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Assessing ICT Infrastructure Requirements for AI-Powered Virtual Assistants in Delivering ICT Technical Support to Kenyan Public Universities

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Abstract: In recent years, the global landscape has witnessed a significant surge in the utilization of artificial intelligence (AI) for devising intelligent solutions across corporate entities and institutions of higher education. This paper underscores the profound impact of AI in shaping the landscape of smart solutions and particularly emphasizes the deployment of AI-powered virtual assistants. These virtual assistants hold the potential to revolutionize ICT technical support provision in public universities by expediting the resolution of routine technical issues faced by students and potentially reducing dependency on dedicated ICT support personnel. However, the successful implementation of such transformative technology necessitates a comprehensive understanding of the requisite ICT infrastructure. This study aims to meticulously analyze the essential ICT infrastructure components crucial for the effective deployment of AI-powered virtual assistants.

Employing a content analysis approach, the study gathered pertinent data from a corpus of 20 peer-reviewed journal articles centered on the themes of "ICT infrastructure" and "AI-powered Virtual Assistant." The investigation disclosed prominent AI platforms such as IBM Watson, Google Dialogflow, Microsoft Azure, and Amazon Lex as prevalent choices for Natural Language Processing in constructing AI-powered virtual assistants. These platforms exhibited inherent capabilities encompassing natural language comprehension, processing, and generation.

Programming languages such as JavaScript, Java, C#, SQL, Python, and Php emerged as popular choices for coding the AI-driven chatbot. Core hardware requirements included servers, smartphones, routers, and PCs. Pertinent software components encompassed Application Programming Interfaces (APIs), Operating Systems (OS), and Integrated Development Environments (IDEs). Furthermore, Facebook and WhatsApp emerged as prevalent messaging platforms for the testing, deployment, and user interaction aspects of the AI-powered chatbot. The outcomes of this study are anticipated to provide valuable insights for policy makers, IT practitioners, and university administrators, facilitating informed decision-making on the strategic integration of AI-powered virtual assistants to bolster ICT technical support for students.

Keywords: ICT Technical Support Provision, AI-Powered Virtual Assistant, ICT Infrastructure Requirements

I. INTRODUCTION

We are currently experiencing an unparalleled era of technological advancement characterized by rapidity, breadth, and profound influence [1]. Over time, technology has reshaped our environment and daily routines, influencing our behaviors, work dynamics, and communication patterns. Computers are undergoing a continuous evolution, becoming progressively faster, more portable, and exceptionally powerful, as highlighted by [2]. This progress has prompted numerous corporations to integrate Information Technology into their operational processes as a means of thriving, achieving operational excellence, and maintaining a competitive edge, as noted by [3]. Among the notable technological revolutions, Artificial Intelligence (AI) stands out as a prominent contender. AI constitutes a novel technical discipline dedicated to conceiving, refining, and applying theories, methodologies, and practical systems for emulating and expanding human intelligence, according to [4]. The central objective of AI involves the creation of machines capable of replicating human thought processes and actions. Originating from John McCarthy's conceptualization in 1956, AI has been defined as the field concerned with crafting intelligent machines, particularly computer programs endowed with intelligence. The scope of AI applications has considerably progressed in recent times, permeating virtually every sector of business, as affirmed by [5].

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Of the numerous domains where AI finds application, this study particularly fixates on the development of AI-powered Virtual Assistants tailored to offer ICT technical support to students within Kenya's public universities. Gartner's projection (2018) anticipates that by 2020, a quarter of customer service and support functions will adopt virtual customer assistants (VCAs) or chatbot technology across communication channels, marking a substantial rise from the meager 2% observed in 2017. Hence, this article centers on comprehending the ICT infrastructure prerequisites indispensable for effectively harnessing AI-powered virtual assistants to automate the provision of ICT technical support services.

II. ICT INFRASTRUCTURE

Information and Communication Technology (ICT) infrastructure refers to the physical and virtual resources, networks, and systems that facilitate the flow, processing, and storage of data and information within an organization or institution [6]. In the context of public universities in Kenya, an efficient and robust ICT infrastructure is crucial for supporting various academic, administrative, and research activities. The emergence of artificial intelligence (AI) technologies, specifically AI-powered virtual assistants, has opened up new possibilities for enhancing ICT technical support provision in public universities. Public universities in Kenya have progressively embraced ICT infrastructure to improve operational efficiency, facilitate learning, and foster innovation [7]. The ICT infrastructure in these universities encompasses both hardware and software components, along with the necessary network infrastructure and connectivity as discussed in sections A, B, C and D.

A. Hardware Infrastructure

The hardware infrastructure consists of physical devices and equipment necessary for ICT operations. This includes servers, storage devices, routers, switches, desktop computers, laptops, tablets, printers, scanners, and other peripheral devices. These hardware components form the foundation for the establishment of a reliable and efficient ICT system.

B. Software Infrastructure

The software infrastructure comprises the operating systems, application software, and databases that enable the execution of various ICT functions. It includes licensed operating systems such as Windows, macOS, or Linux, productivity software like Microsoft Office or Google Workspace, database management systems, and other specialized software applications required for academic and administrative tasks [8].

C. Network Infrastructure

An effective network infrastructure is essential for seamless communication and data transfer within and outside the university premises. Public universities typically have a Local Area Network (LAN) that interconnects different departments, administrative offices, and computer laboratories. The LAN is connected to a Wide Area Network (WAN) to establish connectivity with other institutions, the internet, and external resources. The network infrastructure also includes routers, switches, firewalls, and cabling systems to ensure secure and efficient data transmission [9].

D. Connectivity

Reliable internet connectivity is a fundamental requirement for modern ICT infrastructure in public universities. High-speed broadband connections enable access to online resources, e-learning platforms, research databases, and collaborative tools. Universities may employ different technologies, such as fiber-optic connections, wireless networks, or satellite-based solutions, to ensure widespread connectivity across the campus [10].

III. AI-POWERED VIRTUAL ASSISTANT

AI-powered virtual assistants have emerged as transformative tools in various domains, including ICT technical support provision. These intelligent systems leverage artificial intelligence and natural language processing capabilities to understand and respond to user queries, automate tasks, and provide personalized assistance [11]. Implementing AI-powered virtual assistants in public universities in Kenya can enhance ICT support services, improve operational efficiency, and enhance user experience. AI-powered virtual assistants, also known as chatbots or conversational agents, are software applications designed to simulate human-like interactions and provide assistance in a conversational manner. These virtual assistants employ AI algorithms, machine learning, and natural language processing techniques to interpret user queries and generate appropriate responses [12].

At the core of AI-powered virtual assistants lies natural language processing (NLP), a subfield of AI that focuses on enabling computers to understand and interpret human language. NLP algorithms analyze user input, decipher the meaning, and extract relevant information to generate appropriate responses. This allows virtual assistants to understand user queries, even in complex and ambiguous contexts [13].

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AI-powered virtual assistants can automate routine tasks, such as providing information, answering frequently asked questions, and guiding users through processes or procedures. These virtual assistants can retrieve data from databases, access relevant information from knowledge bases, and offer real-time assistance to users, reducing response times and freeing up human resources for more complex tasks [14].

Through machine learning techniques, AI-powered virtual assistants can learn from user interactions and adapt their responses over time. They can analyze user preferences, historical data, and contextual information to provide personalized recommendations, tailored assistance, and targeted solutions to specific issues [15].

AI-powered virtual assistants can be seamlessly integrated with existing ICT infrastructure in public universities. They can access and retrieve information from databases, interact with other software applications, and be deployed across various platforms, such as university websites, mobile applications, or messaging platforms. Implementing AI-powered virtual assistants in public universities' ICT support services can yield several benefits. These include enhanced user experience, 24/7 availability, scalability and cost-effectiveness, improved response times, and knowledge base expansion.

IV. METHODOLOGY

The main drive of this section was to describe the methodology that the researcher employed in order to meet the study's objectives. It explains the research process, including the sample frame, and data collection methods. A systematic content analysis was conducted. There were three stages to the analysis: planning, conducting, and then reporting. The definition of the bibliography databases and the choice of the query phrase were both done during the planning stage. Since they deliver the most pertinent and precise findings, the chosen databases were Scopus and IEEE Xplore. The title, keywords, and abstract of the search used the terms "AI-powered virtual assistant" AND "ICT infrastructure Requirements." The content analysed were limited to those papers published between January 1 of 2015 and September 30 of 2022, a period of seven years. Only peer-reviewed, English-language works that were accessible in institutional repositories were taken into account. Table I outlines the number of papers that were filtered from the initial step to the last step.

TABLE I NUMBER OF PAPERS USED IN THE ANALYSIS

Source		**Search Results**	**Repeated and Full Text**	**Title and Abstract**
Scopus		125	35	13
IEEE - Xplore		155	22	7
Total		**280**	**57**	**20**

Table I indicates a total of 280 journal articles of which 125 and 155 of the search results were from Scopus and IEEE-Xplore databases respectively. With the selection of the relevant papers and the removal of the rest, the second phase (conducting) got under way. Repeated items and papers without full-text PDF availability were not included, reducing the articles to a total of 57 of which 35 were from Scopus and 22 from IEEE-Xplore respectively. The selection of the most relevant articles was done in a subsequent step using title and abstract analysis. Papers that were not relevant were removed. The remaining papers, which totalled 20 (13 from Scopus and 7 from IEEE-Xplore), were then the most pertinent ones.

Aside from content analysis, the researcher issued questionnaires to ICT staff in Kibabii University who were to rate whether the ICT infrastructure requirements listed from content analysis were appropriate for the development of ICT Technical Support Virtual Assistant for students in Universities in Kenya. All The 16 ICT staff were purposively sampled. The criteria for sampling was based on the fact that these staff had the technical expertise in ICT infrastructure and were fairly knowledgeable with regards to the domain of research.

V. DATA ANALYSIS AND FINDINGS

This section presents and analyses the collected data from the field using research tools as deliberated in section (2). The research question addressed in this section was: “what are the ICT infrastructure requirement for the implementation of ICT support service virtual assistant?” Through content analysis, from the resulting papers, the findings were addressed in five broad thematic categories: hardware, software, programming languages, natural language processing platforms, and messaging platforms. In addition, ICT staff perception on ICT infrastructure requirement for virtual assistant implementation was also captured. The findings were as outlined below:

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A. Hardware Requirements for Virtual Assistant Implementation

The study sought to establish the hardware requirements for the implementation of the virtual assistant (chatbot). The findings were as presented in Table II.

TABLE III HARDWARE REQUIREMENTS FOR VIRTUAL ASSISTANT IMPLEMENTATION

Specific Requirement	**Justification**
Smart phone	Testing Environment/ Deployment
Personal Computer (Dual Core CPU / Quad Core CPU 8 GB RAM / 16 GB RAM 20 GB / 50 GB Free Disk Space)	To configure the development environment
Internet Router (Wireless/wired)	connection and synchronization of the various applications and the server

Table II reveals the core hardware requirements for the implementation of the chatbot as outlined by [16]. To test the chatbot against its functionality, a smartphone with touchscreen capability was found to be very appropriate. This is supported by [17]who also looks at the smartphone as an important component during chatbot deployment. [16] also proposes a personal computer with the minimum specifications of Dual Core CPU, 8GB RAM and 20 GB HDD as a core requirement for configuration of the development environment. In addition, the authors suggest that internet access is mandatory for connection and synchronization of the various third-party applications, the application and the virtual servers.

B. Software Requirements for Virtual Assistant Implementation

Apart from the hardware requirements, the study also sought to establish the software requirements for the implementation of the virtual assistant (chatbot). The findings were as presented in Table III.

TABLE IIIII SOFTWARE REQUIREMENTS FOR VIRTUAL ASSISTANT IMPLEMENTATION

Requirements' Category	**Specific Requirement**	**Justification**
System Software	Operating system (android 4.1/win 7/IOS 6 or higher).	System Software
IDE	Python IDE, Java IDE, Php IDE, General Purpose IDE (i.e., VS Code)	For coding environment (Code Editor)
DBMS	MS SQL, MySQL, Postgre SQL, SQLite or Oracle	Database Management

Table III reveals the core software requirements for the implementation of the chatbot as outlined by [16].The authors address the software requirements for chatbot implementation into three main sub-categories i.e. system software, Integrated Development Environment (IDE), and Relational Database Management System (DBMS). [18] agrees with [16] that Operating system, a system software, is a core software requirement for chatbot development. The two authors agree that Windows 7(32-bit) or above, android 4.1 and above and iOS 6 and above are the minimum operating system requirement.

Program writing is made simpler by IDE, which uses a set of tools to construct software applications. [19] outlines the various IDEs for chatbot development including python, java, php, and general-purpose IDEs as outlined in Table III. They argue that the primary benefit of utilizing a general-purpose IDE is that it enables rapid and effective coding. [20] seem to agree with them and additionally argue that general-purpose IDEs have built-in compilers that quickly turn programs into machine-level code or bytes of code.

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Table III also reveals that RDBMS is a crucial component of software requirement with regards to storage and implementation of Knowledge base for the chatbot. The table outlines various RDBMS such as MS SQL, MySQL, Postgre SQL, SQLite and Oracle among the commonly used Database management systems for chatbot development as proposed by [21] and supported by [19]. They argue that a database, developed with the use of MySQL as the RDBMS, was employed for the storage of bot knowledge.

C. Programming Languages for Virtual Assistant Implementation

In addition to the above outlined software requirement for chatbot implementation, the findings also revealed the various programming languages for chatbot development. Python [19] ,Java [18], C++, LISP, Php, and Ruby [22]. were among the proposed programming language for chatbot development. [23] agreed with these authors and went further to propose open source chatbot frameworks for developers who may not want to build chatbots from scratch. including Botkit, Botpress Botman built on Node.Js and Microsoft Bot Framework that supports python, JavaScript, C# and Java.

D. NLP Platforms for Virtual Assistant Implementation

Apart from the hardware and software requirements, the study also sought to establish the Natural Language Processing (NLP) platforms required for the implementation of the virtual assistant (chatbot). The findings were as presented in Table IV.

TABLE IVV NLP PLATFORMS FOR VIRTUAL ASSISTANT (CHATBOT) IMPLEMENTATION

Requirements' Category	**Specific Requirement**	**Justification**
NLP platforms	• Dialogflow (Google) • Wit.ai (Facebook) • Azure Bot Service (Microsoft)	Designing and integrating the chat flow with communication platform
	• Watson Assistant (IBM)	
	• Lex (Amazon)	

Table IV portrays the six leading NLP platforms that developers can use to create chatbot applications, able to understand natural languages: Google's Dialogflow, Facebook's wit.ai, Microsoft Azure Bot Service, IBM's Watson Assistant, and Amazon Lex [22]. All these platforms are supported by machine learning [22]. They share some standard functionality (they are cloud-based, they support various programming and natural languages) but differ significantly in other aspects [24]. Apart from the six commonly used NLP platforms by developers, [22] proposes other known NLP platforms for chatbot development including RASA, Botsify, Chatfuel, Manychat, Flow XO, Chatterbot, Pandorabots, Botkit, and Botlytics.

E. Messaging Platforms for Virtual Assistant Implementation

The study also sought to determine the various online messaging platforms that facilitate user interaction (communication) with the chatbot. The findings were as outlined in Figure I.

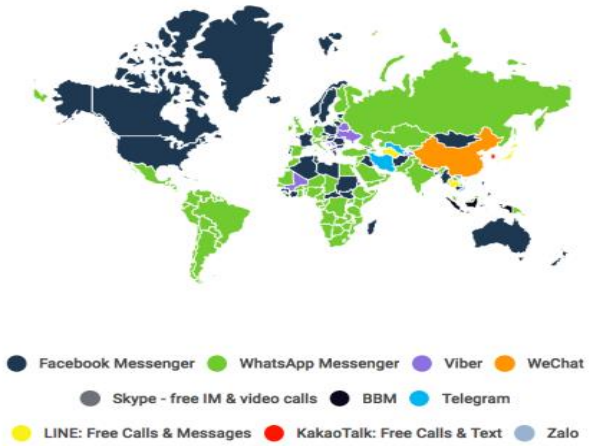

Fig I: Most Popular Online Communication Platforms by Country,
Source: Daniel (2017)

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Fig. I depicts the various messaging platforms by popularity based on country. The communication platforms include but not limited to: Facebook Messenger, WhatsApp Messenger, Viber, WeChat, Skype, BBM, Telegram, Line, Kakao Talk and Zalo [25]. From the figure, the target market is the primary factor in platform selection. Different audiences favor various platforms, so in some circumstances one product may be more appropriate than another [22]. It is evident from fig I, that WhatsApp is the commonly used messaging app and its popularity is large in South America, Africa and Asia. In Kenya, about 22.2 million people use WhatsApp daily according to data by *CNBC Africa*.

F. ICT Staff Perception on ICT Infrastructure Requirement for Virtual Assistant Implementation

Aside from the data and insights obtained from content analysis, the study went further to issue a questionnaire to the ICT staff in Kibabii University who were to rate whether the ICT infrastructure requirements listed from content analysis were appropriate for the development of ICT Technical Support Virtual Assistant for students in Universities in Kenya . The responses were gauged on a 5-point Likert scale: (1) Strongly Disagree; (2) Disagree; (3) Neither Agree nor Disagree; (4) Agree; and (5) Strongly Agree as presented in Table V.

TABLE V ICT STAFF PERCEPTION ON ICT INFRASTRUCTURE REQUIREMENT FOR VIRTUAL ASSISTANT IMPLEMENTATION

ICT Infrastructure Requirement	**1**	**2**	**3**	**4**	**5**	**Mean**	**Total**
Smartphone	2 (12.5%)	2 (12.5%)	3 (18.8%)	4 (25.0%)	5 (31.3%)	**3.50**	**16 (100.0%)**
PC	2 (12.5%)	2 (12.5%)	6 (37.5%)	3 (18.8%)	3 (18.8%)	**3.19**	**16 (100.0%)**
Internet Router	0 (0.0%)	2 (12.5%)	5 (31.3%)	2 (12.5%)	7 (43.8%)	**3.88**	**16 (100.0%)**
Server	0 (0.0%)	0 (0.0%)	1 (6.3%)	3 (18.8%)	12 (75.0%)	**4.69**	**16 (100.0%)**
Operating System	0 (0.0%)	0 (0.0%)	5 (31.3%)	5 (31.3%)	6 (37.5%)	**4.06**	**16 (100.0%)**
IDE	1 (6.3%)	2 (12.5%)	4 (25.0%)	3 (18.8%)	6 (37.5%)	**3.69**	**16 (100.0%)**
API	1 (6.3%)	1 (6.3%)	3 (18.8%)	5 (31.3%)	6 (37.5%)	**3.88**	**16 (100.0%)**
DBMS	0 (0.0%)	0 (0.0%)	4 (25.0%)	8 (50.0%)	4 (25.0%)	**4.00**	**16 (100.0%)**

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Python	0 (0.0%)	1 (6.3%)	3 (18.8%)	2 (12.5%)	10 (62.5%)	**4.31**	**16 (100.0%)**
Java	0 (0.0%)	4 (25.0%)	3 (18.8%)	6 (37.5%)	3 (18.8%)	**3.50**	**16 (100.0%)**
C++	0 (0.0%)	7 (43.8%)	5 (31.3%)	3 (18.8%)	1 (6.3%)	**2.88**	**16 (100.0%)**
C#	0 (0.0%)	3 (18.8%)	8 (50.0%)	5 (31.3%)	0 (0.0%)	**3.13**	**16 (100.0%)**
LISP	2 (12.5%)	5 (31.3%)	7 (43.8%)	2 (12.5%)	0 (0.0%)	**2.56**	**16 (100.0%)**
Php	3 (18.8%)	2 (12.5%)	2 (12.5%)	6 (37.5%)	3 (18.8%)	**3.25**	**16 (100.0%)**
JavaScript	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (31.3%)	11 (68.8%)	**4.69**	**16 (100.0%)**
SQL	1 (6.3%)	0 (0.0%)	5 (31.3%)	6 (37.5%)	4 (25.0%)	**3.81**	**16 (100.0%)**
Dialogflow	0 (0.0%)	0 (0.0%)	2 (12.5%)	6 (37.5%)	8 (50.0%)	**4.38**	**16 (100.0%)**
Watson	0 (0.0%)	0 (0.0%)	5 (31.3%)	3 (18.8%)	8 (50.0%)	**4.19**	**16 (100.0%)**

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Lex	1 (6.3%)	3 (18.8%)	5 (31.3%)	6 (37.5%)	1 (6.3%)	**3.19**	**16 (100.0%)**
Azure	0 (0.0%)	4 (0.25%)	3 (18.8%)	5 (31.3%)	4 (0.25%)	**3.56**	**16 (100.0%)**
Wit.ai	1 (6.3%)	6 (37.5%)	4 (25.0%)	3 (18.8%)	2 (12.5%)	**2.94**	**16 (100.0%)**
WhatsApp	0 (0.0%)	0 (0.0%)	4 (25.0%)	3 (18.8%)	9 (56.3%)	**4.31**	**16 (100.0%)**
Facebook	0 (0.0%)	2 (12.5%)	5 (31.3%)	3 (18.8%)	6 (37.5%)	**3.81**	**16 (100.0%)**
Telegram	2 (12.5%)	2 (12.5%)	3 (18.8%)	6 (37.5%)	3 (18.8%)	**3.38**	**16 (100.0%)**

To establish the hardware requirements, the researcher examined the indicators smartphone, Personal Computer (PC), internet routers, and servers. The results from Table V indicate that smartphone had a mean of 3.50, PC (3.19), internet router (3.88) while server had a mean of 4.69.

This implies that most ICT staff agreed that server and internet router were very crucial as a virtual assistant data store and for internet access respectively. Smartphone with a mean of 3.50 implies that the device is very crucial when it comes to testing and deployment of the artefact. PC had the lowest mean of 3.19. This goes in agreement with the result from content analysis, where a PC was majorly required for setting up of the coding environment for the virtual assistant.

To establish the software requirements, the researcher examined the indicators operating system (OS), Integrated Development Environment (IDE), Application Programming Interface (API), and Database Management System (DBMS). The results from Table V indicate that OS had a mean of 4.06, IDE (3.69), API (3.88) while DBMS had a mean of 4.69. This implies that most ICT staff agreed that all the four components were crucial for the development of the virtual assistant.

To establish the programming languages appropriate for the development of the virtual assistant, the researcher examined the indicators Python, Java, C++, C#, LISP, Php, JavaScript, and SQL. The results from Table V indicate that python had a mean of 4.31, Java (3.50), C++ (2.88), C# (3.13), LISP (2.56), Php (3.25), JavaScript (4.69), while SQL had a mean of 3.81. This implies python and JavaScript were the most commonly preferred programming languages for the development of the virtual assistant, while C++ and LISP were the least used. To establish the natural language processing platforms (NLPP) appropriate for the development of the virtual assistant, the researcher examined the indicators Dialogflow, Watson, Lex, Azure, and wit.ai.

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The results from Table V indicate that Dialogflow had a mean of 4.38, Watson (4.19), Lex (3.19), Azure (3.56), while wit.ai (2.94). This implies that Dialogflow and Watson were the commonly preferred NLP platforms for the development of the virtual assistant, while Facebook's wit.ai, with a mean of 2.94, was the least used.

To establish the Messaging Platforms (MP) appropriate for the development and deployment of the virtual assistant, the researcher examined the indicators WhatsApp, Facebook, and Telegram. The results from Table V indicate that WhatsApp had a mean of (4.31), Facebook (3.81), while Telegram had a mean of (3.38). This implies that WhatsApp and Facebook Messenger are the most preferred MP for the development and deployment of the virtual assistant, while Telegram, with a mean of 3.38, was the least used.

VI. CONCLUSION

The objective of this paper was to analyze the ICT infrastructure requirement for the implementation of ICT technical support virtual assistant in public universities in Kenya.

The key ICT infrastructure requirements identified were: Natural Language Processing Platforms, Programming Languages, Software Requirement, Hardware Requirement and Messaging Platforms. From these key requirements, the study makes the following conclusions:

i. IBM's Watson, Google's Dialogflow, Microsoft's Azure, and Amazon's Lex are among the most commonly used natural language processing platforms. The study recommends Dialogflow because its open source, it has multi-language support, and it's also easy to integrate with other third- party applications.

ii. JavaScript, python, Java, C#, SQL and Php are the commonly used programming languages for chatbot implementation. JavaScript and Python are the most preferred and are therefore recommended by this study.

iii. To develop a chatbot, servers, PC, router and smartphone are key hardware requirements for chatbot development.

iv. In terms of software requirements, IDE, API and OS are Key.

v. WhatsApp and Facebook are the common Messaging platforms for testing and deployment of AI-powered virtual assistants in Kenya. WhatsApp is most preferred for deployment.

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