to develop a model that focusses on function "v" that states, "*The framework identifies key areas that nursing professionals need for CPD trainings.*" to scale up continuous education. There is need for a standardized structured way of engaging in CPD activities that the can be utilized by nurses and midwives. The model if adopted would be annexed to the existing CPD framework. The model would adopt the ICM Midwifery clinical competencies from the various categories (Table 7 below) with a focus on having all the competencies covered in 4 trimesters within the year. Suggestions will be tabled to the Nursing Council of Kenya is to consider having the CPD course content aligned to the competencies in order to maintain

relevance in practice based on the reports by many respondents in this study that many CPD topics were not relevant to practice.

The model if adopted by NCK would be recommended for adoption and use by different institutions/ health care facilities, and tailored to suit their needs, considering the existing knowledge and skills gaps in the midwifery competencies. Thus by the end of the year, the facilities should ensure that hours given for continuous education are advised by specific competencies and skills gaps. Thus, the facilities across board would be expected to offer education forums based on the competencies and using the model as a tool for reference, to cross-check that basic content from each section is regularly covered.

The CPD activities within the hospitals can be conducted through CMEs, workshops, seminars, among other methods. Development of the CPD model was guided by the concepts outlined in the 'Nursing Professional Development (NPD) Practice Model (2022).

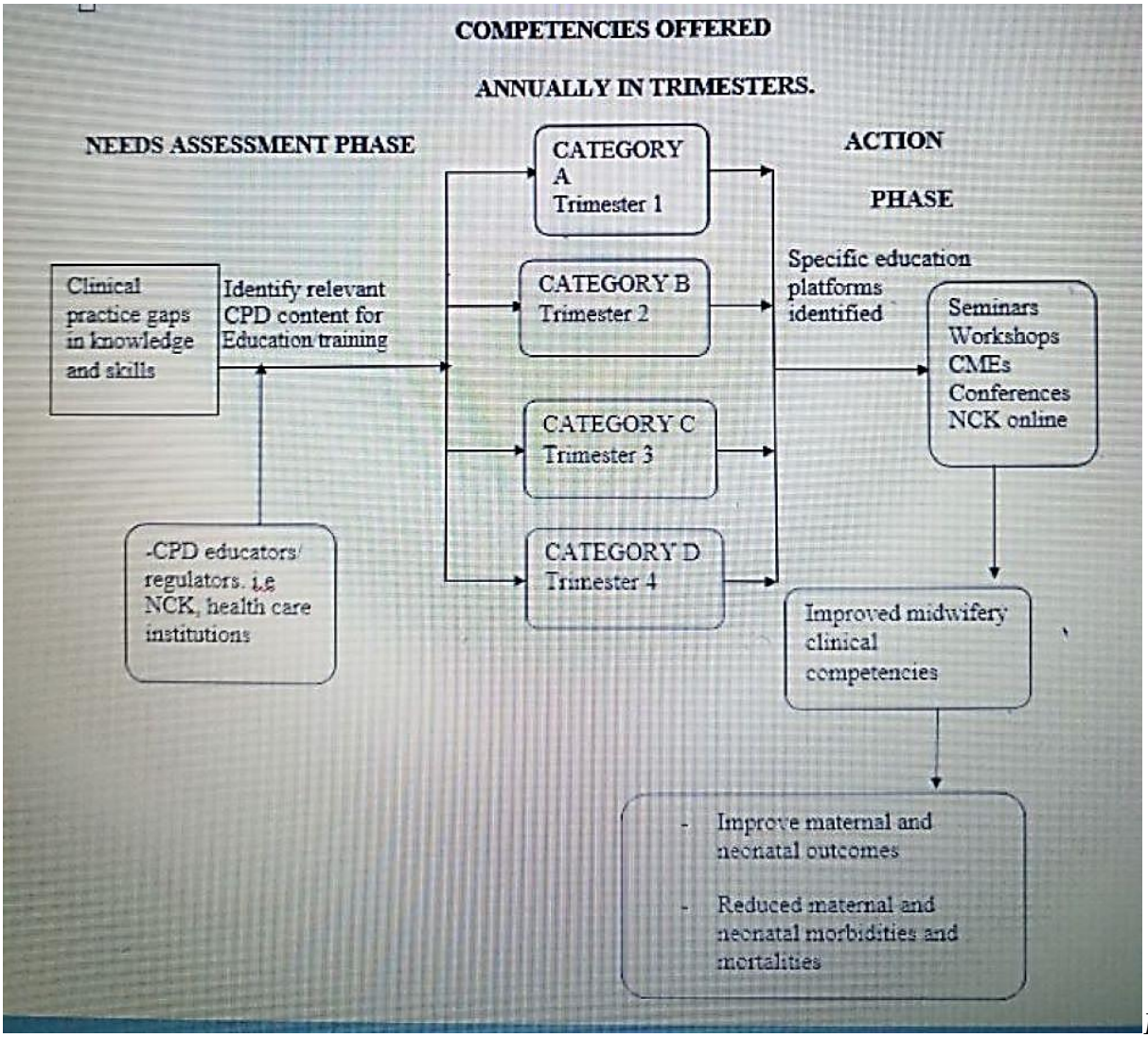


Figure 3: Proposed CPD model by Odhiambo Roselyne (2025).

Table 7: Key to proposed CPD Model

Trimester /category	Category	Key clinical skills competencies
January-March	A: Preconception and contraception	Counselling skills on Preconception care

		Family planning methods
April – June	B: Pregnancy care Competencies in this category involve evaluating the health of the woman and fetus, enhancing health and well-being, identifying pregnancy complications, and providing support to women with unexpected pregnancies.	Performing focused obstetric examination Counselling and testing HIV PMTCT care Counselling on Individual birth plan and complication readiness Fetal monitoring
July-September	C: Labor and delivery care Competencies in this category focus on assessing and caring for women during labor to support physiological processes and ensure a safe birth, providing immediate care to the newborn, detecting complications in the mother or infant, stabilizing emergencies, and making referrals when necessary.	Management of complications like shoulder dystocia, PPH, Severe pre-eclampsia with MgSo4 Performing spontaneous vaginal delivery Active Management of Third stage of labour APGAR scoring for the newborn Induction of labour Monitoring labor progress using the WHO patograph Repair of perineal tears Performing a vaginal examination Manual removal of the placenta Administering an episiotomy and its repair
October - December	D: Care during postpartum period Competencies in this category include performing continuous	Perform postnatal assessment for a mother Counsel on immediate newborn care

	health assessments for both the mother and infant, providing health education, supporting breastfeeding, identifying and managing complications, stabilizing and referring in emergencies, and offering family planning services.	

Conclusion

The **CPD Uptake Model** proposed herein for midwifery clinical competencies is an essential step toward improving professional development of nurses and midwives in Kenya. By structuring CPD activities, aligning them with relevant competencies, and ensuring their integration into healthcare facilities, the model will enhance clinical competence of nurses and midwives, ultimately improving the quality of care for mothers and new-borns. Adopting this model will not only strengthen the healthcare workforce but also contribute to a more effective, accountable, and competent health system that meets the evolving needs of the Kenyan population.

References

1. Sherman L.T., Chappell K.B. (2018). Global perspective on continuing professional development. The Asia pacific scholar 3(2):1.
2. Davidson K.W., Terry M.B., Braveman P., Reis P.J., Timmermans S., Epling Jr JW (2022). Maternal mortality: a National Institutes of Health pathways to prevention panel report. Obstetrics & Gynecology 5:10-97.
3. Sookram B.P., Botha R., Naidoo N. (2023). Accreditor and employer experiences of emergency care CPD provision. International Paramedic Practice 13(3):42-50.
4. Bäck L., Karlström A. (2020). Developing confidence during midwifery training: the experience of Swedish final year students. Sexual & Reproductive Healthcare 25:100535.
5. International Confederation of Midwives (ICM). Essential competencies for midwifery practice. The Hague, Netherlands: International Confederation of Midwives; 2019.

6. Koblinsky M., Moyer C.A., Calvert C., Campbell J., Campbell O.M., Feigl A.B., Graham W.J., Hatt L., Hodgins S., Matthews Z., McDougall L. (2016). Quality maternity care for every woman, everywhere: a call to action. Lancet 388(10057):2307-20.
7. Gitonga L.K., Muriuki N.S. (2014). Evaluation of midwives' and nurses' continuing professional development in reducing maternal and neonatal mortality in Embu county, Kenya. Open Journal of Obstetrics and Gynecology 4(6):249-59.
8. Ni C, Hua Y., Shao P., Wallen G.R., Xu S., Li L (2014). Continuing education among Chinese nurses: A general hospital-based study. Nurse education today 34(4):592-7.
9. Nursing Council of Kenya. Nursing Council of Kenya; 2021. https://engagement.wcea.education/nck
10. Viljoen M., Coetzee I., Heyns T. (2017). Critical care nurses' reasons for poor attendance at a continuous professional development program. American Journal of Critical Care 26(1):70-6.
11. Hosey K.N., Kalula A., Voss J. (2016). Establishing an online continuing and professional development library for nurses and midwives in East, Central, and Southern Africa. Journal of the Association of Nurses in AIDS Care 27(3):297-311.
12. Feldacker C., Pintye J., Jacob S., Chung M.H., Middleton L., Iliffe .J, Kim H.N. (2017). Continuing professional development for medical, nursing, and midwifery cadres in Malawi, Tanzania and South Africa: A qualitative evaluation. PloS one 12(10):e0186074.
13. McGonigle D., Mastrian K.. Nursing informatics and the foundation of knowledge. Jones & Bartlett Learning; 2024 Mar 21.
14. Gong S, Li J, Tang X, Cao X (2022). Associations among professional quality of life dimensions, burnout, nursing practice environment, and turnover intention in newly graduated nurses. Worldviews on Evidence-Based Nursing 19(2):138-48.
15. Alving BE, Christensen JB, Thrysøe L (2018). Hospital nurses' information retrieval behaviours in relation to evidence based nursing: a literature review. Health Information & Libraries Journal 35(1):3-23.
16. World Health Organization (WHO). United Nations Population Fund, United Nations Children's Fund, Averting Maternal Death and Disability Program. Monitoring Emergency Obstetric Care: A Handbook. Geneva: WHO; 2018

17. Amanuel T, Dache A, Dona A (2021). Postpartum hemorrhage and its associated factors among women who gave birth at Yirgalem General Hospital, Sidama Regional State, Ethiopia. Health Services Research and Managerial Epidemiology **8:23333928211062777**.
18. Ngwenya S (2016). Postpartum hemorrhage: incidence, risk factors, and outcomes in a low-resource setting. International journal of women's health 2:647-50.
19. Lhbibani A, Lamiri A, Lotfi S, Tridane M, Belaaouad S (2021). Factors hampering the participation of nursing staff in the continuing education activities of hospitals centers in the Casablanca-Settat region. The Open Nursing **Journal 10;15(1).**
20. Mlambo M, Silén C, McGrath C (2021). Lifelong learning and nurses' continuing professional development, a metasynthesis of the literature. BMC nursing 20(1):62.
21. Jamuna N, Thayumanavan M (2023). Utilization of Partograph for Labor Management Among Healthcare Providers in Healthcare Facilities in India: A Systematic Review. **Cureus 15(8)**
22. Zelellw DA, Tegegne TK (2018). Level of partograph utilization and its associated factors among obstetric caregivers at public health facilities in East Gojam Zone, Northwest Ethiopia. PloS one 13(7):e0200479.
23. Mezmur H, Semahegn A, Tegegne BS (2017). Health professional's knowledge and use of the partograph in public health institutions in eastern Ethiopia: a cross-sectional study. BMC pregnancy and childbirth 17:1-7.
24. Kemei J, Etowa J (2021). Continuing professional development: Perspectives of Kenyan nurses and midwives. Open J Nurs 11(3):121–131.

AI-DRIVEN INFORMATION SERVICES: ARE KENYAN UNIVERSITY LIBRARIES READY?

Ubaga E.M.[1] Gichohi P.M.,[2] Karani J.M.[3]

[1]Daystar University, KENYA

[2]Kenya Methodist University, KENYA

[3]Kirinyaga University, KENYA

***Correspondence** : eubaga@daystar.ac.ke

Abstract

Artificial Intelligence (AI) presents substantial opportunities to advance library services and user experiences in university libraries. However, despite the growing global adoption of AI in university libraries, Kenyan university libraries face challenges that hinder AI-driven innovation, affecting service delivery and user satisfaction. This study assessed the readiness of Kenyan university libraries for AI adoption by examining key enablers and challenges of AI adoption. A systematic review of journal articles and research papers from Google Scholar, EBSCOhost and Emerald databases from 2020-2025 was conducted, focusing on AI adoption in university libraries in Kenya. Themes were identified through thematic analysis, ensuring a comprehensive understanding of AI readiness. Results showed that Kenyan University libraries have poor ICT infrastructure; library staff lack AI specific skills, and users have mixed perceptions about AI use in libraries. These challenges are common across many university libraries in Kenya, and inhibit seamless integration of AI into library operations. Although there are challenges, the interest in AI adoption creates an opportunity for policymakers and universities to promote digital transformation in library services. If these challenges are resolved, Kenyan university libraries can effectively provide AI-driven information services. There is need for government, university administration, and library associations to collaborate, increase funding for AI adoption, formulate appropriate policy and initiate capacity building programs. This paper provides a basis for development of a framework to guide policy and practice in AI-enhanced library service delivery.

Keywords: AI Readiness in Libraries, Artificial Intelligence (AI), University Libraries, AI Integration in Libraries, Digital Transformation.

Introduction

The evolving needs of library users and digital transformation have forced university libraries to change their modes of service delivery [1]. As a result, university libraries have explored and integrated Artificial Intelligence (AI) into their daily operations to meet the ever-evolving user needs while simultaneously remaining relevant in the rapidly evolving technology society [2]. AI is a field of computer science whose aim is to build intelligent systems that can perform tasks that typically need the intelligence of human beings [3]. AI tools have the potential to completely transform university libraries through improvement of efficiency, effectiveness, and usability of their services. According to [4], using AI in university libraries has resulted in the improvement of efficiency and effectiveness of library services such as acquisition, indexing, cataloguing, reference services circulation, and information storage and retrieval. However, while university libraries in the developed world have integrated AI into a range of library services, such as reference and circulation services, those in developing countries like Kenya are still lagging behind [2]. Sang [5] observed that despite the numerous benefits of AI, university libraries in Kenya have exhibited a slow pace of adoption, with most university libraries still relying on traditional library management systems with minimal AI integration.

Given the importance of AI in enhancing information services in university libraries, this study, a systematic review, evaluated the readiness of Kenyan university libraries for AI-driven information services guided by the following objectives.

i. Examining the status of ICT infrastructure readiness to provision of AI-driven information services in university libraries in Kenya
ii. Assessing the library staff level of ICT competence and readiness to provision of AI-driven information services
iii. Users' perception and readiness towards AI-driven information services in university libraries in Kenya

By analyzing global AI adoption trends, identifying enablers and barriers to AI adoption, and evaluating the readiness of Kenyan university libraries to provision of AI-driven information

services, this study offers guidance on how Kenyan university libraries can successfully integrate AI into their operations.

Problem Statement

Artificial Intelligence has a great potential of transforming the services offered by university libraries. A Semi et al 2020 [6] observed that libraries around the world have embraced AI in provision of information services including acquisition, information retrieval, indexing, reference services, and cataloguing and classification of information materials. Tella [7] however noted that, whereas university libraries in the developed world have embraced AI for provision of information services, those in developing nations like Kenya have been slow in adoption of this technology. This assertion is collaborated by observations of Sang (2020) [5] that University libraries in Kenya are still lagging in the use of AI despite the potential of AI in enhancing services. A study by Masinde et al 2024 [2] established that adoption of AI in Kenyan university libraries was still at the initial stages based on the maturity model. Sang 2025 [5] attributed the slow uptake of AI in Kenyan university libraries to inadequate ICT infrastructure, inadequate ICT skills and competencies among library staff, and lack of a policy framework for successful adoption. Thus, if these challenges are not resolved, university libraries in Kenya risk becoming obsolete due to inability to improve their efficiency, effectiveness and user experience. Knowledge of the enablers and challenges of implementing AI in Kenyan university libraries would support development of strategies to accelerate AI adoption for provision of information services.

Literature Review

Literature was reviewed in line with the objectives of the study.

ICT Infrastructure Readiness for AI-driven Information Services

A significant investment in a robust ICT infrastructure is necessary to support deployment of AI in University libraries. Oyile et al 2024 [8] observed that infrastructure comprises computer hardware, software, and the required network infrastructure and connection. The readiness of ICT infrastructure for adoption of AI can be determined by examining the availability, quality and capacity of technical resources required to support AI services such as high-performance computing resources, AI development tools and platforms, network infrastructure and cyber

security procedures(9–11). A study conducted in Saudi Arabian academic libraries by [12] in 2021 established that all the respondents, 29(100%), indicated that AI adoption was hindered by inadequate ICT infrastructure and insufficient technical skills and competencies among the staff. Additionally, the study indicated that the most crucial technical prerequisites for implementing AI technologies in libraries were setting up the right ICT infrastructure, including a robust communication network and contemporary equipment. Amoah and Minishi-Majanja 2023, [13] studied Ghanaian university libraries ICT infrastructure readiness for 4IR and established that 85 (39%) of the respondents indicated that they were somehow ready, 77 (35.3%) were not sure, 36 (16.5%) were sure, and 20 (9.2%) had no idea. Elsewhere, [14] it was observed that poor infrastructure, such as low Internet bandwidth in most of the Tanzanian academic libraries, hindered the deployment of AI in Tanzanian University libraries.

Library Staff ICT Skills and Competencies Readiness for AI-driven Information Services

Integration of ICT in operations of university libraries has resulted in modifications to many activities within the libraries, including automation of previously manual processes for information gathering, processing, and dissemination[7]. To stay relevant in the face of competition in the contemporary online environment, librarians must upgrade their ICT skills and competencies [15]. Effective integration of AI in information services is highly dependent on the librarians' degree of AI literacy [16]. A multidisciplinary approach is required for University libraries to provide AI driven including data literacy, technological competence, critical thinking, and flexibility [17]. Thus, there is need for libraries to have the skills necessary to comprehend how AI works in addition to creatively applying it to information services in order to improve user experiences and their contribution to the spread of knowledge [18]. The AI skills readiness of library staff and competencies for AI-driven information services can be assessed by examining staff competence with basic, intermediate and advanced ICT skills and their confidence in their capacity to successfully utilize AI technologies [19,20]. A study in Pakistani university libraries established that readiness to adopt AI was impacted by factors such as staff's ICT skills and competencies [21]. Another study on AI skills of academic library staff in Nigeria [22] established that academic libraries in Nigeria had significant challenges in effectively using AI technology due to a lack of technical expertise and a skill gap among library personnel.

Users Perception on Readiness for AI-driven Information Services

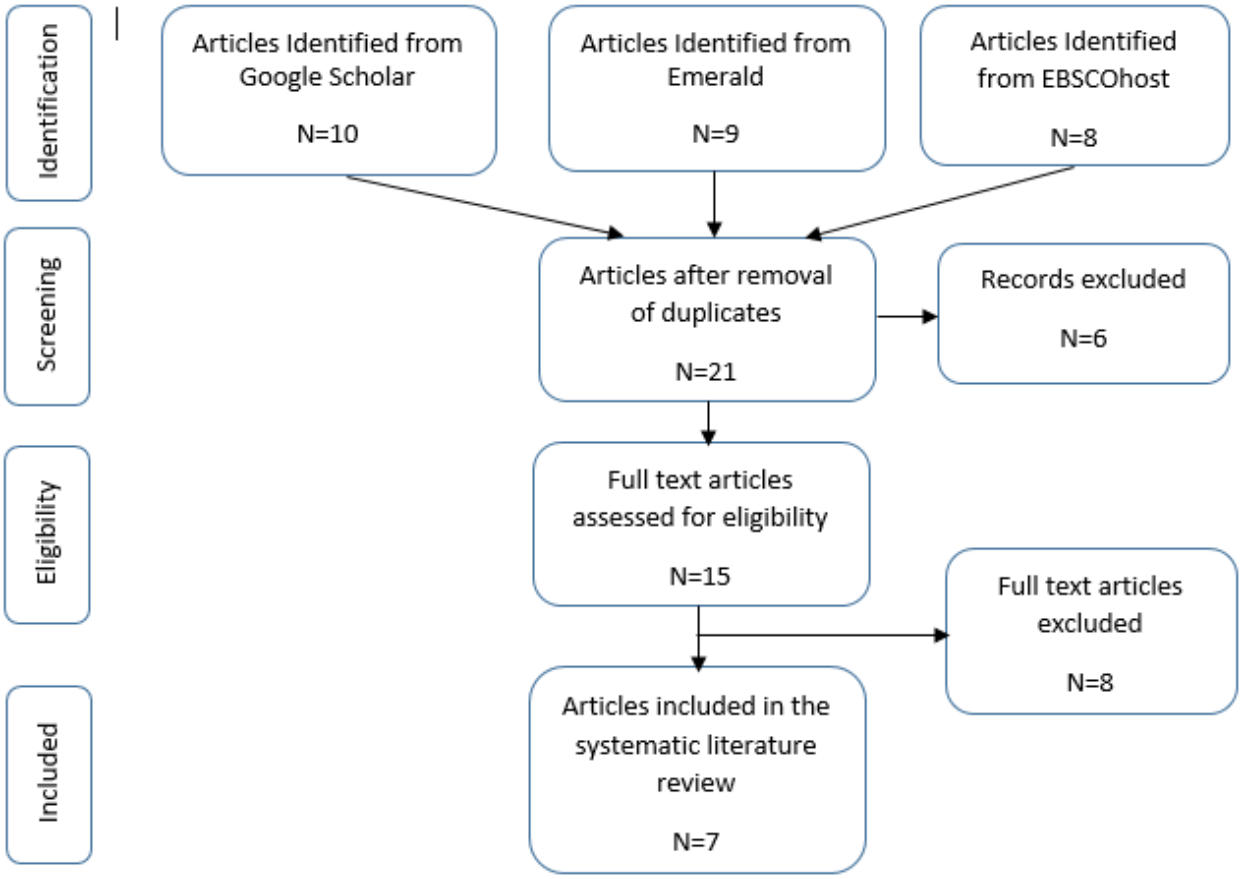
Anyone who comes to the library with the intention of using its resources to meet their information needs is considered a library user. University libraries user communities include students, faculty, and researchers who visit the library with the intention of satisfying their information needs. User readiness for AI adoption is hinged on possession of positive attitudes toward AI-driven information services and possession of the necessary ICT skills and competencies for operating AI systems [23]. The way users perceive AI-driven information services can determine whether the adoption of AI is successful or not [24]. Thus, if users have doubts about AI-driven information services, chances are high that utilization of these services would be poor. User readiness for AI-driven information services can be assessed by the users' perceived usefulness of AI, perceived ease of using of AI, and their perception of the challenges of AI. A study of library users in Pakistani university libraries established that users were generally positive about using AI in libraries, though they had concerns about privacy and the ethical use of information collected by AI systems [25]. Elsewhere, a study on the perception of Korean university libraries students towards AI-related educational content recommendation systems established that all the respondents, regardless of their age, gender, year, or major, intended to use the AI-related educational content recommendation system, with task suitability, perceived benefits and perceived ease of use as the influencing factors [26].

Methodology

A Systematic Literature Review (SLR) was applied to obtain a comprehensive overview of relevant research on the readiness of Kenyan university libraries to providing AI-driven information services [27]. The study was conducted by reviewing journal articles and research papers from Google Scholar and EBSCOhost and Emerald databases. Google Scholar was chosen because of its broad and comprehensive coverage of the research topic, in addition to the open access advantage it offers, Emerald was chosen because of its high quality and peer reviewed content that is focused on library and information science, while EBSCOhost was selected because of its subject specific database with a robust coverage of library and information science. Inclusion criteria included English research articles and papers on the adoption of Artificial Intelligence in Kenyan universities that were published between 2020-2025. Studies focusing on AI applications outside the Kenyan university libraries' context, and

studies in languages other than English were excluded from the study. Book chapters, editorials, and guest editorials were also excluded. To retrieve articles for the study, "Artificial Intelligence" AND "university library" OR "university libraries" AND Kenya was used as the search key phrase. PRISMA model was used to select the final sample of articles that were considered for the study (28) as shown in figure 1 below.

Figure 1: PRISMA model for the systematic review



Ten (N= 10) articles were retrieved from Google Scholar, (N-9) articles from Emerald, and (N=8) articles from EBSCOhost resulting in (N=27) articles from the three databases. Upon merging the results from three databases, (N=6) duplicated records were removed, obtaining a sample of (N=21) articles. Thereafter, all abstracts were used and in case of doubts, complete papers. This resulted in exclusion of (N=6) articles. Reasons for excluding papers varied, such as only covering the librarian's role or minor aspects on the use of AI in university libraries in Kenya. In the end, a total of fifteen (N=15) articles were obtained for closer analysis. These papers were read thoroughly, and (N=8) articles were removed, leaving a final sample of (N=7) articles.

Data extracted from the articles identified for the SLR was categorized into themes based on the study's research questions for more straightforward analysis, enabling key observations to be identified and conclusions to be drawn. Results were presented on tables to enhance clarity and comprehension. Ethical considerations such as clear description of the search strategy, inclusion and exclusion criteria, proper citation and use of genuine and verifiable articles were observed.

Findings and Discussion

ICT infrastructure Readiness for AI-driven information services in university libraries in Kenya

Results of ICT infrastructure readiness for AI-driven information services in university libraries in Kenya are summarized on Table 1 below.

Table 1: Findings on ICT infrastructure readiness for AI-driven information services in university libraries in Kenya

Authors	Year	Main topics covered
Sang, L. J.	2025	Inadequate ICT infrastructure hinder adoption of AI
Masinde, J. M. , Mugambi, F. & Wambiri, D. M.	2024	Inadequate ICT Infrastructure due to the high cost of AI tools
Nzioki, R.	2021	Deployment of basic ICT infrastructure to support AI Financial resources required to upgrade the ICT infrastructure, internet connectivity and other ICT related facilities in order to support adoption new disruptive technologies

These findings revealed that Kenyan university libraries lack the necessary ICT infrastructure to support AI-driven information services [2,5,29]. This is because AI tools and systems rely on good ICT infrastructure that includes high speed Internet, scalable storage, high performance computers and proper cybersecurity measures. Poor ICT infrastructure in Kenyan university libraries is attributed to high cost of AI tools such as RFID technologies [2,29]. These findings agree with previous reports of several other studies in Saudi Arabia, [13] in Ghana, and [14] in Tanzania that established one of the reasons why AI had not been adopted in the university libraries in their studies was poor ICT infrastructure. According to [30], if the challenges with the

ICT infrastructure are not resolved, they will prevent university libraries in Kenya from reaping the numerous benefits that AI may provide. University libraries in Kenya therefore need to make substantial investments in the ICT infrastructure in order to provide AI-driven information services.

Staff ICT Skills and Competencies Readiness for AI-driven information services in University libraries in Kenya

Results on the staff ICT skills and competencies in readiness for AI-driven information services in university libraries in Kenya are summarized on Table 2 below.

Table 2: Results on staffs' ICT skills and competencies readiness for AI-driven information services in university libraries in Kenya

Authors	**Year**	**Main topics covered**
Masinde, J. M. , Mugambi, F. & Wambiri, D. M.	2024	Scarcity of skilled personnel
Jebet, T. & Gichugu, M.	2025	Staff are moderately well informed on AI's use in libraries Need for training and awareness programs on AI tools
Chepchirchir, S. & Kagoiya, R.	2025	Training and skill gaps in staff to manage AI tools
Sang, L. J.	2025	Significant gap in training on using AI tools
Nzioki, R.	2021	Staff to upgrade and update their skills
Abok, V, & Masako, D. R.	2024	Staff training and support for seamless integration
Sang, L. J.	2024	Policymakers need to make investment in staff training a priority to enhance their readiness to adopt AI

These findings reveal a skills gap among the library staff in university libraries in Kenya, with some librarians being moderately informed on the use of AI in libraries [2,31,32]. It has also been reported elsewhere that librarians in Kenyan university libraries lack proficiency in advanced ICT skills such as deep learning, big data and analytics that are necessary for effective use of AI systems [2,5,30,33,34]. Thus, for seamless integration of AI in information services, there is need for librarians to be trained on use of AI tools in libraries [5,29,31,32,35,36]. These findings corroborate

previous reports [18] showing that there was need for university libraries to invest in the training of their staff to accelerate uptake of AI.

User perception or readiness for AI-driven information services in university libraries in Kenya

Results on the user perception on readiness for AI-driven information services in university libraries in Kenya are summarized on Table 3 below.

Table 3: Results on user' perception readiness for AI-driven information services in university libraries in Kenya

Authors	**Year**	**Main topics covered**
Chepchirchir and Kagoiya	2024	Lack of trust in AI-driven tools and services.
Sang L. J.	2025	Ethical concerns Users comfortable in utilizing AI-powered resources AI-powered tools are user friendly and effective.
Masinde, J. M. , Mugambi, F. & Wambiri, D. M.	2024	AI can streamline various library processes Users confident in their own skills to utilize AI tools Positive experiences with AI tools
Nzioki, R.	2021	AI tools significant to the library users

These results indicate that users in Kenyan university libraries were comfortable using AI-powered resources, they found AI tools to be friendly and effective, they believed AI could streamline various library processes, they were confident in their own skills to use AI, and had had positive experiences with AI tools [2,5,29]. These findings reflect a positive perception among library users toward AI-driven information services, positioning it as a valuable asset in the future of Kenyan university libraries. These findings are corroborated by reports of other studies on university library users in Pakistani [25] and on Korean university libraries' users [26] which established that users were overwhelmingly positive about the use of AI-driven information services. However, concerns such as the ethical use of AI tools and lack of trust in AI systems [5,31] could contribute to resistance to change [5]. These concerns align with global discussions about responsible AI and reflect anxieties about the use and potential misuse of sensitive data in academic environments [37,38]. To address the issues of privacy concerns, there

is need for university libraries to put in place ethical frameworks that would ensure safe and responsible use of AI-driven information services [39].

Conclusion

This study assessed the readiness of Kenyan university libraries for AI-driven information services. Based on the findings, it was concluded that the ICT infrastructure in Kenyan university libraries was not ready for AI driven information services. That in as much as the libraries had foundational ICT infrastructure, they lacked advanced computing systems and reliable network connectivity. Consequently, there is need for university libraries to invest in strengthening their ICT infrastructure to enable them provide AI-driven information services. Library staff were not ready, with majority lacking in advanced ICT skills required to handle AI tools and systems in the library. This calls for structured training programs to equip library staff with the requisite ICT skills and competencies. Library users had a positive attitude and perception towards AI-driven information services. However, they also recognized the privacy, ethical concerns in the use of AI that must be addressed for successful provision of AI-driven information services.

6.0 Recommendations

University libraries should partner with other stakeholders such as the developers of AI tools and library users to ensure customization of the AI tools to the specific needs of the library users. There is also need for university libraries in Kenya to create AI adoption policies that address the privacy and ethical concerns that surround the use of AI for provision of information services.

References

1. Hussain A. Use of Artificial Intelligence in the library services: Prospects and challenges. Library Hi Tech News 2023. 40(2):15–7. A https://doi.org/10.1108/LHTN-11-2022-0125

2. Masinde JM, Mugambi F, Wambiri DM. Exploring the current landscape of Artificial Intelligence adoption in Kenyan academic libraries. In: Proceedings of the 17th International Conference on Theory and Practice of Electronic Governance [Internet]. New York, NY, USA: Association for Computing Machinery; 2024. 403–8. (ICEGOV '24). https://dl.acm.org/doi/10.1145/3680127.3680156

3.Kamble AM. Transforming academic libraries: Tapping into the power of Artificial Intelligence tools (2023). Aarhat Multidisciplinary International Education Research Journal XII(V):13–9. https://www.aarhat.com/journals/amierj

4.Abba T. Use of Artificial Intelligence technologies in rendering library services: Empirical evidence from university libraries in Africa. Informology 2023;2(2):23–40. https://informology.org/2023/v2n2/a21.pdf

5.Sang LJ. Artificial Intelligence (AI) for smart library systems: A focus on awareness and level of adoption in the kenyan university libraries. CUEA Journal of Science. 2025;2(1).

6.Asemi A, Ko A, Nowkarizi M. Intelligent libraries: A review on Expert Systems, Artificial Intelligence, and robot. Library Hi Tech 2020 ;39(2):412–34. https://doi.org/10.1108/LHT-02-2020-0038

7.Tella A. Robots are coming to the libraries: Are librarians ready to accommodate them? Library Hi Tech News 2020. 37(8):13–7. https://www.emerald.com/insight/content/doi/10.1108/LHTN-05-2020-0047/full/html

8.Oyile PO, Ongare RM, Ikoha AP. Assessing ICT infrastructure requirements for AI-powered virtual assistants in delivering ICT technical support to Kenyan public universities. International Journal of Advanced Research in Computer and Communication Engineering 2023. 12(8):27–36. https://www.researchgate.net/publication/373328412

9.Masawi A, Matthee M. Guidelines for the adoption of Artificial Intelligence in identity and access management within the financial services sector. In: Nagar AK, Jat DS, Mishra D, Joshi A, editors. Intelligent Sustainable Systems. Singapore: Springer Nature Singapore; 2024. 111–27. (Lecture Notes in Networks and Systems; vol. 812). https://link.springer.com/10.1007/978-981-99-8031-4_11

10.Sangwan RS, Badr Y, Srinivasan SM. Cybersecurity for AI systems: A survey. Journal of Cybersecurity and Privacy 2023.3(2):166–90. https://www.mdpi.com/2624-800X/3/2/10

11.Tursunbayeva A, Chalutz-Ben Gal H. Adoption of Artificial Intelligence: A top framework-based checklist for digital leaders. Business Horizons 2024. 67(4):357–68. https://www.sciencedirect.com/science/article/pii/S000768132400051X

12.Farag HA, Mahfouz SN, Alhajri S. Artificial Intelligence investing in academic libraries: Reality and challenges. Library Philosophy and Practice 2021. (150;1–34. https://www.proquest.com/openview/6066025cec97947027134fcb198f8d41

13.Amoah GB, Minishi-Majanja MK. Ghanaian university libraries' preparedness for the fourth industrial revolution. African Journal of Library, Archives & Information Science 2023 22];33(1):51–64.
https://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=163503626&site=ehost-live

14. Mwilongo K, Mwageni R. Assumptions of the future application of Artificial Intelligence in Tanzanian academic libraries: A review of literature. In: Proceedings of the 4th COTUL Scientific Conference, Arusha: Dar es Salaam University Press (DUP); 2022. 201–23. https://cotul.or.tz/phocadownloadpap/2022-Proceeding_New/13 ASSSUMPTIONS%20OF%20THE%20FUTURE.pdf

15. Narasappa KC, Kumar PD. ICT skills for LIS professional in the digital environment. International Journal of Research in Library Science 2016.2(2):55–8. https://www.ijrls.in/wp-content/uploads/2016/08/ICT-Skills-for-LIS-Professional-in-the-Digital-Environment.pdf

16. Alam AF, Subaveerapandiyan A, Mvula D, Tiwary N. AI literacy and Zambian librarians: A study of perceptions and applications. Open Information Science 2024. 17];8(1). https://www.degruyter.com/document/doi/10.1515/opis-2022-0166/html?lang=en

17. David-West BT, Ig-worlu MO. AI-driven future: Strategies and skills development for Nigerian librarians. Gateway Information Journal 2023. 24(1 & 2):20–32. https://www.gatewayinfojournal.org/index.php/gij/article/view/33

18. Ayinde L, Kirkwood H. Rethinking the roles and skills of information professionals in the 4th Industrial Revolution. Business Information Review 2020. 37(4):142–53. ttp://journals.sagepub.com/doi/10.1177/0266382120968057

19. Bhargava A, Bester M, Bolton L. Employees' perceptions of the implementation of Robotics, Artificial Intelligence, and Automation (RAIA) on job satisfaction, job security, and employability. J technol behav sci 2021.6(1):106–13. https://link.springer.com/10.1007/s41347-020-00153-8

20. Edelmann N, Mergel I, Lampoltshammer T. Competences that foster digital transformation of public administrations: An Austrian case study. Administrative Sciences 2023.13(2):44. https://www.mdpi.com/2076-3387/13/2/44

21. Jan SU, Khan MSA, Khan AS. Organizational readiness to adopt Artificial Intelligence in the library and information sector of Pakistan. EBLIP 2024. 19(1):58–76. https://journals.library.ualberta.ca/eblip/index.php/EBLIP/article/view/30408

22. Ogwo U, Ibegbulem F, Nwachukwu VN. Applications and perceived impact of Artificial Intelligence in academic libraries in Nigeria. Library Philosophy and Practice (e-journal) L 2023;(7907). https://digitalcommons.unl.edu/libphilprac/7907

23. Owolabi KA, Okorie NC, Yemi-Peters OE, Oyetola SO, Bello TO, Oladokun BD. Readiness of academic librarians towards the use of robotic technologies in Nigerian university libraries. Library Management 2022. 43(3/4):296–305. Ahttps://doi.org/10.1108/LM-11-2021-0104

24.Modiba M. User perception on the utilisation of Artificial Intelligence for the management of records at the council for scientific and industrial research. CC 2023. 22];42(3):81–7. https://www.emerald.com/insight/content/doi/10.1108/CC-11-2021-0033/full/html

25.Shaheen MA, Khurshid A. Perceptions and experiences of Artificial Intelligence (AI) use in libraries: A study of library users in Pakistan. Library Philosophy & Practice. 2023 [cited 2024 Jun 30];1–13. Available from: https://digitalcommons.unl.edu/libphilprac/7905/

26.Seonghun K, Park J, Oh Y, Park S. A study on the intention to use of the AI-related educational content recommendation system in the university library: Focusing on the perceptions of university students and librarians. Journal of Korean Library and Information Science Society 2022.;53(1):231–63. https://doi.org/10.16981/KLISS.53.1.202203.231

27.Williams M, Wiggins R, Vogt PR. Beginning quantitative research [Internet]. SAGE Publications Ltd; 2021. https://methods.sagepub.com/book/beginning-quantitative-research

28.Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. bmj 2021. 8];372. https://www.bmj.com/content/372/bmj.n71.short

29.Nzioki R. An assessment of the level of adoption of disruptive technologies in academic libraries in Kenya: A case study of the Mahatma Gandhi graduate research library, University of Nairobi, kenya [Internet] [PhD Thesis]. University of Nairobi; 2021 http://erepository.uonbi.ac.ke/handle/11295/161040

30.Akello J. Artificial Intelligence in Kenya Nabenyo E, editor. Paradigm Initiative; 2022. https://paradigmhq.org/wp-content/uploads/2022/02/Artificial-Inteligence-in-Kenya-1.pdf

31.Chepchirchir S, Kagoiya R. Integrating Artificial Intelligence literacy in Library and Information Science training in Kenyan academic institutions. In: Standing Conference of Eastern, Central and Southern African Library and Information Associations (SCECSAL XXVI) Mombasa: SCECSCAL; 2024. https://karuspace.karu.ac.ke/handle/20.500.12092/3201

32.Jebet T, Gichugu M. Adoption and use of artificial intelligence tools in service delivery in selected academic libraries in Kenya. International Academic Journal of Information Sciences and Project Management 2025. 3(7):287–301. https://ir-library.ku.ac.ke/bitstreams/8208d9e1-e177-44c7-bafc-5dc81486f2d6/download

33.Agava SL, Underwood PG. ICT proficiency: Perspectives of Tangaza University College librarians in Kenya. LM 2020. 41(6/7):487–501. https://www.emerald.com/insight/content/doi/10.1108/LM-03-2020-0057/full/html

34.Maina PK, Muthee DW. Preparedness towards adoption of cloud computing technologies by academic libraries in Kenya. ijrls 2020.6(1):200. http://www.ijrls.in/wp-content/uploads/2020/07/Preparedness-towards-adoption-of-cloud-computing-technologies-by-academic-libraries-in-Kenya.pdf

35.Abok VA, Mosako DR. Futuristic view of robotics in enhancing library accessibility for differently-abled users in Kenya and south africa. Re-Imagining Library and Information Services in the Digital Era/editors, Tom Kwanya, Irene 2024. 128. https://www.researchgate.net/profile/Kizito-Ongaya/publication/384254095_Policy_Challenges_in_Establishing_Institutional_Repository_Business_Process_Modelling_of_Universities_in_Uganda/links/66f153d997a75a4b48414ff7/Policy-Challenges-in-Establishing-Institutional-Repository-Business-Process-Modelling-of-Universities-in-Uganda.pdf#page=138

36. Sang LJ. Adopting artificial intelligence in Kenyan academic libraries: analyzing through the technology-organization-environment framework. Library Management 2024. https://www.emerald.com/insight/content/doi/10.1108/lm-03-2024-0029/full/html

37. Gajbhiye CK. Impact of Artificial Intelligence (AI) in library services. IJFMR - International Journal for Multidisciplinary Research 2024.6(3). https://www.ijfmr.com/research-paper.php?id=22452

38. Mallikarjuna C. An analysis of integrating Artificial Intelligence in academic libraries. SSRN Journal 2024. https://www.ssrn.com/abstract=4898532

39. Shahzad K, Khan SA, Iqbal A, Javeed AMD. Identifying university librarians' readiness to adopt Artificial Intelligence (AI) for innovative learning experiences and smart library services: An empirical investigation. Global Knowledge, Memory and Communication 2024. https://doi.org/10.1108/GKMC-12-2023-0496

CONSTRUCTION INDUSTRY OUTPUT GROWTH RATE RESPONSE TO INFLATION RATE IN KENYA

Mbusi E.T.

Kirinyaga University, Kenya
Correspondence: *embusi@kyu.ac.ke*

Abstract

Construction industry is a key sector in a nation's economy, and therefore, understanding the effects of inflation on this industry can enable policymakers to ensure its stable growth and contribution to Kenya's Gross Domestic Product (GDP). This study presents empirical findings on the impact of inflation rate (IR) on construction output growth rate (COGR) and its implications for policy formulation. A time series data analysis approach was employed, using data from the Kenya National Bureau of Statistics (KNBS) and Central Bank of Kenya (CBK), covering 47 years (1977–2023). Data was analysed using EViews version 10, incorporating graphical analysis, correlation analysis, stationarity tests, and regression analysis. Construction output growth rate (dependent variable) was regressed against the inflation rate (independent variable) using second-difference transformations. Results showed that IR had no immediate significant impact on the growth of Kenya's construction industry, as indicated by a coefficient of determination (R^2) of 0.000043. However, a lagged regression model demonstrated a stronger explanatory power, with an R^2 value of 0.594232, suggesting that inflation influences construction output growth with a time lag. These findings highlight the delayed effects of inflation on the industry and provide insights for economic and policy interventions.

Keywords: Construction output, Time series, Stationarity, Explanatory power

Introduction

Due to its size, construction industry is important to global economy. Several reasons in support of this notion have been outlined in Hillebrandt[1] who attributed this to Significant Output Contribution (SOC) by the industry. The industry produces a large output, making it a significant part of the economy. It accounts for approximately 10% of the Gross National Product (GNP) globally, which translates to approximately US$3,000 billion as of 1997. The second reason for viewing this industry as important, according to Hillebrandt[1] is due to Investment Goods Production (IGP). The industry produces investment goods, which are essential for further production, infrastructure improvement, social investment, and direct enjoyment. These include factory buildings, roads, hospitals, and housing. Wholesomely, this has a value addition to the country's economy as noted by Hillebrandt[1]. Therefore, performance and management of the industry are a major concern to everyone who is keen on keeping it playing its role in a specific economy. However, it is not clear whether the inflation rate has any bearing on the growth rate of the industry in Kenya. This poses a challenge in policy design and implementation regarding its growth.

The third reason for branding the industry as important is Employment Generation (EG). Construction is more labour-intensive compared to many other industries, which means it generates substantial employment. This can have a multiplier effect, where the wages paid to construction workers are spent on other goods and services, further boosting the economy. Fourthly, as observed in Hillebrandt[1], the industry is an Economic Indicator (EI). The size and activity level of the construction industry often reflect the overall health of the economy. High levels of construction activity typically indicate economic growth, while low levels may signal economic downturns. Finally, there is the Government's Influence (GI) through the industry. Governments often use the construction industry as a tool for economic management. Thus, by increasing or decreasing public sector construction projects, they can influence overall economic activity.

Overall, the construction industry's size and output are crucial for economic stability, growth, and development. Hillebrandt[1] further noted that the actual value, quantified in monetary terms, of all works involving *buildings and civil engineering* works in the industry produced within a specific time duration, usually a single calendar year, is termed the gross output of the construction industry in any economy.

Construction Industry of Kenya

In Kenya, the construction industry depends a lot on borrowed funds. During the year 2023, the industry borrowed Kshs. 602.7 billion from commercial banks [2]. This translates to a 7.2% increase in borrowing from the previous year; 2022. This means the cost of finance is a critical factor which affects the industry and the inflation rate is a major component of this cost. In 2023, year-on-year inflation was 4.16% as compared to 7.1% in 2022[2].

Trends in the construction industry in Kenya have mostly been very slow and have been fluctuating for a very long time. In the past few years; from 2019 to 2023, as reported in an economic survey by Kenya National Bureau of Statistics (KNBS) displayed Kenya's building and construction to have contributed 6.2%, 7.0%,7.1%, 7.1% and 6.6% to the Gross Domestic Product (GDP). The growth of the industry is shown in the table below.

TABLE 1: Construction Industry Growth

YEAR	2019	2020	2021	2022	2023
% **CHANGE**	7.2	10.1	6.7	4.1	3.0

Source: KNBS[2].

Data presented on the table I above demonstrate that Kenya's construction industry growth fluctuates substantively.

Fluctuations in construction output, often referred to as building cycles, are a common phenomenon in the construction industry. These fluctuations can be attributed to several factors, as observed in Hillebrandt[1], as follows:

(a) **Economic Cycles**: Construction industry is closely linked to overall economy. Thus, when the economy is booming, there is typically an increase in construction activity due to higher demand for residential, commercial, and industrial buildings. Conversely, during economic downturns, construction activity tends to decrease as demand falls. (b) **Government Policies**: Government actions, such as changes in interest rates, public sector spending, and taxation policies, can significantly impact construction output. For example, an increase in interest rates can lead to higher borrowing costs, reducing the demand for new construction projects. (c) **Investment and Demand**: The construction industry produces investment goods, which are often expensive and have a long life. Small fluctuations in the demand for these goods can lead to significant changes in construction output. For instance, a slight increase in demand for housing can result in a substantial rise in construction activity. (d) **Technological Changes**: Advances in construction technology can also cause fluctuations. For example, introduction of new building materials or construction methods can lead to a temporary increase in output as firms adopt these innovations. (e)**External Shocks**: Events such as natural disasters, wars, or significant population changes can cause sudden and significant fluctuations in construction output. These shocks can either increase demand for reconstruction of new buildings or decrease is due to economic instability. (f)**Market Dynamics**: Construction market is influenced by availability and cost of resources, such as labour and materials. Shortages or surpluses of these resources can lead to fluctuations in construction output. From the foregoing observations, it is demonstrable that construction industry is sensitive to a wide range of economic, political, and social factors, leading to inherent fluctuations in output. Therefore, it is rational to establish the impact of the inflation rate and how it interacts with the construction industry of Kenya.

Inflation Rates and the Construction Industry

It is a common factor that inflation rate, which is a key component of interest rates, plays out openly and strongly in any general capital investment. This captures other economic factors as elaborated in Akintoye and Skitmore[3]. Policymakers in both public and private sectors, including real estate property developers, require economic and technical knowledge related to investment decision-making in construction industry for them to maximise their analysis of cost-benefits of an investment. This is alluded to in Akintoye and Skitmore[3], where the level of inflation is said to be among other factors considered in construction investment decision-making.

The cost of construction materials is another factor that one must consider when entering an investment in construction. According to Akintoye and Skitmore[3], economic factors that influence construction investment trends include the following, among others:

(a) **Inflation**: Affecting user's cost of capital and investment decisions. (b) **Price Changes**: There is an inverse relationship between construction investment and price changes. (c) **Interest Rates**: Higher interest rates tend to reduce construction investment.

These factors interact in complex ways to influence the overall trends in construction investment. This paper looks at the influence of levels of inflation in Kenya's construction output growth rate.

Method

To test the significance of the relationship between IR and the Construction Output Growth Rate (COGR) in Kenya, the null hypothesis is that annual changes in the construction industry output growth rate are not significantly affected by annual changes in IR.

Time series analysis was employed to examine the time series data, which were gathered using a data abstraction sheet. The procedure involved entering the data into a computer utilising Microsoft Office Excel software and subsequently opening it in Economic Views (EViews) software as foreign data, which was ultimately converted into an EViews work file. The data were then analysed by conducting graphical, correlation, and stationarity tests, as well as regression analysis. Regression model used in this analysis is:

$$\mathbf{COGR_t = \alpha + \beta_1 IR_t + \beta_2 IR_{t-1} + \ldots\ldots\ldots + \beta_8 IR\text{-}7_t + \varepsilon} \quad [1]$$

Where:

$COGR_t$	=	Construction output Growth Rate at a given time
IR_t	=	Inflation rate at any given time
β	=	Coefficient
α	=	(the value of $COGR_t$ when the explanatory variable is set at zero)
ε	=	Error term or residual
t	=	Specific year

Construction Output Growth Rate (COGRt) was regressed on the inflation rate (IR) using the second differences of the time series data.

Data

I. Graphical Analysis

Fig. 1 illustrates the trend in construction output growth rates from 1977 to 2023. The output growth rate has fluctuated significantly. Figure 2 also indicates that the IR has fluctuated throughout the forty-seven (47) year period, while Figure 3 demonstrates the differing trends of the two time series. This analysis reveals that changes in annual IR are significantly affecting annual construction output growth.

Fig.1: Construction Output Growth Rate (%) (1977 - 2023)

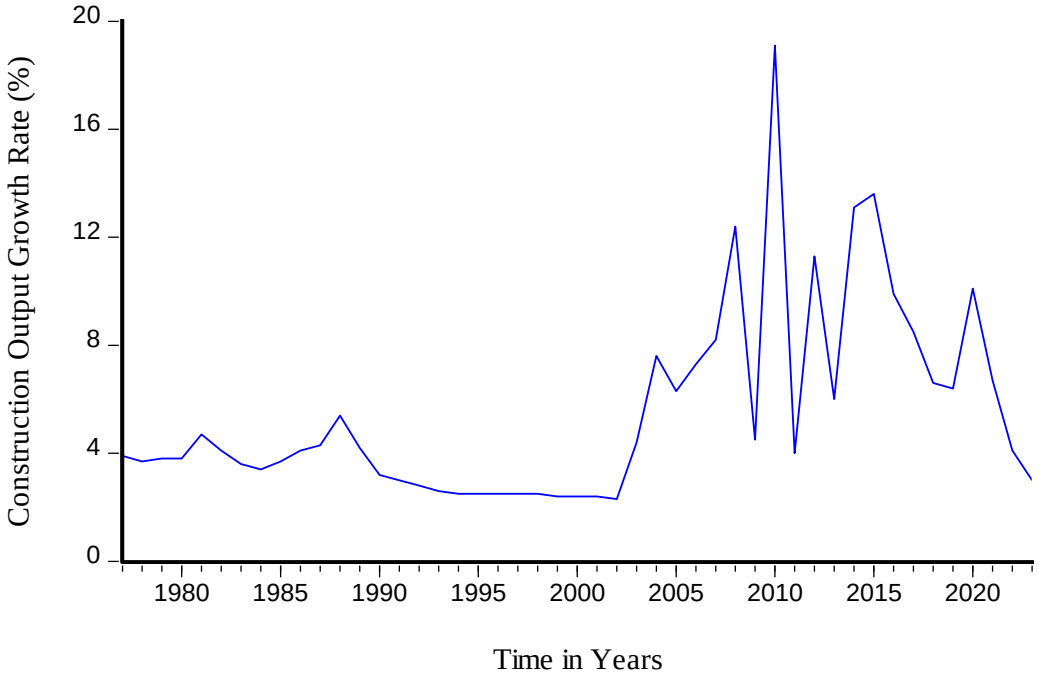


Fig.2: Inflation Rate (%) (1977 -2023)

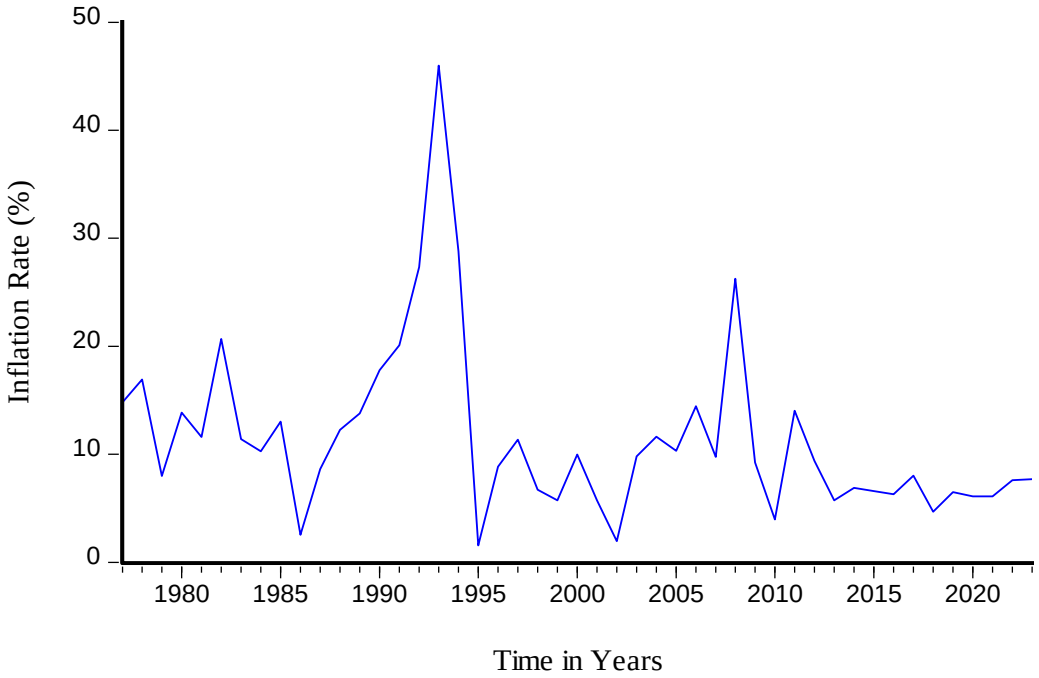
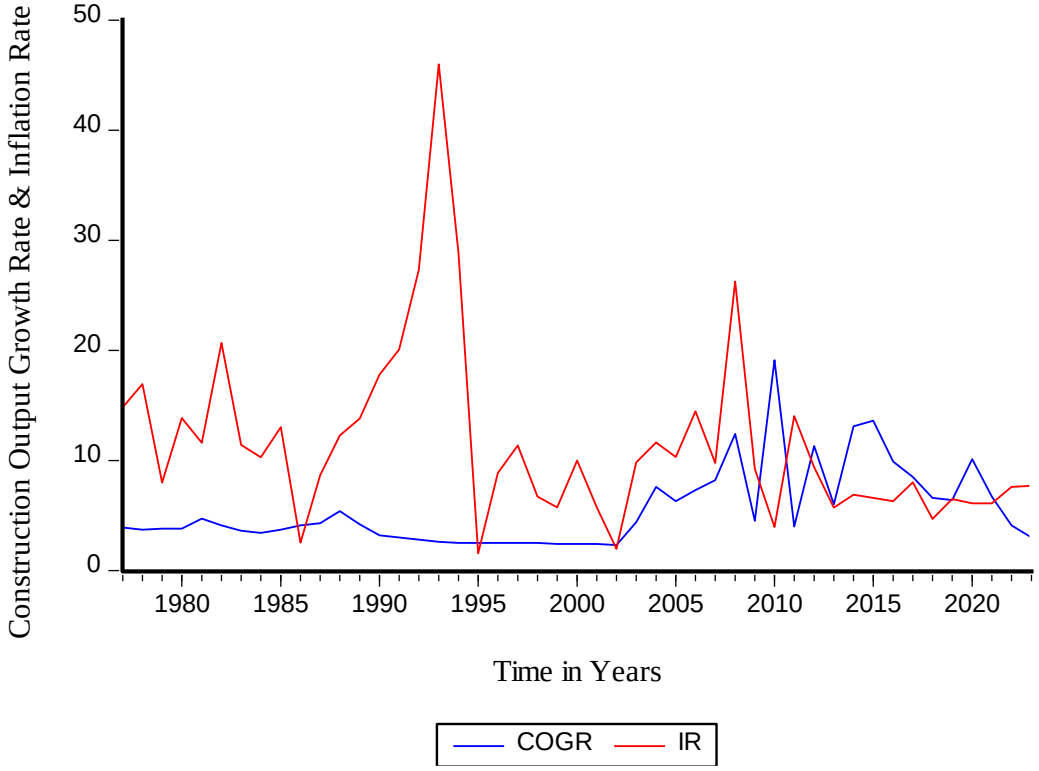


Fig.3: Construction Output Growth Rate and Inflation Rate (%) (1977 - 2023)



II Correlation Analysis

Table 2: Correlation Coefficient (r)

	COGR	IR
COGR	1.000000	-0.202193
IR	-0.202193	1.000000

Correlation analysis showed an inverse correlation of inflation rate and construction output growth rate for the period under consideration; 1977 to 2023. This is observed in Table 2 above, which gives a correlation coefficient (r) of -0.202.

III Stationarity Test

This test comes before regression analysis to ensure the regression analysis is not spurious. The test of stationarity is an important process in time series analysis, as seen in Gujarati and Porter[4]. Thus, time series analysis relies a lot on the stationarity of time series data. This ensures the data analyzed gives reliable results. These tests were carried out at a 5% level of confidence. The augmented Dickey-Fuller (ADF) method of the stationarity test was used for this purpose.

The second differences were found to be stationary. This is observed in Tables 3 and 4, which gave P-values of 0.0000 and 0.0000, respectively.

Table 3: Unit Root Test for Second Differences of Construction Output Growth Rate

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.221155	0.0000
Test critical values:	1% level	-3.610453	
	5% level	-2.938987	
	10% level	-2.607932	

Table 4: Unit Root Test for Second Differences of Inflation Rate

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-9.974710	0.0000
Test critical values:	1% level	-3.592462	
	5% level	-2.931404	
	10% level	-2.603944	

IV Regression Analysis

Table 5 presents regression results of the second difference of COGR and IR. These results indicate that IR has no significant impact on construction output in the current year. This is evidenced by the low value of $R^{2,}$ which is 0.000043. Regression coefficient β is equal to 0.003995, which could be due to low explanatory power, as seen in the low value of R^2. As observed from Table 6, the R^2 value is 0.5942, which is an indication of strong explanatory power. Regression coefficient β is -0.0488, depicting the adverse influence of IR on COGR when IR is lagged by up to four (7) years.

Table 5: Regression Results of Second Differences of COGR and IR

Dependent Variable: D(COGR,2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.019822	1.145704	-0.017301	0.9863
D(IR,2)	0.003995	0.092629	0.043128	0.9658
R-squared	0.000043			

Table 6: Regression Results of Second Differences of COGR and IR (IR Lagged by 7 Years)

Dependent Variable: D(COGR,2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.259546	0.967386	-0.268296	0.7904
D(IR,2)	0.170698	0.117861	1.448298	0.1583
D(IR(-1),2)	-0.137181	0.157252	-0.872364	0.3902
D(IR(-2),2)	0.309306	0.201786	1.532839	0.1362
D(IR(-3),2)	-0.196622	0.212126	-0.926907	0.3616
D(IR(-4),2)	0.261474	0.212942	1.227913	0.2294
D(IR(-5),2)	-0.212444	0.196921	-1.078829	0.2896
D(IR(-6),2)	0.131489	0.154913	0.848793	0.4029
D(IR(-7),2)	-0.048840	0.109413	-0.446381	0.6586
R-squared	0.594232			

Discussion

Graphical, correlation and regression analyses show similar results that construction output growth rate and IR in Kenya pull in different directions. Thus, it can be seen in Figure 3 that when IR was very high in 1993, construction output was dwindling. A similar picture was portrayed by a correlation coefficient of r = -0.202 and a regression coefficient (β) of -0.0488. However, these results also show that annual changes in the inflation rate (IR) are not the only

factor contributing negatively towards the growth of the construction industry in Kenya. Therefore, other factors affect the construction industry alongside IR.

Since a construction project does not happen at once, this is the reason for having very minimal effects of IR on COGR in the current year. The effects are felt much later after the rise in inflation rates. This is confirmed by lags of the inflation rate up to seven (7) years. Table 6 gives this picture of IR lagged by up to seven (7) years.

Conclusions

Looking at the trends of COGR and IR in Kenya, an observation is made that when IR goes up, COGR drops. This does not happen spontaneously but gradually. A good example is 1993. During this time, construction industry's growth rate was dropping. Very low construction was happening in the country.

Correlation analysis gave a similar scenario by giving a negative coefficient. This is an indication that the relationship between IR and COGR in Kenya is inverse. The two variables showed that their second differences were stationary, and hence the regression, which was carried out thereafter, was not spurious.

Taking the annual Inflation Rate (IR) and lagging it by one to seven years shows a significant relationship between the annual IR and construction output growth rate in Kenya. This shows the effect that a rise in general prices has on the growth of the construction industry in Kenya.

These findings are logical as investment in the construction industry in Kenya is hindered by the inflation rate (IR). It is therefore notable that the link between the construction market and the financial market in Kenya is seen to be strong, and should therefore inform policy formulation in the country.

References

1. Hillebrandt P. M. Economic Theory and Construction Industry. 3rd Edition. London: Macmillan; 2000.
2. KNBS. Economic Survey. Nairobi: KNBS; 2024.

3. Akintoye A, Skitmore M. Dynamics of Investment in New Housing and Other New Construction Works. European Symposium on Management. Lisbon, Portugal: QUTeprints. 1991; 1623 - 1635.

4. Gujarati D N, Porter D C. Basic Econometrics. Fifth Edition. New York: McGraw-Hill Education; 2009.

EXTENSION OF HORIZONTAL CONTROLS USING STATIC GLOBAL NAVIGATION SATELLITE SYSTEM TECHNIQUE IN KWALE AND MOMBASA COUNTIES, KENYA

ODHIAMBO, S.

University of Eldoret, KENYA.

Correspondence: *sodhiambo53@yahoo.com*

Abstract

Static global navigation satellite system (GNSS) surveys provide high positions accuracy by occupying a point for longer periods of time than kinematic systems. It includes a range of survey styles from rapid static surveys to continuously operating stations. This study sought to undertake survey data search for all the existing Survey of Kenya (SoK) old control pillars within the project area; identify appropriate sites for setting up new ground control (GCPs) pillars; monument the new GCPs as per SoK manual requirement and bserve the new GCPs, process and reduce observations to get their adjusted coordinates. Existing old control pillars within the project area were located using three topographical maps i.e. 200/2 (Kwale), 201/1 (Mombasa) and 201/3 (Ukunda). As per section I on survey marks of the SoK manual, eight appropriate sites were selected for new controls pillars and monumented. Two of the five dual frequency GNSS receivers were set up on two base stations and three were used to rove over the new controls for a minimum of one hour before moving them to other new points. The GNSS data was later downloaded, converted into receiver independent exchange (RINEX) format and processed using Leica Geo-Office 8.2 (LGO) GNSS software. The GNSS survey file was compiled as per section VII on presentation of computations of the survey manual and the coordinates of new points plotted in Form 3 as per section VIII on plotting of cadastral survey plan of survey manual. The survey computation file and the plan were forwarded to e director of survey for quality checks and authentication. Static differential GNSS technique provides best accuracy with reasonably low cost and time. The study recommends use of static differential GNSS technique in extension of horizontal controls for use in mapping, planning of land and future surveys since it gives high accuracy results.

Keywords: static GNSS survey; GCPs

Introduction

Global navigation satellite system (GNSS) as explained by Hofmann et al. is made up of a network of satellites transmitting ranging signals used for positioning and navigation anywhere around the world [1]. Madry S states that modern GNSS equipment can track Global Positioning System (GPS) satellite by United States Department of Defense, Global Navigation Satellite System (GLONASS) by Russian, GALILEO system by European, COMPASS system (Beidou "Big Dipper") by China, IRNSS system by India and QZSS system by Japan in either static or real time kinematic (RTK) modes. Initially, GNSS were mainly for the military but slowly also used for surveying and mapping [2].

Gebre agrees that GNSS surveying methods employ satellite signals to determine precise coordinates, enabling professionals in various disciplines to carry out accurate measurements [3]. For instance, companies that by the nature of their operations remove carbon dioxide from the atmosphere by growing trees for sale to polluter companies, require accurate mapping of locations of these farms to ensure carbon offsets claims are backed by factual, verifiable data which can preserve the integrity of the carbon credit system. Mapping locations with traditional survey method is time consuming and expensive. Use of Static differential global navigation satellite systems (GNSS) provides the best accuracy at affordable cost and time [4]. Elsewhere, it has been confirmed that Sino GNSS equipment gives static horizontal/vertical accuracy of 2.5mm/5mm + 0.5ppm and RTK horizontal/vertical accuracy of 8mm/15mm + 1 ppm [5].

Static systems include a range of survey styles from rapid static surveys to continuously operating stations such as CORS and PBO sites. The equipment setup varies significantly, depending on how long the site will be operational, which could vary from 15 minutes to several years [6]. Ground control points that have been fixed and referenced to an existing reference framework provide a basis of uniformity in mapping and planning of the existing land. In this report, the observed GCPs will offer new controls for mapping, planning of land and future surveys.

This study sought to undertake survey data search for all the existing Survey of Kenya old control Pillars within the project area, identify appropriate sites for setting up new GCPs in

Tsimba Golini ward in Kwale County and parts of Tudor, Shimanzi/Ganjoni wards in Mombasa County, monument the new GCPs as per Survey of Kenya manual requirement and observe the new GCPs, process and reduce observations to get their adjusted coordinates.

2.0 Materials and Methods

Study Area

The project covered parts of Tsimba Golini ward in Kwale County with location coordinates 4°12°0°S, 39°27°0°E; Tudor and Shimanzi/Ganjoni wards in Mombasa County with locations coordinates 4°4°30°S, 39°39°0°E. Figure 2.1 shows study area map.

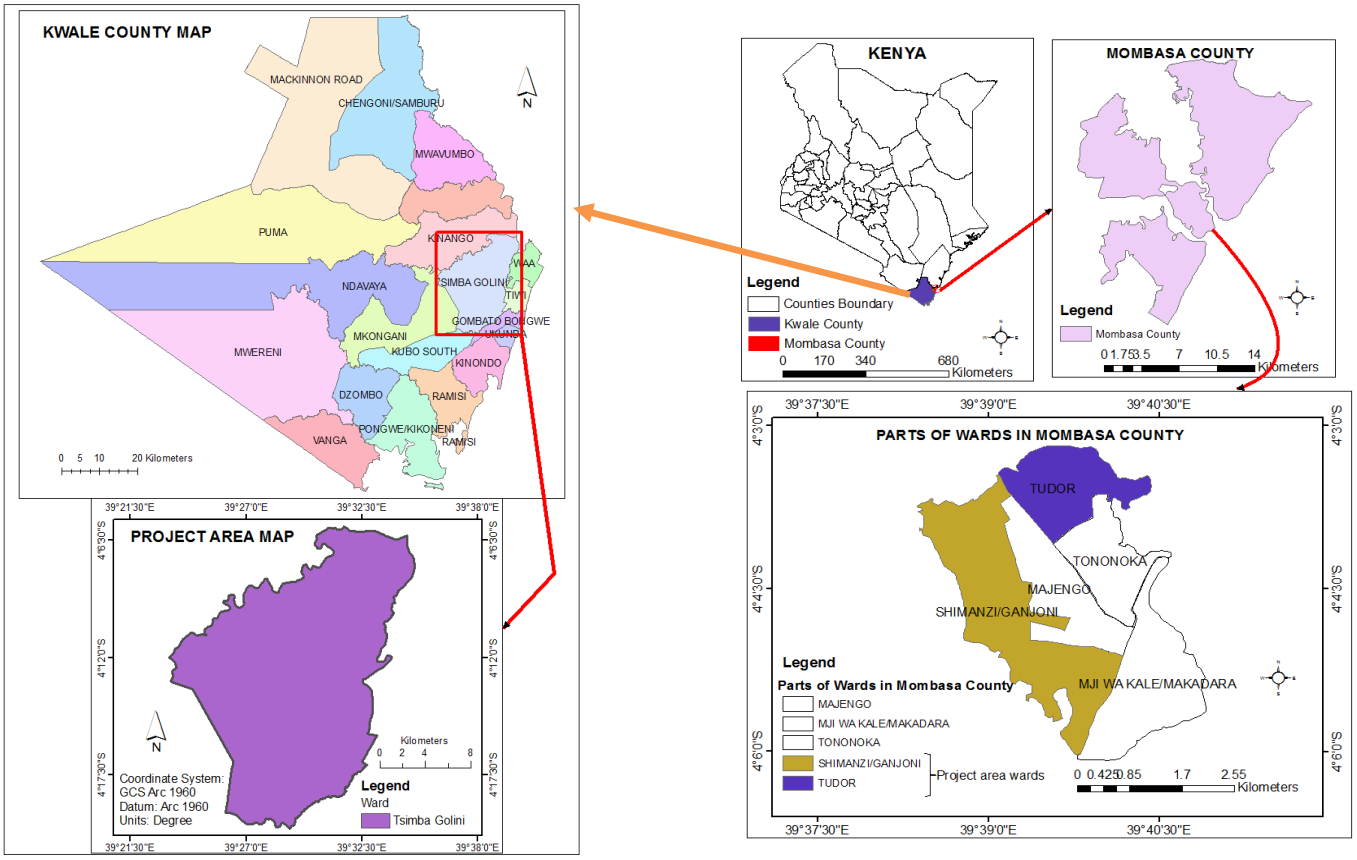


Figure 2.1: Map of Project area

Field work

The field work followed the processes below until the final adjusted coordinates for the new control points were obtained as outlined in the Figure 2.2.

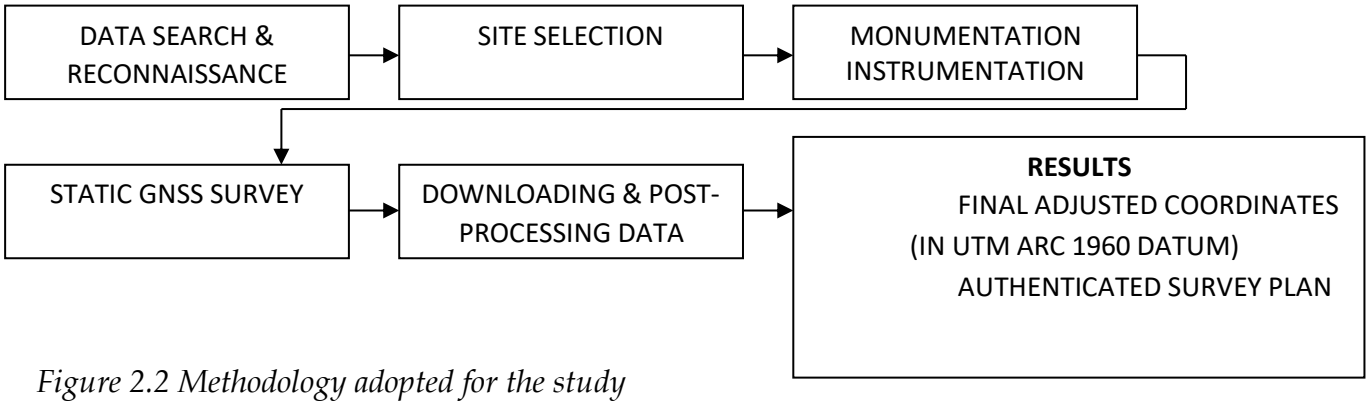


Figure 2.2 Methodology adopted for the study

Data Search and Reconnaissance

Topographical map sheet index at a scale of 1:1,000, 000 was used to identify the topographical maps of the project area. These were used to identify existing old Survey of Kenya (SoK) control pillars. Some of these control pillars were used as base stations for the study. The Topographical maps included; 200/2 (Kwale), 201/1 (Mombasa) and 201/3 (Ukunda). Trigonometric Index Cards for SKP 59, 201.S.5, a printout of excel sheet containing coordinates of 201.TT.17 and Survey plan TC & ST 1207 containing coordinates of NR RALLI all obtained from Survey of Kenya Ruaraka were used to get their coordinates that helped in locating them on the ground using handheld GPS during reconnaissance.

Site Selection

Eight sites for new control points were successfully identified between 5th to 6thApril, 2019. These sites were accessible, away from overhead structures such as powerline, buildings, walls among other objects that can hinder the sky view and create multi-path signal error. The new sites selected formed good geometry. These sites were in Kwale Cultural centre, Golini market, Kwale County water offices, Mtasarani ECD Kwale, Road junction to Godoni, Vuga market, Junction between Makande road Masai street and Junction connecting Tom Mboya road and Taratibu Street (Tudor).

Monumentation

After selecting the sites and ensuring they were all spread within the project area, monumentation was done on 12th April, 2019 where a total of eight new control points were

monumented. The control points were SKW002, SKW003, SKW004, SKW005, SKW007, K6, A7 and HMB9.

Model of Short Truncated Pillar from Survey Manual with dimensions as indicated in figure 2.3 was adopted for this exercise [7].

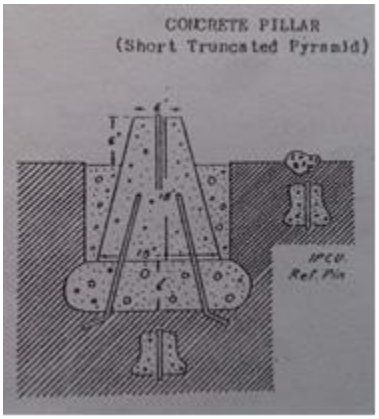


Figure 2.3: Short Truncated Pillar (Source, Survey Manual)

Instrumentation

Equipment used for this project were five Trimble Geodetic GNSS survey receivers (two series 5700 of Serial numbers were: 0220329256, 0220311835 and three series 5800 of serial numbers 4808145829, 4320121736 and 4534155875). The two receivers of series 5700 were set on the two base stations (SKP 59 and NR RALLY) and the three of series 5800 were used to rove over the eight new control points. They receive signals from the antenna and compare the satellite and receiver time code to calculate distance between them. Time difference was fed into a complex code for determining position based on at least 4 satellite signals. The receiver is responsible for sending the position data to the controller computer for user viewing and for taking user input and executing commands.

Static GNSS Survey

Two receivers of series 5700 of Trimble Geodetic GNSS were set over the two old SoK control pillars that were used as base stations for the static survey while three 5800 series of the receivers were set over the new pillars. The project name, vertical/slant heights, station name, location, physical location, date of observation, name of observer, geographical location, point ID, start and end recording time, receiver model/serial number, photograph of the point and

sketch of the point were recorded in the field observation log sheet. All receivers powered on at the same time to start logging in data. The three rovers were left to log in data for a minimum of one hour before being switched off and moving them to other new pillars. The two base station receivers remained on until all the new pillars had been proved. This process was repeated until all the new pillars had been proved.

Downloading and Post-Processing Static GNSS Survey Data

In the office, the five receivers were connected to a personal computer via Trimble data transfer utility and all the files that had earlier been collected and saved in the field downloaded into the computer hard disk.

The raw data collected by the GNSS receivers was translated into different formats for data processing or sharing. GNSS receivers collected the data in .TO1 file format. This file format needed to be converted into a format that can be read into any geodetic processing software. Thus, raw data was converted into RINEX (Receiver Independent Exchange Format) since it is a widely readable data format for raw GNSS observation data since RINEX is read by most processing software, including Leica Geo-Office 8.2, GNSS Solution and Topcon Tools among others. Leica Geo-Office 8.2 (LGO) GNSS post-processing software was used to find the coordinates of the eight unknown new control points by differentially processing data relative to a fixed base location. The processing begins by correcting base and rover position to establish a baseline vector from base to rover position that the GNSS receivers acquired simultaneously. SKP 59 base station was held as fixed with its known coordinates and its relative position used to solve coordinates for the other base station (NR RALLI) and the other new control pillars.

Results and Discussions

Existing Survey of Kenya old control Pillars within the project area

From reconnaissance survey that was carried out within the project site on 25th and 26th March 2019, four SoK pillars were found i.e. SKP 59 at Kwale KWS gate, NR RALLI on top of Ralli house Mombasa Central Business District (CBD), 201.S.5 at Diani Veterinary offices and 201.TT.17 at Ukunda. 201.S.5 and 201.TT.17 were physically partially vandalized hence were not used since it could have interfered with their location. Plate 3.1 shows four SoK control

pillars and Figure 3.1 shows their overlay on the georeferenced topographical maps 200/2 (Kwale), 201/1 (Mombasa) and 201/3 (Ukunda).

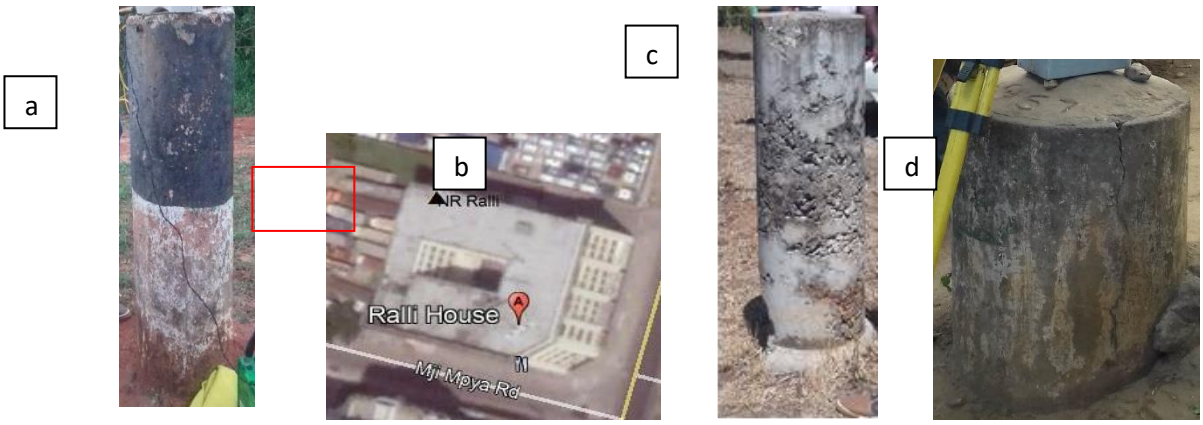


Plate 3.1: (a) SKP 59 (I order); (b) NR RALLI; (c) 201.S.5 (II order) and (d) 201.TT.17 control pillars

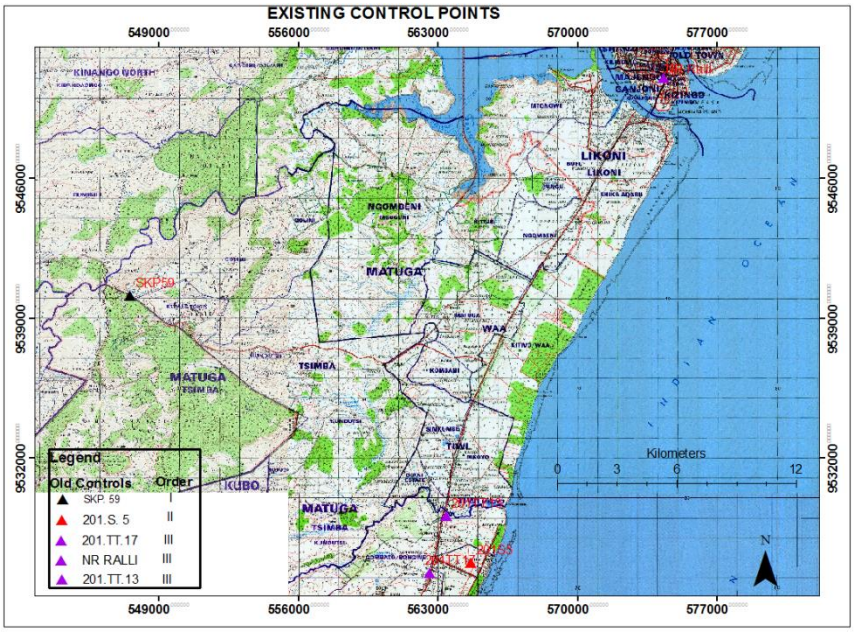


Figure 3.1: Map of old SoK pillars (SKP 59 (I order); NR RALLI; 201.S.5 (II order) and 201.TT.17)

Appropriate sites for setting up new GCPs within the project area

Figure 3.2 shows an overlay of eight new control sites selected on the georeferenced topographic maps 200/2 (Kwale), 201/1 (Mombasa) and 201/3 (Ukunda).

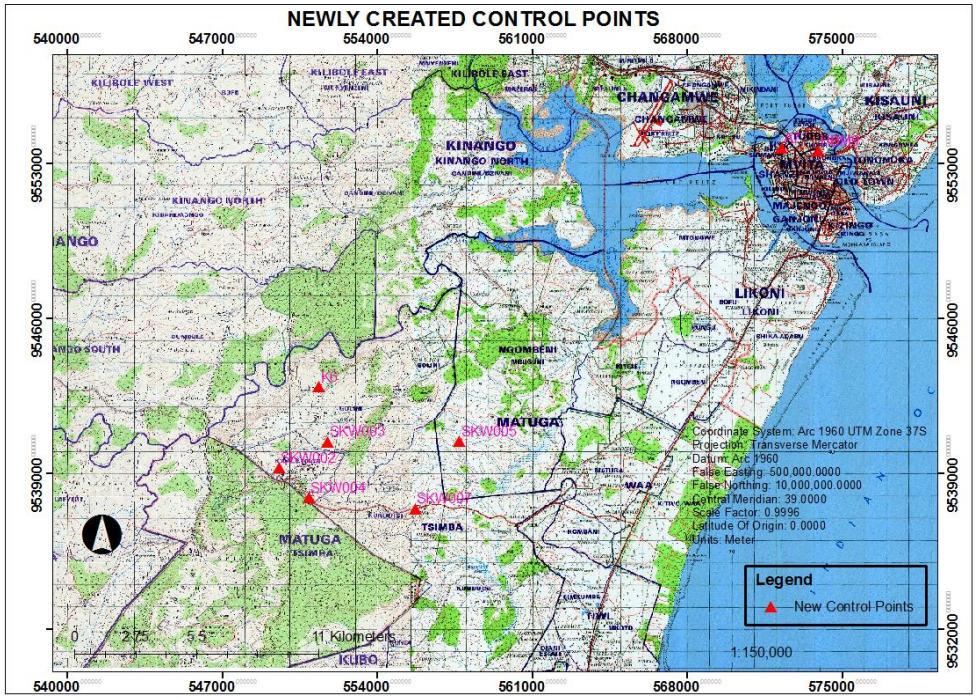


Figure 3.2: Map of new control sites (SKW002, SKW003, SKW004, SKW005, K6, A7, HBM9)

Monument of the new GCPs within the project area

A model was constructed from timber with measurements as per Survey Manual for Short Truncated Pillar. The height was 18 inches, the base was 15 inches and its top surface was 6 inches. Eight holes were then dug at those selected sites for new points and the model inserted. Concrete was made to a mixture of 1:3:6 (cement:sand:ballast) as per the survey manual. They were then monumented, left to dry and the station name marked on top of their bases. Plate 3.2 shows a model of short truncated pillar and already monumented and marked new pillar. Table 3.2 shows a list of site names against their station names.

Plate 3.2: Model of Short Truncated Pillar and Monumented new control pillar (SKW 007) at Vuga market.

S/No	SITE NAME	STATION NAME
1.	Kwale Cultural centre	SKW002
2.	Golini market	SKW003
3.	Kwale County water offices	SKW004
4.	Mtasarani ECD Kwale	SKW005
5.	Road junction to Godoni	K6
6.	Vuga market	SKW007
7.	Junction between Makande road Masai street	A7
8.	Junction connecting Tom Mboya road and Taratibu Street	HBM9

Table 3.1: Final Adjusted coordinates (Arc 1960_UTM_Zone_37S)

2.1 Adjusted Coordinates for new GCPs.

Coordinates of two old SoK control pillars and newly established GCPs are given on table 3.2.

UTM ARC 1960 Zone 37S adjusted final coordinates				
STATION	**PCLASS**	**CLASS OF BEACONS**	**EASTINGS (m)**	**NORTHINGS (m)**
SKP. 59	Control	SoK standard pillar	547557.042	9540130.909
NR RALLI	Control	Corner of metal plate on roof	574327.783	9551029.426
SKW007	Adjusted	I.P.C	555724.8565	9537438.288

SKW005	Adjusted	I.P.C	557732.5896	9540456.797
SKW004	Adjusted	I.P.C	550922.0658	9537927.172
SKW003	Adjusted	I.P.C	551783.1219	9540437.619
SKW002	Adjusted	I.P.C	549569.2772	9539280.893
K6	Adjusted	I.P.C	551369.0972	9542919.417
HBM09	Adjusted	I.P.C	573941.5765	9553552.536
A7	Adjusted	I.P.C	572277.914	9553669.484

Table 3.3: Final Adjusted coordinates (Arc 1960_UTM_Zone_37S)

Computations

The main result for this project was an authenticated survey plan number TC & ST 1372 (Standard Traverse and Chart) that shows the control network and their coordinates values (Northings, and Eastings). The authenticated survey plan was achieved by compilation of field survey data as per section VII of the survey manual, plotting the coordinates of new pillars in Form 3 as per section VIII on plotting of cadastral survey plan of survey manual and forwarded to Director of Survey-Ruaraka Nairobi on 1st July, 2019 for quality checks and authentication. The survey plan was authenticated on 17th September, 2019. Figure 3.3 shows authenticated survey plan drawn in Form 3.

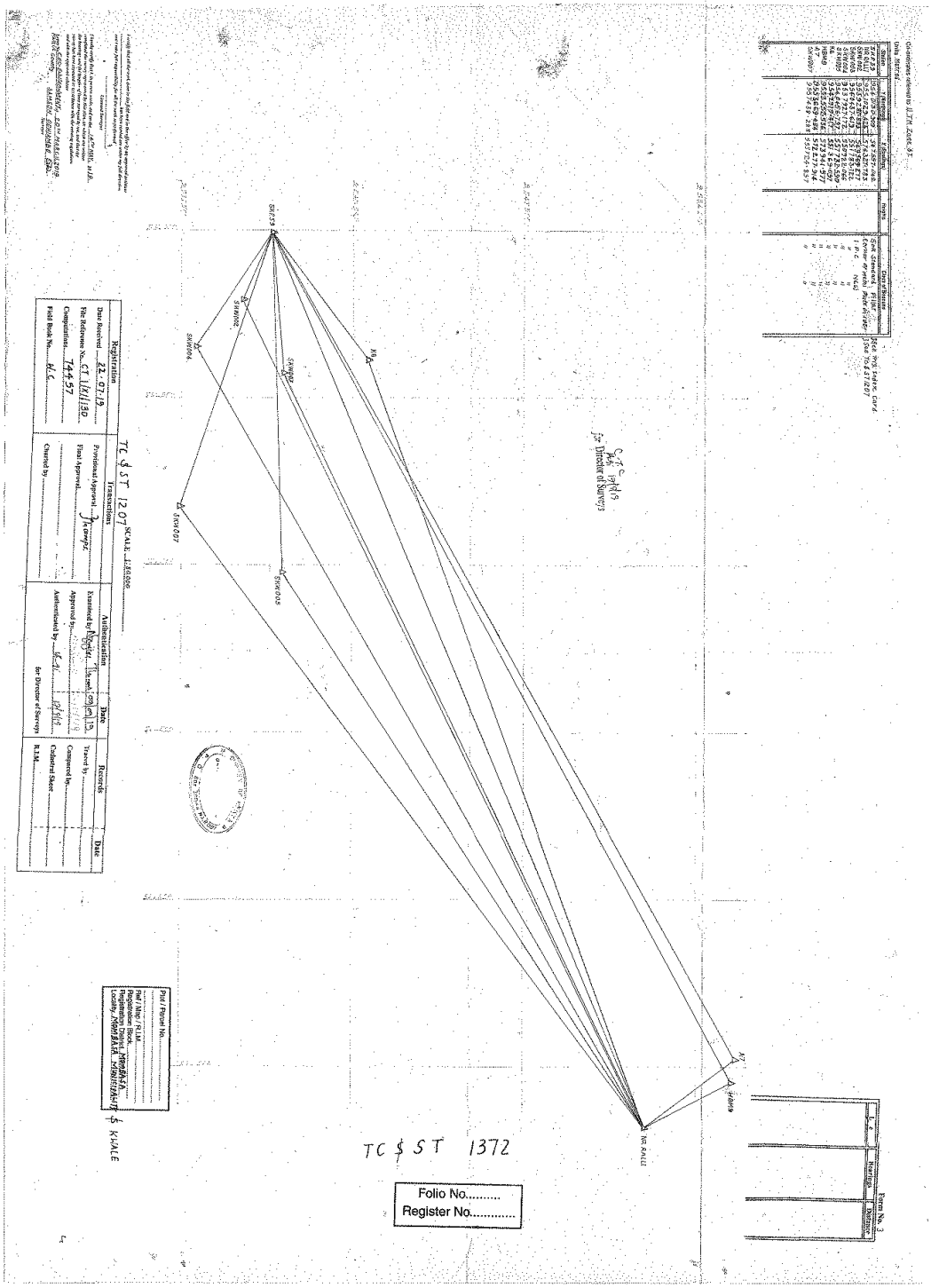


Figure 3.3: Authenticated Survey Plan No. TC & ST 1372 (Form No. 3)

Conclusion

The best accuracy, reasonable low cost and time is provided by Static differential GNSS technique. Therefore, coordinates of adjusted new controls points for this project should be used for further survey as control pillars since the data has been Approved and Authenticated by the Director of Survey.

Acknowledgment

The support received from Mr. David O. Adhola, a land surveyor expert teaching at Siaya Institute of Technology is acknowledged.

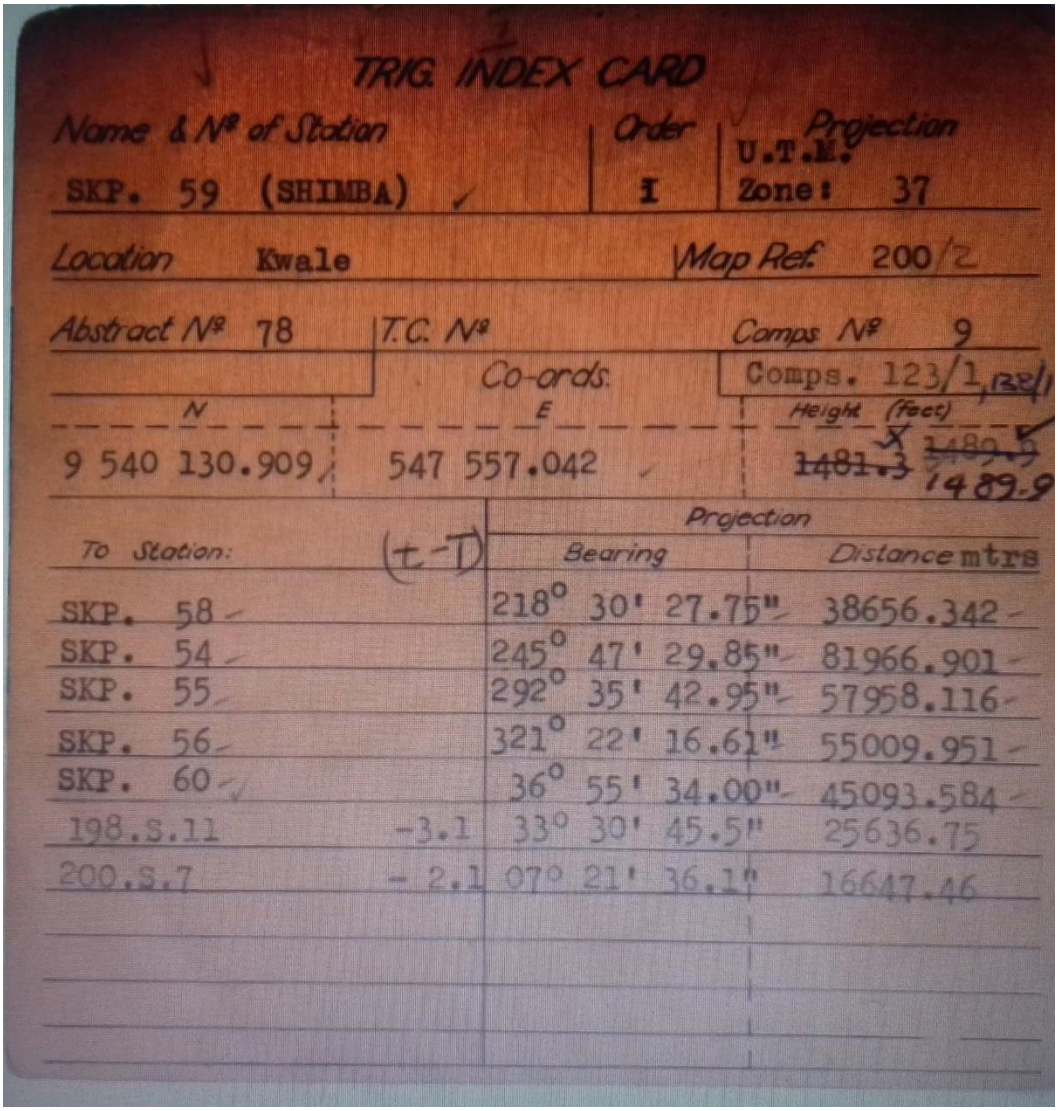
Disclosure statement: No potential conflict of interest was reported by author

References

1. **Hofmann-Wellenhof B., Lichtenegger H., Wasle E. GNSS (2007).** Global Navigation Satellite Systems: GPS, GLONASS, Galileo, and more. Springer Science & Business Media; Nov 20.
2. **Madry S. (2015).** Global navigation satellite systems and their applications. New York: Springer
3. **Gebre-Egziabher D, Gleason S. (2009).** GNSS applications and methods. Artech House
4. **Naesset E., Bjerke T., Bvstedal O., Ryan LH. (2000).** Contributions of differential GPS and GLONASS observations to point accuracy under forest canopies. Age (years). 12; 15 (111):58.
5. Chengzhi L. **(2013).** The Chinese GNSS—System development and policy analysis. Space Policy. 29(1):9-19.
6. **Snay RA, Soler T. (2008).** Continuously operating reference station (CORS): history, applications, and future enhancements. Journal of Surveying Engineering. 134(4):95-104.
7. Kenya Survey manual

Annexure

Annex 1: Trig Index Card for SKP. 59



TRIG. INDEX CARD

Name & Nº of Station	Order	Projection
SKP. 59 (SHIMBA)	I	U.T.M. Zone: 37

Location: Kwale — Map Ref: 200/2

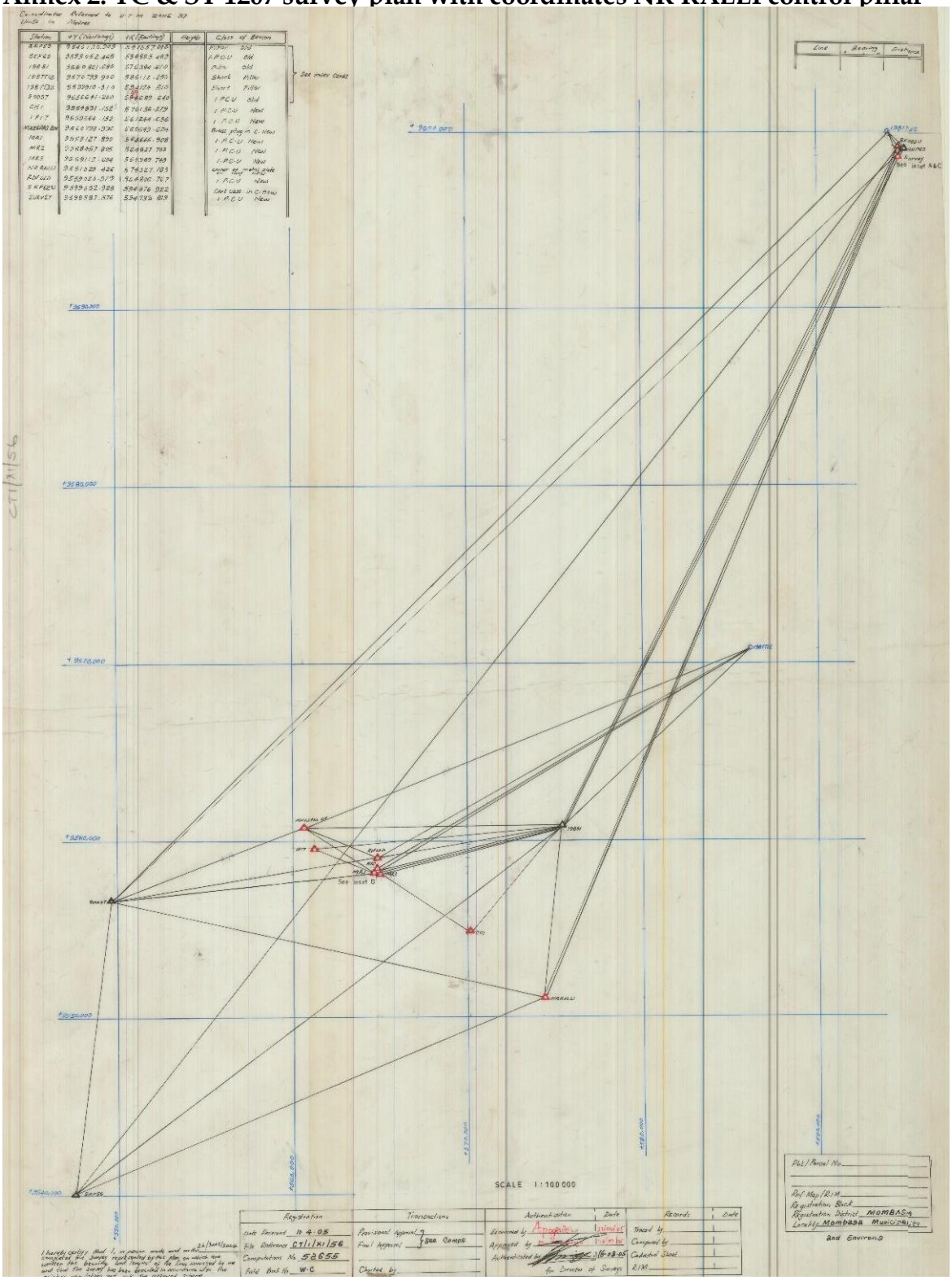
Abstract Nº 78 — T.C. Nº — Comps Nº 9

Comps. 123/1, 138/1

Co-ords. N	Co-ords. E	Height (Feet)
9 540 130.909	547 557.042	~~1481.3~~ ~~1489.5~~ 1489.9

To Station:	(t-T)	Projection Bearing	Distance mtrs
SKP. 58		218° 30' 27.75"	38656.342
SKP. 54		245° 47' 29.85"	81966.901
SKP. 55		292° 35' 42.95"	57958.116
SKP. 56		321° 22' 16.61"	55009.951
SKP. 60		36° 55' 34.00"	45093.584
198.S.11	-3.1	33° 30' 45.5"	25636.75
200.S.7	- 2.1	07° 21' 36.1"	16647.46

Annex 2: TC & ST 1207 survey plan with coordinates NR RALLI control pillar



Annex 3: Static GNSS Survey Field Observation Log sheet

<table>
<tr><td colspan="2">PROJECT NAME:</td><td>Extension of Horizontal Controls</td></tr>
<tr><td colspan="2">PROJECT LOCATION:</td><td>Kwale and Mombasa Counties</td></tr>
<tr><td colspan="2">PHYSICAL LOCATION:</td><td>At Kwale KWS gate</td></tr>
<tr><td colspan="2">DATE: 14th May, 2019</td><td>OBSERVER: Samson Odhiambo and David Adhola</td></tr>
<tr><td colspan="3">GEOGRAPHIC LOCATION: (FROM TRIG. INDEX CARD)</td></tr>
<tr><td colspan="2">NORTHING (M)</td><td>EASTING (M)</td></tr>
<tr><td colspan="2">9540130.909</td><td>547557.042</td></tr>
<tr><td colspan="2">POINT INFORMATION:</td><td rowspan="8">PHOTO:  </td></tr>
<tr><td>POINT ID:</td><td>SKP. 59</td></tr>
<tr><td>START TIME:</td><td>11.39AM</td></tr>
<tr><td>END TIME:</td><td>17.52PM</td></tr>
<tr><td>SLANT HEIGHT:</td><td>0.4730 metres</td></tr>
<tr><td>RECEIVER MODEL:</td><td>Trimble 5700</td></tr>
<tr><td>RECEIVER S/NUMBER</td><td>0220329256</td></tr>
<tr><td colspan="2">Remarks: it is a Ist order SOK control pillar in good condition.</td></tr>
</table>

Annex 4: GNSS observations

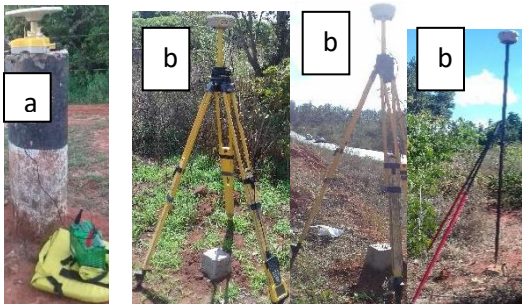


Plate 3.2: (a) Trimble receiver set over SKP 59 and (b) set over new pillars

PREDICTING URBAN SPRAWL PATTERNS USING INTEGRATED MARKOV CHAIN, CELLULAR AUTOMATA MODELS AROUND ELDORET TOWN, KENYA

ODHIAMBO S., MWASI B.
University of Eldoret, KENYA

Correspondence : *sodhiambo53@yahoo.com*

Abstract

One of the rapidly growing urban problems in the 21st Century is the emergence of unplanned settlements around urban centers. These settlements put considerable burden on major urban centres even though they offer necessary services. Studies have shown that these settlements are attracted by some factors such as roads, existence of utilities such as water and electricity, among others. This study applied the CA-Markov model to known land use changes between 2016 and 2020 and selected change factors to predict 2029 land use patterns and isolate expected sprawl areas around Eldoret town. The CA-Markov models predicted new sprawl settlements mostly along roads (linear developments) and some isolated settlements (leapfrog pattern), increasing from 138.91 km² in 20202 to 154 km² in 2029. The predicted settlement patterns are consistent with prior observed developments between 2016 to 2020. The Uasin Gishu County government can guide future urban development by providing or restricting these change factors.

Keywords: Predicting Urban Sprawl; Markov Chain; Cellular Automata; Urban Sprawl Patterns

Introduction

Emergence of sprawling settlements is one of the most rapidly growing urban problems in the 21st Century [1]. Such settlements provide essential services as well as some strain on these centers [2]. Controlling and managing the growth of such settlements requires an understanding of socio economic factors that control them and GIS and remote sensing modeling techniques to minimize against the stress they cause [3]. CA-Markov model integrated with GIS and remote sensing are thought to be a reliable method for forecasting future LULC dynamics; temporal and spatial dynamics [4,5,6]. **I**mproving the performance further, the logistic regression model, frequency ratio (FR), analytical hierarchy process (AHP), and CA-Markov chain model must all be integrated [7]. Using CA-Markov model in monitoring and forecasting LULC change in Zaria city, Nigeria it was revealed that barren land will be lost to built-up and vegetation for the next 30 years by 65.88% and 29.95% respectively during 2035 and 2050 [8]. The GIS and CA-Markov model was applied elsewhere in evaluating urban spatial growth in Malaysia during 1992-1998[9]. Results suggest that this model can be potentially used along with existing planning documents in order to evaluate the impact of the proposed planning policy on existing urban landscape since it obtained an overall classification accuracy of 92.3% and 81.0% for 1992 and 1998 respectively [9]. What is not known is the likely location of future new sprawl areas. Knowing the likely locations of sprawl developments can enable planners to support or suffocate such developments by either creating a conducive environment or otherwise. Odhiambo et al. identified roads, powerline and waterline as the main factors that promote sprawl development [10]. These variables will be employed in this paper's CA-Markov chain model to forecast the probable locations of sprawl areas surrounding Eldoret town in 2029.

Materials and methods

Study Area

The study was done around a gazetted Eldoret Municipality boundary in Uasin Gishu County, Kenya, and covers 58 sub-locations. It is bounded by Latitudes 00°52' 00''N and 00° 18' 00''N and Longitudes 34° 51 '00''E and 35° 31' 00''E covering approximately 1973km^2. The majority of the study area receives an average of 625 mm to 1,560 mm of rainfall, with two distinct peaks between March and June and August and September. This rainfall falls in the western part of

the area (Turbo area), the eastern part (Ainabkoi and Moiben area), the northern part (Ziwa area), and the southern part (Kapseret and Cheptiret area). Between November and February is when the drying phase takes place. The two most common soil types are humic nitosols (Hn) and orthotic ferralsol (Fo), with temperatures ranging from 7 to 29 degrees Celsius. Generally, these conditions are favorable for livestock keeping, crop and fish farming. The interpolated population figures of the study area (58 sub-locations) for the years 2000, 2016 and 2020, shows a steady population increase from 437,049 to 774, 201 and 870, 271 respectively. Figure 1 shows a study area map.

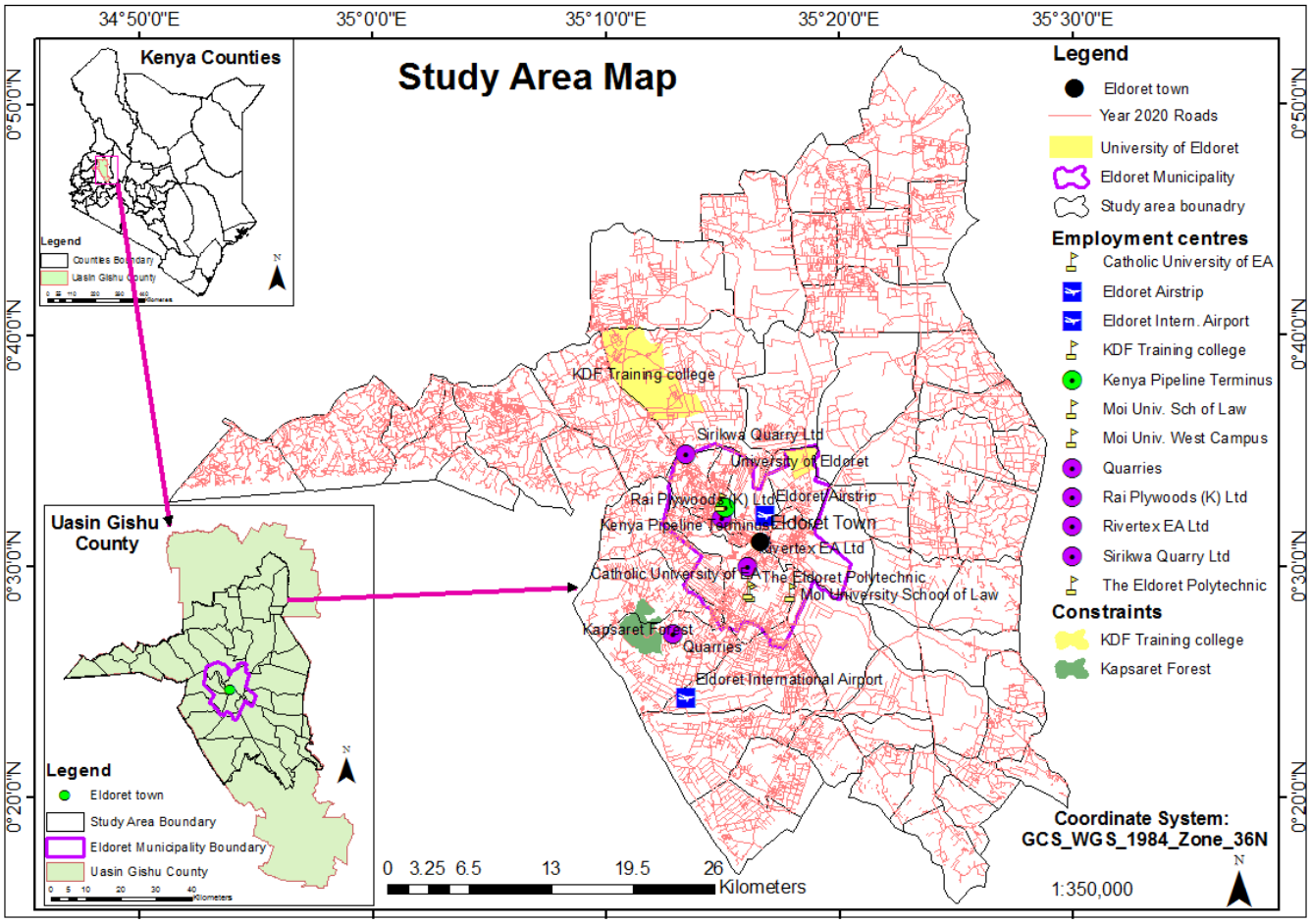


Figure 1: *Location of the study area*

Datasets

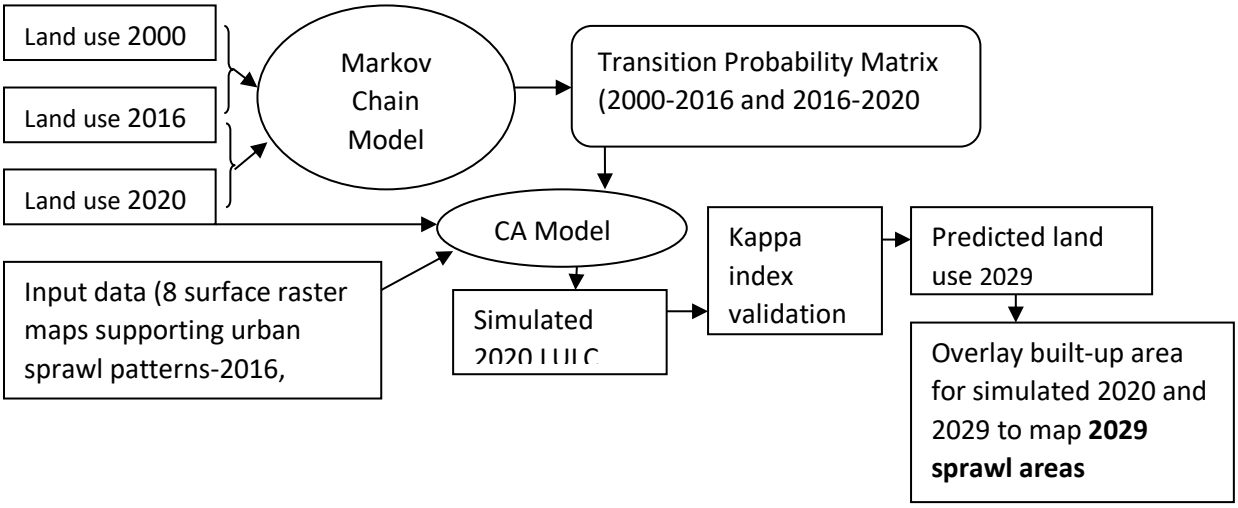
Data for this study was obtained from both primary and secondary sources (Table 1).

S/No.	Data used	Data type	Years	Source
1.	Land Use/Cover maps	Primary	2000,2016 and 2020	Author's image classification
2.	Sprawl areas map	Primary	2020	Author's; overlay of two successive LULC maps
3.	8 raster surface maps supporting urban sprawl	Primary	2020 2016 and 2020	Obtained from 30m Digital Elevation Model (DEM) Author's; created from distance algorithm
4.	Sub-location data	Secondary	2019	Kenya National Bureau of Statistics (KNBS) [11]

Table 1: *Characteristics of Data Used*

Methods

Figure 2 describes the steps followed in predicting future urban sprawl areas of the study area for the year 2029.



Methodology adopted in predicting 2029 urban sprawl areas

First, transition probability matrices (TPM) were calculated by inputting two consecutive LULC maps for 2000-2016 and 2016-2020 into the model.

Secondly, to generate the simulated 2016 and 2020 LULC maps, 2000-2016 and 2016-2020 TPM, 2016 and 2020 LULC maps and 2016 and 2020 raster maps for factors were inputted each year at a time into the CA model.

Third, the simulated and classified LULC maps for 2020 were compared to assess the accuracy of results of the model. It was observed that these changes are quite similar and matching. Also the Kappa (overall) value obtained when validating the 2020 LULC map was 0.68779 which is substantial with the simulation accuracy being 81.21% [12].

Finally, to predict the 2029 LULC map, the 2016-2020 TPM, 2020 simulated LULC map and 2020 supporting factors raster maps were inserted in the CA model after validation. Lastly the built-up area for simulated 2020 and predicted 2029 LULC maps were overlaid and 2029 sprawl areas identified and mapped (Figure 3.3).

Each cell has six different states representing land use activities in the study area. This is given by the equation 1 below.

$$^{t}LU_{ij} = \begin{cases} 1=\text{Agriculture} \\ 2=\text{Built-up} \\ 3=\text{Forest} \\ 4=\text{Grassland or shrubland} \\ 5=\text{Swamp} \\ 6=\text{Water} \end{cases} \quad (1)$$

Where $^{t}LU_{ij}$ = state of pixel i, j at time *t*

The study area is represented by the six land use categories. *Samat N* states that the evolution of a cell from time t to t+1 is determined by the function of its state, its neighborhood space and the set of transition rules [13]. This is given by the equation 2 below.

$$^{t+1}LU_{ij} = f\left(\left(^{t}LU_{ij}\right) * \left(^{t}S_{ij}\right) * \left(^{t}P_{x,y,i,j}\right) * \left(^{t}N_{ij}\right)\right) \quad (2)$$

Where;

$^{t+1}LU_{i\,j}$= the potential of cell i, j to change at time *t+1,*

f ($^{t}LU_{ij}$)= state of cell i, j at time *t,*

($^{t}S_{ij}$)= suitability index of cell i, j at time *t,*

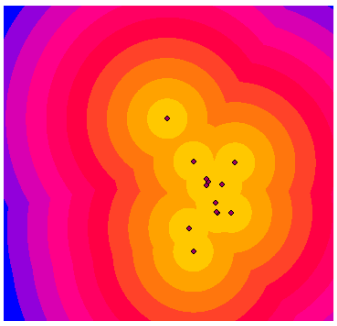
($^{t}P_{x,y,i,j}$)= probability of cell i, j to change from state x to state y at time *t,* and

($^{t}N_{ij}$)= neighborhood index of cell i,j.

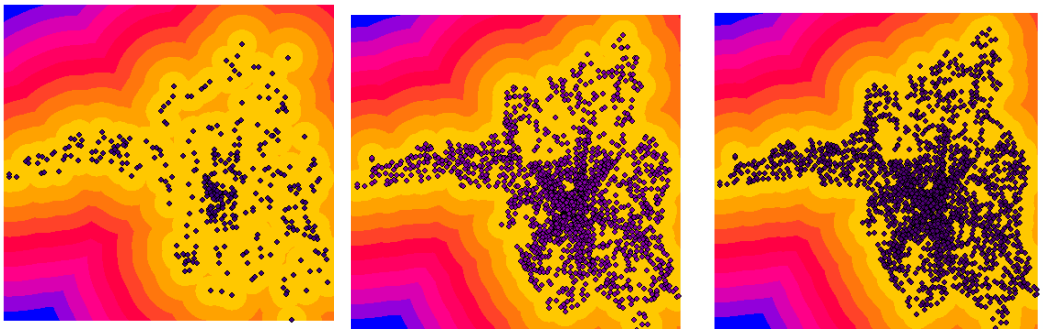
3.Results and Discussions

Raster maps

Continuous surface maps representing Euclidean distances for connectivity factors; (roads, employment centers, constraints to development maps, powerline, and water line) were created using distance algorithm. Population data were used to create population density maps at the smallest administrative unit (sub-location for 2000, 2016 and 2020). Elevation and slope maps were created from DEM (Figure 3).

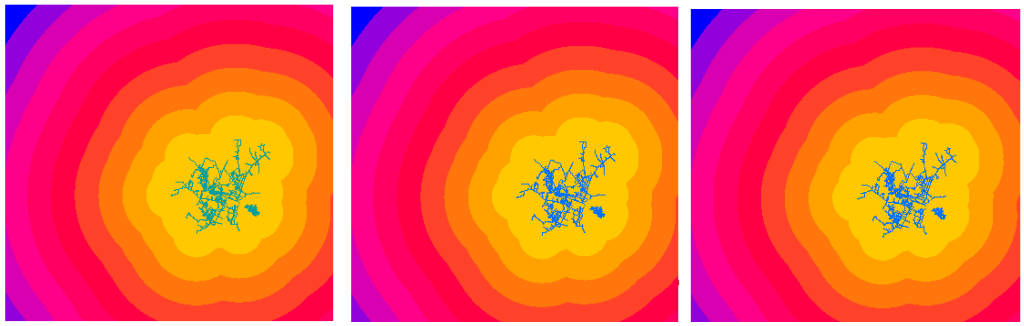


Distance to Employment Centers



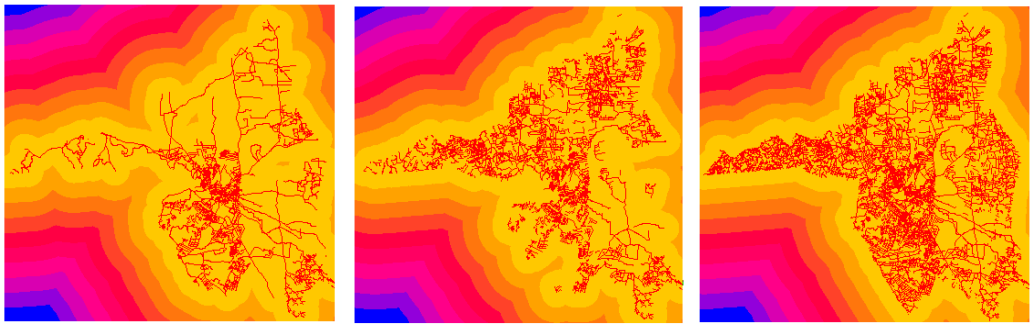
2000 **2016** **2020**

Distances to Powerline Transformers



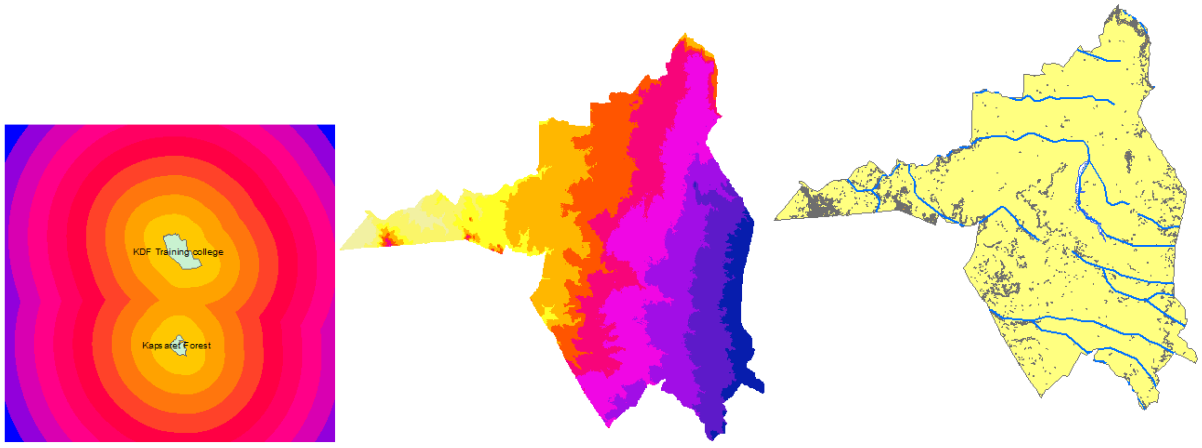
2000 **2016** **2020**

Distances to Waterline Network

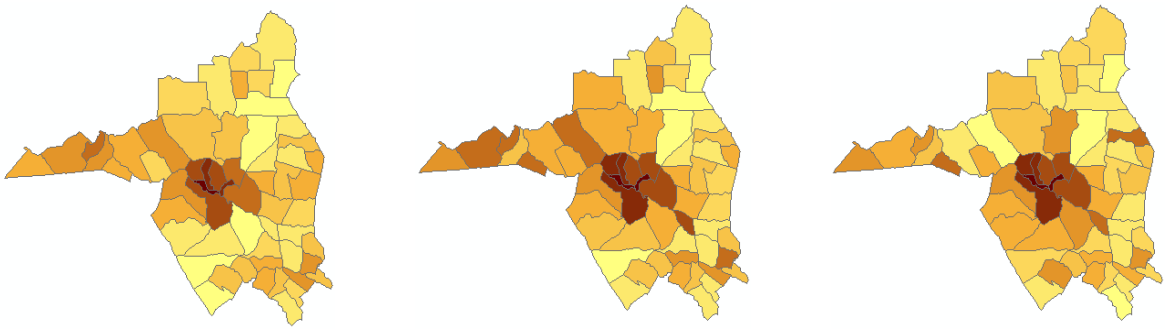


2000 **2016** **2020**

Distances to Roads



Distance to Constraints to Development **Elevation** **Slope**



2000 **2016**

2020

Population density

Figure 3: *Raster maps of Supporting Factors*

Markov Transition Probability Matrix Table

Markovian transition probability matrix table (TPM) (Table 2) for the years 2000-2016 and 2016-2020 shows the percentage of each of the land use classes likely to change to another with approximate quantities in predicting future land use change around Eldoret Town. Results in the TPM table shows that the greatest remarkable land use conversion occurred during the period 2000-2016. Agricultural land changed to built-up areas and forest to agriculture by 0.117579 and 0.722307 probability rates.

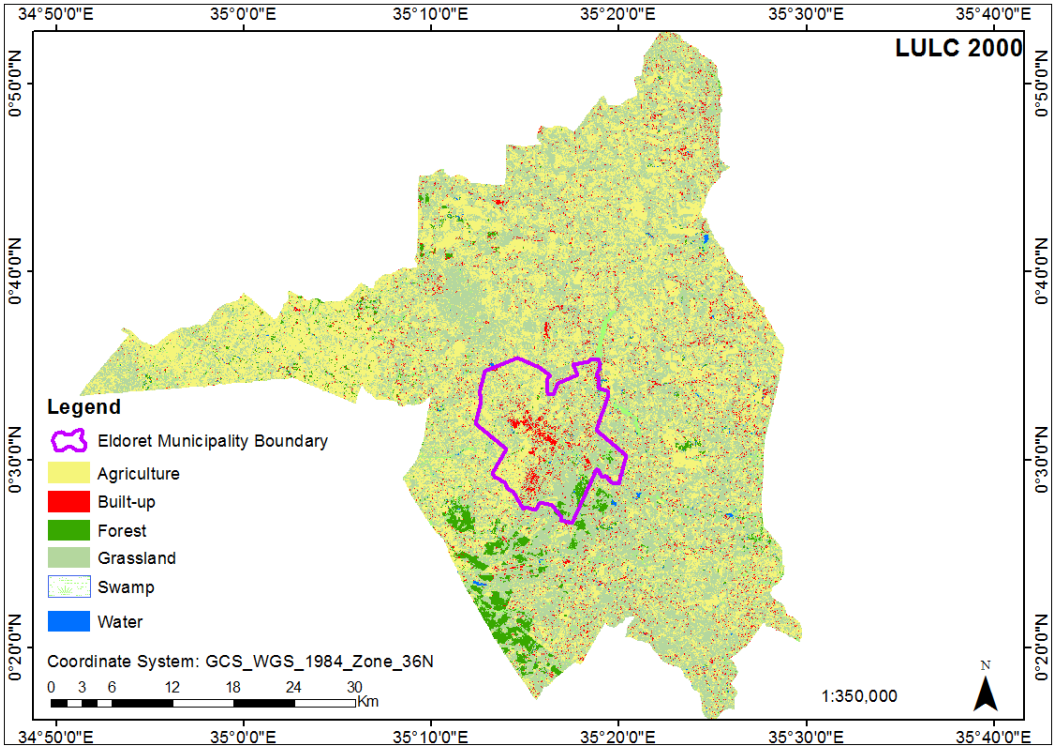
Table 2: Markov Transition Probabilities Matrix of Periods: 2000-2016 and 2016-2020.

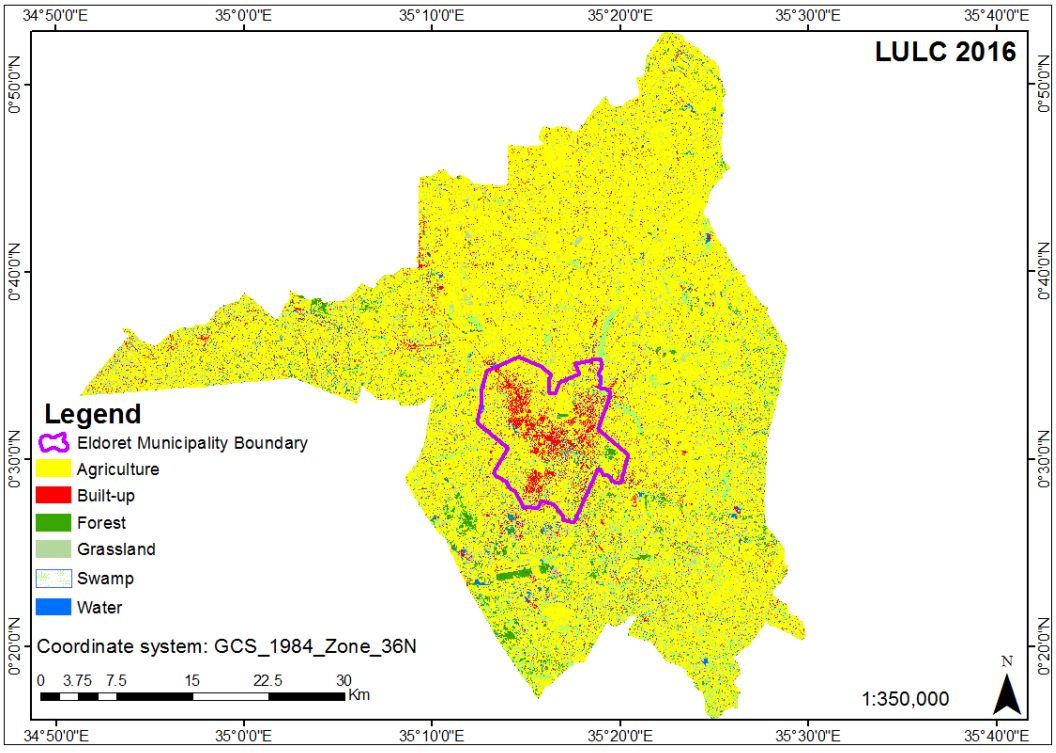
	Class	**Agriculture**	**Swamp**	**Water**	**Grassland**	**Built-up**	**Forest**
2000 - 2016	**Agriculture**	0.594752	0.076579	0.033979	0.146961	0.117579	0.030150
	Swamp	0.413714	0.133455	0.231706	0.114661	0.058587	0.047877

	Water	0.545026	0.078542	0.030176	0.141052	0.035284	0.169919
	Grassland	0.785370	0.023611	0.019084	0.117641	0.041026	0.013268
	Built-up	0.442944	0.242964	0.041334	0.140238	0.035000	0.097520
	Forest	0.722307	0.066175	0.021961	0.125090	0.039393	0.025074
2016 - 2020	**Agriculture**	0.059664	0.022736	0.003337	0.830809	0.043966	0.039489
	Swamp	0.023657	0.224349	0.005419	0.630614	0.023044	0.092917
	Water	0.042219	0.022039	0.084930	0.576300	0.220139	0.054373
	Grassland	0.092801	0.024009	0.004530	0.720592	0.091197	0.066872
	Built-up	0.108458	0.005415	0.012374	0.386035	0.466402	0.021315
	Forest	0.023065	0.073970	0.002849	0.487615	0.032546	0.037995

Classified 2000, 2016, 2020 and Simulated 2020 LULC Maps

It was observed that these changes are quite similar and matching by comparing the simulated and classified LULC map for 2020 (Figures 4 a, b). The Kappa (overall) value of 0.68779 and simulation accuracy of 81.21% obtained when validating the 2020 LULC map is substantial [12].





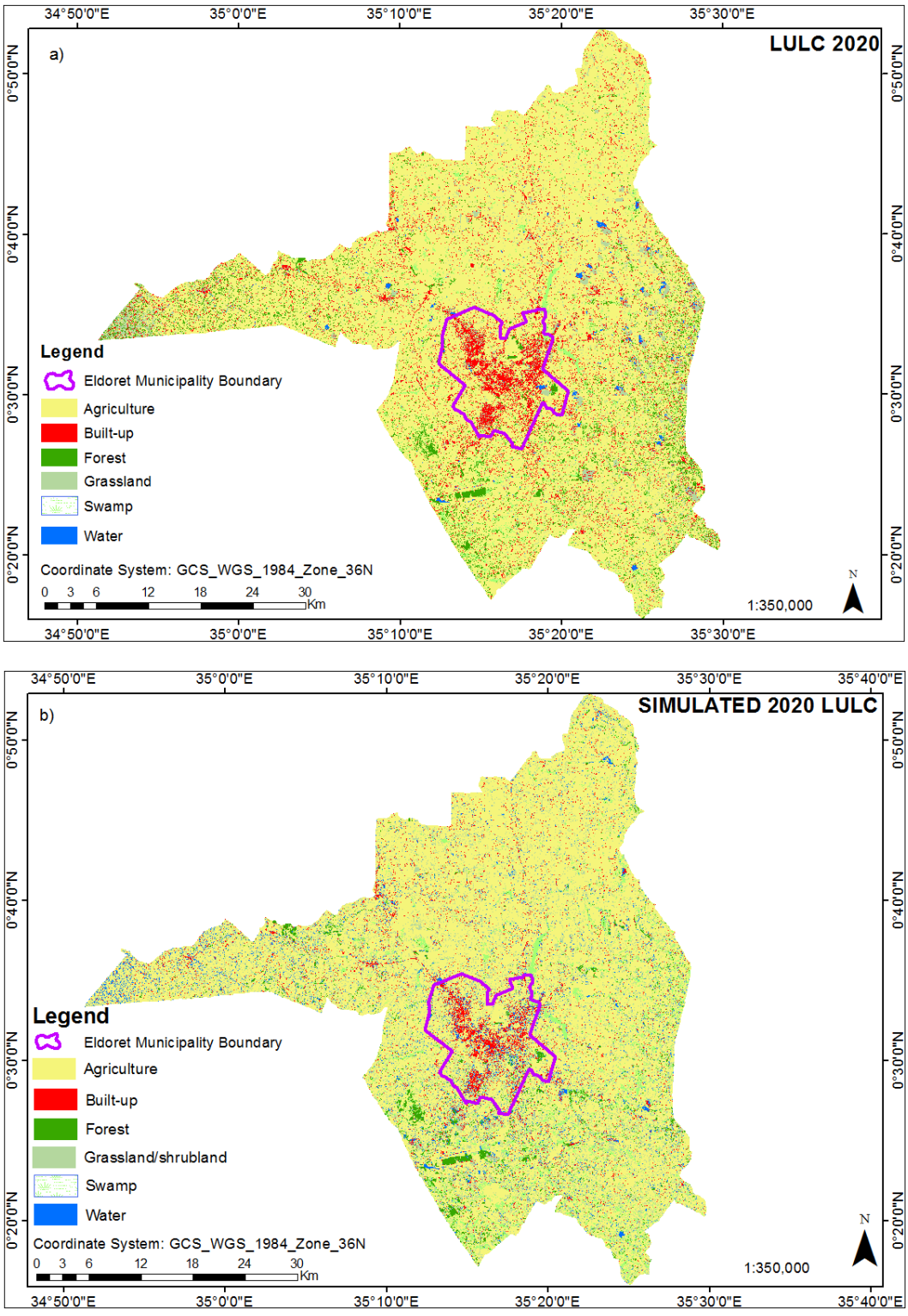


Figure 4: *Classified 2000, 2016 and 2020 (a) LULC Maps; Simulated LULC Map for 2020 (b) based on CA-Markov and AHP Model*

Table 3: Summary of LULC Classification Statistics for built-up areas during 2000-2029 (area in km^2)

LULC Type	Year 2000	Year 2016	Year 2020	Year 2029
	Area in km^2	**Area in km^2**	**Area in km^2**	**Area in km^2**
Built-up areas	71.5959	84.3366	138.912	154.00

Future urban sprawl for the year 2029 was predicted using integrated remote sensing and GIS, CA-Markov and AHP models achieving a prediction accuracy of 83%. The findings predicted that built-up areas would increase to 154 km^2 in 2029 from 138.9 km^2 in 2020.

Similar results reported previously in a study of dynamic simulation of urban expansion through CA-Markov model a case study of Hyrcanian region, Gilan, Iran whereby the extent of built-up areas would increase to 71265 and 78075 Hectares 2025 and 2037 respectively [14]. In another study done in Tripoli, Libya eighty-five percent (85%) simulation accuracy was achieved in a study in which CA model was integrated with Markov chain to predict future urban sprawl in Tripoli, Libya [15]. In a similar study using only the CA model as a basis of integrated dynamic regional modeling, 65% accuracy was achieved [16]. Nevertheless, better simulation accuracy of 88% was achieved in a study elsewhere in 12th municipal district in Isfahan, when a CA model with AHP was used [17]. The CA-Markov model predicted that most agricultural lands will be converted to built-up areas on the basis that policy makers should restrict themselves to proper urban planning in order to mitigate challenges of urban growth.

Urban Sprawl Growth areas for 2029

Markov transition probabilities matrix of 2016-2020, simulated 2020 LULC map and 2020 raster maps were used to predict 2029 sprawl areas.

When sprawl areas for 2020-2029 were then overlaid, eighteen more new sprawl areas that would be built-up by 2029 were mapped taking different patterns occurring in Kaptuktuk, Kelji, Kapsombee, Torochmoi, two in Kongasis, two in Soy, Kiplombe, Osorongai, two in Lotonyok, Songich, Ndumbeneti sub-locations taking leapfrog pattern; Kuinet, Megun, Lengut

and Toloita sub-locations taking linear patterns covering an area of 138.91 km^2 to 154 km2 during 2020 to 2029 respectively as shown in Figure 5.

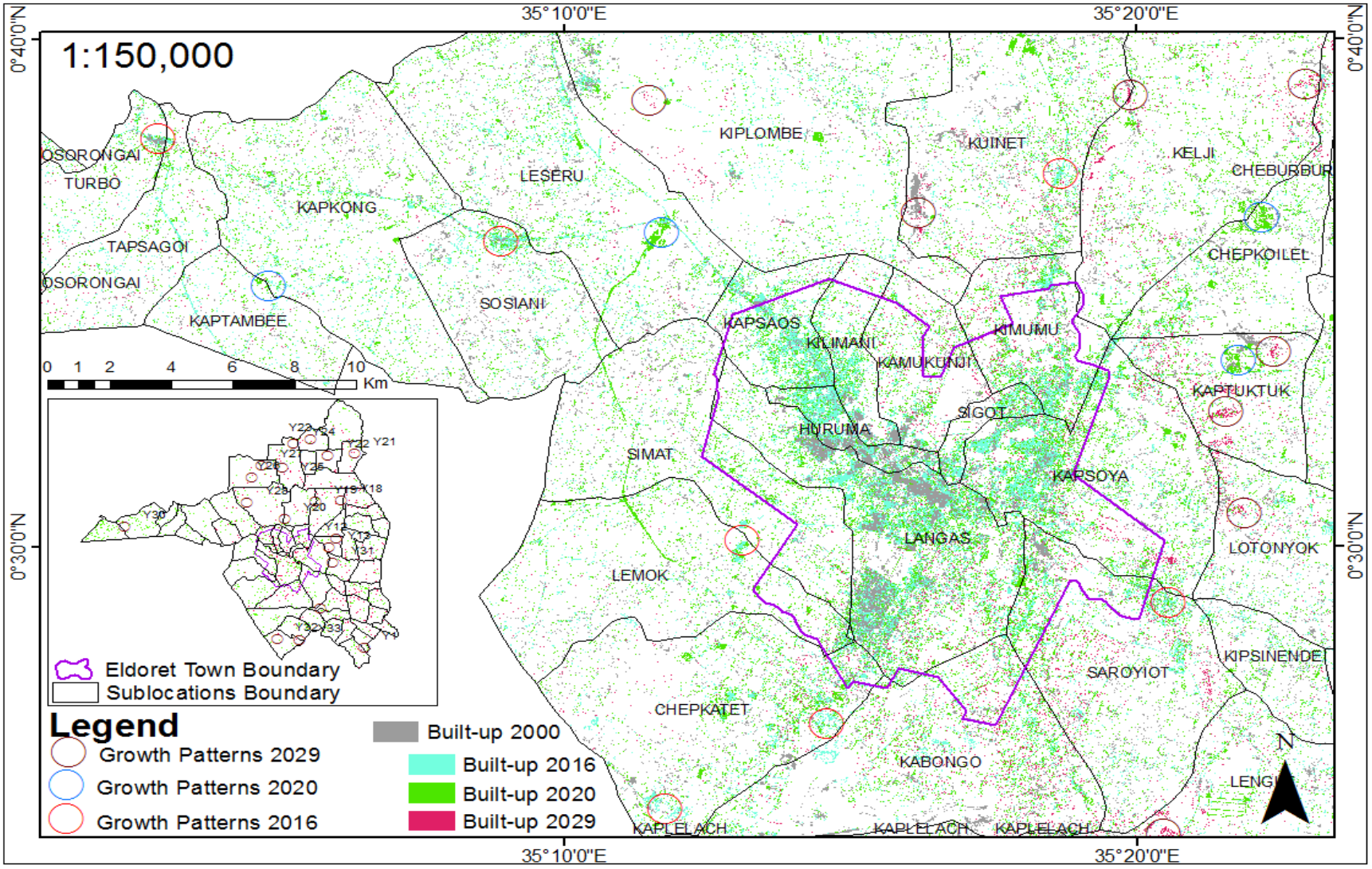


Figure 5: Predicted Urban Sprawl Patterns 2029 Map of the Study Area

Conclusion

Using the classified LULC maps of 2000- 2020, 2000-2020 transition probability table and 2000-2020 raster surface maps, the future (2020 & 2029) LULC of the study area was successfully simulated and predicted using CA-Markov and AHP models.

This study suggests some of the following recommendations to save agricultural lands from invasion by built-up areas. First, priority should be given to roads, power lines and water by the Uasin Gishu County Government in areas destined for future development and withdrawal of these services in areas that are not earmarked for future development in order to control sprawl. Second, policies that limit urban expansion should be recommended by urban planners to save agricultural lands from conversions. For example, policies that are aimed at increasing densities like attaching extra conditions to building plan approval that limits the number of floors; embracing Sectional Properties Act No. 21 of 2020 which provide for division of buildings into units to be owned by individual proprietors and the common property to be owned by the proprietors of the units as a tenant in common. Third, infill developments should be encouraged since utilities such as sewer, water, roads, powerline already exist. This reduces the cost of providing these utilities in sprawled areas. Fourth, policy makers and planners should carry out forward planning of areas and provide requisite infrastructure ahead of development in order to avoid proliferation of slums and economic effects brought about when trying to bring services closer. Lastly, Uasin Gishu County physical planning, standards, guidelines and regulations on minimum plot sizes need to be enforced in order to protect the limited natural resources from exhaustion.

Disclosure statement: No potential conflict of interest was reported by author(s)

References

1. Bekele H. Urbanization and urban sprawl. Royal Institute of Technology: Stockholm, Sweden. 2005 Apr.

2. Kombe WJ. Land use dynamics in peri-urban areas and their implications on urban growth and form: the case of Dar es Salaam, Tanzania. Habitat International. 2005 Mar 1; 29(1):113-35.

3. Bhatta B. Analysis of urban growth and sprawl from remote sensing data. Springer Science & Business Media; 2010 Mar 3.

4. Arsanjani JJ, Helbich M, Kainz W, Boloorani AD. Integration of logistic regression, Markov chain and cellular automata models to simulate urban expansion. International Journal of Applied Earth Observation and Geoinformation. 2013 Apr 1; 21:265-75.

5. Mishra VN, Rai PK. A remote sensing aided multi-layer Perceptron-Markov chain analysis for land use and land cover change prediction in Patna district (Bihar), India. Arabian Journal of Geosciences. 2016 Apr; 9:1-8.

6. Subedi P, Subedi K, Thapa B. Application of a hybrid cellular automaton–Markov (CA-Markov) model in land-use change prediction: a case study of Saddle Creek Drainage Basin, Florida. Applied Ecology and Environmental Sciences. 2013 Nov 28;1(6):126-32.

7. Aburas MM, Ho YM, Ramli MF, Ash'ari ZH. Improving the capability of an integrated CA-Markov model to simulate spatio-temporal urban growth trends using an Analytical Hierarchy Process and Frequency Ratio. International Journal of Applied Earth Observation and Geoinformation. 2017 July 1; 59:65-78.

8. Koko AF, Yue W, Abubakar GA, Hamed R, Alabsi AA. Monitoring and predicting spatio-temporal land use/land cover changes in Zaria City, Nigeria, through an integrated

cellular automata and markov chain model (CA-Markov). Sustainability. 2020 Dec 14; 12(24):10452.

9. Samat N. Integrating GIS and CA-MARKOV model in evaluating urban spatial growth. Malaysian Journal of Environmental Management. 2009; 10(1):83-99.

10. Odhiambo S, Mwasi BN, Ngetich J. Analysis of Selected Factors Supporting Urban Sprawl Patterns Using Analytical Hierarchy Process Model: A Case Study of Areas Surrounding Eldoret Town, Kenya.

11. Kenya. December, 2019. Kenya Population and Housing Census, 2019. Kenya National Bureau of Statistics, Ministry of Finance and Planning.

12. Cohen J. A coefficient of agreement for nominal scales. Educational and psychological measurement. 1960 Apr; 20(1):37-46.

13. Samat N. Integrating GIS and CA-MARKOV model in evaluating urban spatial growth. Malaysian Journal of Environmental Management. 2009; 10(1):83-99.

14. Jafari M, Majedi H, Monavari SM, Alesheikh AA, Zarkesh MK. Dynamic simulation of urban expansion through a CA-Markov model Case study: Hyrcanian region, Gilan, Iran. European Journal of Remote Sensing. 2016 Jan 1; 49(1):513-29.

15. Al-sharif, A. A., & Pradhan, B. (2014). Monitoring and predicting land use change in Tripoli Metropolitan City using an integrated Markov chain and cellular automata models in GIS. Arabian journal of geosciences, 7(10), 4291-4301.Saudi Society for Geoscience 2013.

16. White R, Engelen G. Cellular automata as the basis of integrated dynamic regional modeling. Environment and Planning B: Planning and design. 1997 Apr; 24(2):235-46.

17. Mohammad M, Sahebgharani A, Malekipour E. Urban growth simulation through cellular automata (CA), analytic hierarchy process (AHP) and GIS; case study of 8th and 12th municipal districts of Isfahan. Geographia Technica. 2013; 8(2):57-70

Kirinyaga University

AFRICAN JOURNAL OF SCIENCE, TECHNOLOGY AND ENGINEERING (AJSTE)

Published by:

P.O BOX 143 - 10300, KERUGOYA, KENYA

MOBILE +254709742000/+254729499650

Email: info@KyU.ac.ke

Website: www.KyU.ac.ke

KyU is ISO 9000: 2015 Certified

Website: www.KyU.ac.k e