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Internet of Things Adoption in Technology Ecosystems Within the Central African Region: The Case of Silicon Mountain

Godlove Suila Kuaban [1], Valery Nkemeni [2], Onyeka J. Nwobodo [3], Piotr Czekalski [3] and Fabien Mieyeville [4,*]

[1] Institute of Theoretical and Applied Informatics, Polish Academy of Sciences, Baltycka 5, 44-100 Gliwice, Poland; gskuaban@iitis.pl
[2] Laboratory of Electrical Engineering and Computing, University of Buea, Buea P.O. Box 63, Cameroon; nkemeni.valery@ubuea.cm
[3] Department of Computer Graphics, Vision and Digital Systems, Silesian University of Technology, Akademicka 2A, 44-100 Gliwice, Poland; onyeka.nwobodo@polsl.pl (O.J.N.); piotr.czekalski@polsl.pl (P.C.)
[4] University de Lyon, Université Claude Bernard Lyon 1, Ecole Centrale de Lyon, INSA Lyon, CNRS, Ampère, F-69621 Villeurbanne, France
* Correspondence: fabien.mieyeville@univ-lyon1.fr

Abstract: The Internet of Things (IoT) has emerged as a transformative technology with the potential to revolutionize various sectors and industries worldwide. Despite its global significance, the adoption and implementation of IoT technologies in emerging technology ecosystems within the Central African region still need to be studied and explored. This paper presents a case study of the Silicon Mountain technology ecosystem, located in Fako division of the southwest region of Cameroon, focusing on the barriers and challenges to adopting and integrating IoT technologies within this emerging tech ecosystem. Through a survey-based approach, we investigate the factors influencing IoT adoption in the Silicon Mountain tech ecosystem, including technological, economic, social, and regulatory factors. Our study reveals key insights into the current state of IoT adoption, opportunities for growth and innovation, and IoT adoption challenges. Key among the challenges identified for impeding IoT uptake were issues related to standardization and financial resources, labor shortage in the industry, educational and knowledge gaps, market challenges, government policies, security and data privacy concerns, and inadequate power supply. Based on our findings, we provide recommendations for policymakers, industry stakeholders, and academic institutions to promote and facilitate the widespread adoption of IoT technologies in Silicon Mountain and the Central African region at large.

Keywords: Internet of Things; IoT adoption; IoT adoption barriers; technology ecosystems; Silicon Mountain; Central African region

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1. Introduction

The Internet of Things (IoT) has revolutionized the way we interact with technology, creating a network of interconnected devices that communicate and share data to optimize various processes and services [1]. IoT applications span numerous sectors, including healthcare [2], agriculture [3], smart cities [4], industrial automation [5], home automation [6], etc., driving efficiency, innovation, and economic growth [7]. In healthcare, the IoT enables remote patient monitoring [8] and telemedicine [9], improving patient outcomes and reducing healthcare costs. In agriculture, the IoT facilitates precision farming through the use of sensors and data analytics, leading to higher crop yields and sustainable farming practices [10,11]. Smart cities leverage the IoT to enhance urban management, from traffic control and waste management to energy consumption and public safety [12–14]. The potential of the IoT to revolutionize various sectors and industries has led to its adoption worldwide.

While the IoT is present in everyday life in developed countries, its expansion and implementation in different regions of the world differ. In the African context, studies on IoT adoption have been carried out in West Africa, East Africa, and South Africa. For instance, Iwayemi [15] examined the challenges of IoT implementation in Nigeria, identifying key barriers such as cybersecurity threats, privacy concerns, and inadequate infrastructure. Similarly, Dosumu et al. [16] highlighted the shortage of skilled labor and the lack of educational programs focused on the IoT as significant impediments to its adoption in Rwanda, while Moeti et al. [17] highlighted the cost, knowledge gap, perceived value, and risk as some of the factors influencing the adoption of the IoT in South Africa. These studies provide valuable insights but are often limited to specific regions or sectors, making it difficult to generalize their findings across the diverse landscapes of the African continent.

The Central African sub-region [18], comprising countries such as Cameroon, Chad, the Central African Republic, Equatorial Guinea, Gabon, and the Republic of Congo, presents a unique context for IoT adoption. Despite its rich natural resources and strategic geographic location, the region faces numerous challenges, including political instability [19,20], underdeveloped infrastructure [21], and limited access to advanced technologies [22]. In addition, while East and West Africa have attracted substantial investment and developed thriving tech ecosystems, the Central African region has struggled to establish itself in this rapidly evolving landscape. These factors may have hindered the widespread adoption of the IoT in the region. Finally, the limited amount of research focusing on this region and its distinct socio-economic and political conditions makes insights and recommendations from studies conducted in other African regions or countries not directly applicable to the region.

Cameroon, the leading economy in the Central African sub-region, has the most advanced tech ecosystems in the sub-region, with the largest number of tech hubs and startups [23]. The country also leads the region in female representation in the tech sector, running approximately 75 to 80 female-focused programs [24]. The major technology ecosystems in Cameroon include Silicon Mountain, Silicon Wouri, and Silicon River and are concentrated in the cities of Buea, Douala, and Yaoundé, respectively.

Silicon Mountain [25], a sprouting technology ecosystem located in Buea, Fako division of the southwest region of Cameroon, is the most popular tech ecosystem in Cameroon and thus offers an ideal case study for investigating IoT adoption in tech ecosystems within the Central African region. The origin of Silicon Mountain can be traced back to 2006 when young web developers in Buea began exploring technology and building a community. Its prominence grew in 2015, following the graduation of the first batch of engineering and technology students from the University of Buea in December 2014 and the inaugural Silicon Mountain Conference held in June 2015. The University of Buea has played a pivotal role in establishing Silicon Mountain as Cameroon's leading technology hub, as many of these tech entrepreneurs first connected during their studies at the university. Known for its vibrant tech community and innovative startups, Silicon Mountain is home to a growing number of tech enthusiasts, developers, and entrepreneurs who are leveraging technology to address local and global challenges. The ecosystem's unique blend of higher education institutions, tech hubs, developer communities, tech-focused startups, etc., creates a conducive environment for exploring the potential and challenges of IoT adoption.

The objective of this study is to examine the barriers and opportunities for IoT adoption in the Silicon Mountain technology ecosystem and, by extension, the Central African region. This research aims to provide a comprehensive understanding of the factors influencing IoT adoption and to propose actionable recommendations for stakeholders to foster a more conducive environment for IoT implementation.

This study provides the following contributions:

- Identifying the key challenges for IoT adoption in the Silicon Mountain technology ecosystem and, by extension, the Central African region.

- Providing empirical data and insights specific to Silicon Mountain, which can serve as a benchmark for similar ecosystems in the region.
- Proposing strategies to overcome the identified barriers and to enhance the adoption of the IoT in the Silicon Mountain technology ecosystem and, by extension, the Central African region.
- Highlighting the role of educational institutions, government policies, and private sector initiatives in promoting IoT adoption.

The remainder of the paper is organized as follows: Section 2 presents a review of related works, Section 3 presents the methodology adopted, Section 4 presents the results and discussion, and Section 5 concludes the paper.

2. Review of Related Works

Studies on IoT adoption have been conducted globally across various geographic regions and technological domains. Geographically, these studies cover regions such as Europe, the United States, and Asia, as well as Eastern, Western, and Southern Africa. Technologically, the focus of these studies spans sectors like education, healthcare, agriculture, governance, and construction. Table 1 provides a summarized review of the related literature on IoT adoption, highlighting the diverse application areas and demonstrating the broad versatility of IoT technologies. Each sector encounters distinct challenges and opportunities in adopting the IoT, shaped by its specific technological, economic, and regulatory contexts. The following section synthesizes the findings by categorizing the studies based on their application areas: smart cities, education, healthcare, e-government, smart agriculture, and construction.

IoT adoption studies focusing on smart cities emphasize the role of the IoT in improving urban infrastructure management. In India, Mishra et al. [26] identified barriers such as privacy concerns, regulatory gaps, and high operational costs in smart city waste management. Similarly, in Europe, Padyab et al. [27] examined IoT adoption across multiple smart city applications, including autonomous driving and smart agriculture, identifying trust, privacy, and cost as key barriers. These findings highlight that while the IoT can significantly enhance urban services, concerns over data security and financial sustainability continue to hinder its widespread adoption.

In the educational sector, IoT adoption has been explored in both African and international contexts. The studies of Ajigini et al. [28], conducted in South Africa and Evwiekpaefe et al. [29], conducted in Nigeria, found that performance expectancy, effort expectancy, facilitating conditions, and social influence positively impact behavioral intentions to adopt the IoT in higher education institutions (HEIs). Another study in Nigeria [15] points to infrastructure issues, such as power supply shortages and the fear of cyber attacks, as major challenges. These studies reveal that while the IoT holds the potential to transform education, especially in resource-constrained environments, the success of its adoption largely depends on improving infrastructure and addressing security concerns.

The healthcare sector presents a unique opportunity for IoT adoption, particularly in improving patient care and health management. Al-rawashdeh et al. [30] conducted a systematic review of factors influencing medical professionals to adopt the IoT in healthcare, highlighting perceived usefulness, privacy risks, and financial costs as key determinants. The findings suggest that the IoT can bring significant benefits to healthcare, but issues related to privacy and financial feasibility must be addressed to encourage wider adoption by medical professionals.

Table 1. Review of related works on IoT adoption.

Ref	Geography Focus	Technological Focus	Research Objectives	Methodology	Identified Factors Influencing or Hindering IoT Adoption
[26]	India	Smart cities	Investigate the impact of IoT barriers for smart city waste management	An analytic approach involving a hybrid multi-attribute decision-making model applied to 15 IoT barriers identified from the literature and expert opinions	Security and privacy issues, lack of regulatory norms and policies, operational costs and extended payback periods, etc.
[28]	South Africa	Education	Investigate and identify the determinants of IoT adoption by higher educational institutions (HEIs) within the South African setting	A quantitative (empirical) method involving a survey of 250 respondents selected randomly from some tertiary institutions and the use of exploratory factor analysis (EFA) and regression analysis to determine factors affecting IoT adoption in HEIs	Behavioral intention to use the IoT was positively influenced by performance expectancy, social influence, and effort expectancy.
[30]	N.A.	Healthcare	Analyze and statistically classify existing knowledge about the factors that influence medical professionals to adopt IoT applications in the healthcare sector.	Systematic review of relevant IoT adoption studies from 2015 to 2021 carried out on nine major scientific databases and leading to 22 articles being selected as per the inclusion criteria	Social influence, attitude, and personal inattentiveness; perceived usefulness, perceived ease of use, performance expectancy, and effort expectations; perceived privacy risk, perceived severity and perceived health risk; financial cost; and facilitating conditions
[31]	Pakistan	E-government	Explore the success factors of IoT service orchestration to create public value in smart government.	A quantitative method for data collection involving a field survey conducted through online and paper-based questionnaires administered to 87 respondents. Partial least squares structural equation modeling was used for data analysis	Decision transparency, government trust, service collaboration, service effectiveness, service transparency, public engagement, perceived ease of use, public trust, and perceived usefulness are valid success measures of e-gov IoT service orchestration
[17]	South Africa	Smart Agriculture	Identify factors that may determine the adoption and use of IoT within the agricultural sector in Limpopo province.	A quantitative approach involving data collected via interviews, observations, and document reviews. Thematic analysis was used for data analysis	Organizational support, cost, knowledge gap, security, policy, monitoring and control, and perceived value and risk

Table 1. *Cont.*

Ref	Geography Focus	Technological Focus	Research Objectives	Methodology	Identified Factors Influencing or Hindering IoT Adoption
[32]	China	Construction	Investigate factors influencing the adoption of the IoT by construction companies in China.	Review of the related literature, adoption theories, semi-structured expert interviews, and a survey via questionnaires were used for data collection and regression analysis was used for analyzing the data	External environmental pressure, perceived benefit, top management support, company resource readiness, adoption intention, and perceived compatibility
[16]	Rwanda	Construction	Investigate the adoption, application and challenges of IoT technologies in the Rwandan construction industry.	Descriptive survey research method using a questionnaire with closed- and open-ended questions. Data analysis carried out using frequencies, mean scores, and Student's *t*-tests	Lack of training centers, lack of IoT awareness, lack of expertise, poor internet connectivity, etc.
[27]	Europe	Smart cities, autonomous driving, wearables and smart agriculture	Explore IoT adoption barriers in four large-scale pilots in Europe.	Literature review, workshops, and interviews were used to determine relevant IoT adoption barriers	Trust, cost, perceived value, privacy, and security
[33]	US	Agriculture	Explore IoT adoption barriers in precision agriculture practices in the Midwestern (Indiana) region of the US.	Focus group interview sessions conducted with eighteen subject matter experts (SME) in IoT-based precision agriculture practices	Cost, data latency, data scalability, data storage, data interoperability, type of sensors, type of wireless communication, type of precision agriculture application, and power consumption
[29]	Nigeria	Education	Investigate the behavioral intentions of students and staff at tertiary institutions in Kaduna metropolis to adopt IoT technology for educational purposes.	A quantitative method for data collection involving a field survey conducted through online questionnaires administered to 300 respondents. Partial least squares structural equation modeling was used for data analysis	Performance expectancy, effort expectancy, and facilitating condition positively influence behavioral intentions to use IoT technology
[15]	Nigeria	Education	Review IoT implementation challenges in Nigeria.	Literature review and survey via the use of questionnaires	Fraud, lack of power supply, religion, technical know-how, cost of implementing IoT, government policy, cyber attacks, privacy, security, and fear of loss of jobs

The IoT in e-government services has the potential to enhance public value through service efficiency and transparency. In Pakistan, Chohan and Hu [31] explored the success factors for IoT service orchestration in smart government, identifying decision transparency, public trust, and service effectiveness as critical factors. The study emphasizes the importance of public engagement and ease of use in achieving successful IoT implementation in government services. However, fostering trust between the government and citizens remains a key challenge in driving IoT adoption in e-government initiatives.

The agricultural sector, particularly in developing regions, has also embraced IoT applications to improve productivity and resource management. In South Africa, Moeti et al. [17] explored factors such as organizational support and knowledge gaps that influence IoT adoption in smart agriculture. Similarly, Hundal et al. [33] in the US identified technical barriers such as data latency, scalability, and sensor compatibility. These studies indicate that the IoT can play a transformative role in agriculture, but addressing technological constraints and improving farmer awareness and training are essential for successful adoption.

The construction industry offers another unique application area for the IoT, with the potential to improve efficiency and safety in construction projects. In China, Zhao et al. [32] investigated factors influencing IoT adoption by construction companies, identifying external environmental pressure and top management support as significant factors. In Rwanda, Dosumu et al. [16] found that a lack of IoT awareness and poor internet connectivity were major challenges in the construction industry. Both studies emphasize the importance of leadership support and infrastructure development in driving IoT adoption in construction.

The review of related works across these application areas reveals common themes in IoT adoption, such as concerns over privacy, security, and infrastructure. However, the specific challenges vary by sector and region, with industries like healthcare and education focusing on trust and usability, while sectors like agriculture and construction emphasize technological readiness and organizational support. These insights emphasize the need for sector-specific strategies to address the barriers to IoT adoption and fully leverage its potential across different industries and market segments.

While the IoT has attracted significant attention as a transformative technology across various sectors, existing studies primarily focus on sector-specific IoT adoption in areas such as smart cities, education, healthcare, and agriculture, often in more developed regions. Despite these insights, there remains a critical gap in the literature concerning IoT adoption within emerging technology ecosystems, particularly in the underexplored Central African region.

No comprehensive study has examined the factors influencing IoT adoption in technology ecosystems within the Central African region, particularly within innovation clusters like Silicon Mountain. This gap is critical, as the region presents unique barriers (e.g., infrastructure limitations, skill gaps, and regulatory challenges) that are distinct from those found in more developed ecosystems. Understanding these region-specific factors is essential for fostering IoT innovation and growth, yet the absence of targeted research on IoT adoption in Central African technology ecosystems leaves policymakers, industry stakeholders, and academic institutions without the necessary data to inform strategic decision-making. While global studies, including those from international organizations such as the World Bank, Internation Telecommunications Union (ITU), and African Development Bank, have provided valuable insights into the challenges of IoT adoption in developing regions, such as sub-Saharan Africa, there remains a critical need for region-specific studies that address the distinct socio-economic, infrastructural, and regulatory conditions of Central African ecosystems like Silicon Mountain. For example, the World Bank and ITU reports have highlighted common barriers, such as inadequate infrastructure, skill gaps, and regulatory challenges, that are relevant to many African regions [34,35]. However, these global frameworks and findings often provide macro-level data that may not fully capture the unique nuances of smaller technology ecosystems in Central Africa.

This study aims to build upon these global insights by narrowing the focus to the Silicon Mountain technology ecosystem, a hub that has yet to be extensively explored in IoT-specific research. Silicon Mountain presents distinct challenges, such as the limited technological infrastructure and regulatory frameworks that differ from those in better-documented ecosystems, like Kenya's Silicon Savannah [36]. By investigating IoT adoption specifically within the Silicon Mountain context, this study contributes localized insights that complement the broader body of research, helping to address the knowledge gap specific to this underexplored region.

3. Methodology

The methodology employed in this study follows a systematic process to investigate the factors influencing IoT adoption within the Silicon Mountain technology ecosystem. A quantitative survey-based research method, commonly used in management sciences, was applied. This methodology is structured into five key steps: conducting a literature review, designing the survey instrument, sampling and data collection, data validation, and data analysis.

3.1. Literature Review

A comprehensive review of existing studies on IoT adoption, particularly in developing regions, was conducted as presented in Section 2. This helped in formulating the research questions and designing the survey instrument.

3.2. Survey Design and Development

Based on the literature review, a 42-item questionnaire was developed (refer to Appendix A, Table A2). The questions were structured using a 5-point Likert scale and divided into five sections: demographics, IoT awareness, IoT applications, challenges to IoT adoption, and strategies for enhancement. The Likert scale used to assess the challenges to IoT adoption was configured as follows: 1 for "not serious", 2 for "less serious", 3 for "moderate", 4 for "more serious", and 5 for "very serious".

3.3. Sampling and Data Collection

The target population for this study included tech-focused startups, technology hubs, higher education institutions (HEIs), and developer communities located in Buea, all affiliated with the Silicon Mountain technology ecosystem. The ecosystem currently has over fifty registered and active startups, seven tech hubs, five developer communities, and seven tech-focused HEIs. Startups were defined as businesses operating for fewer than five years. A simple random sampling method was used to select 200 participants for the study. Questionnaires were distributed to these participants both online and offline, with data collected through Google Forms and printed forms.

3.4. Data Validation

To ensure face validity, the questionnaire was first reviewed by a data analyst to confirm that the constructs were measured accurately. Data from the field survey were manually coded, except for the data collected online using Google Forms. To ensure the integrity of the data, a series of data verification steps were undertaken. Data collected via online platforms such as Google Forms were checked for any unusual response patterns or inconsistencies that might suggest automation or AI involvement. To ensure data validity and accuracy, responses were manually reviewed and subjected to item analysis using Cronbach's Alpha to assess internal consistency [37]. Construct validity was evaluated through the reliabilities of individual factors [38], also measured using Cronbach's Alpha coefficient and through Exploratory Factor Analysis (EFA) [39].

3.5. Data Analysis

The cleaned and refined data were analyzed using IBM SPSS version 25.0 software. Exploratory Factor Analysis (EFA) and Principal Component Analysis (PCA) with Varimax Rotation [40] were applied to extract key factors influencing IoT adoption. The scale was refined by removing items with low cross-loadings, low factor loadings, and low communalities, improving the interpretability of the factor structure, as recommended by [41]. Challenges with an average seriousness score below 3.5 were excluded from further analysis, as they did not constitute significant barriers to IoT adoption.

4. Results and Discussion

This section presents the findings from the analysis of questionnaires distributed to respondents within the Silicon Mountain technology ecosystem. Out of the 200 questionnaires administered, 160 responses were received, resulting in an 80% response rate, with 146 of these deemed usable for the study.

4.1. Respondent's Demographics

Among the 146 participants who completed the questionnaire, the majority were male (94 or 64.4%), while 52 (35.6%) were female. This result is representative of the field. The tech ecosystem in Cameroon, similar to that of sub-Saharan Africa, is predominantly male-dominated, with most startups being founded and led by men. As of 2020, 85% of co-founders or C-level executives in Africa were male [25]. This can be attributed to cultural practices in the region which significantly contribute to the underrepresentation of women in technical fields. These practices shape societal expectations, gender roles, and access to education, which together create barriers for women [42,43]. The age distribution showed that most respondents were between 21 and 30 years old (69 or 47.3%), followed by those aged 31 to 40 years (30 or 20.5%), with the smallest group being those aged 51 and above. The mean age of the respondents was 30.98 years. This result is representative of the field.

Figure 1 presents the composition of the respondent's affiliation in the Silicon Mountain technology ecosystem obtained from the field survey. The data indicate that 56 respondents (38.4%) are associated with the academic sector within the Silicon Mountain technology ecosystem. Start-up firms comprise 22 respondents (15.1%), developer communities include 15 respondents (10.3%), and incubators account for 18 respondents (12.3%). Furthermore, 4 respondents (2.7%) represent SMEs utilizing IT systems, 16 respondents (11.0%) are technology promoters or enthusiasts, 6 respondents (4.1%) are NGOs involved in technology promotion, 4 respondents (2.7%) are government agencies, and the remaining 5 respondents (3.4%) fall into other categories. This result is representative of the field.

The majority of respondents, 99 (67.8%), held entry-level positions (students, interns, administrative assistants, etc.) in their respective organizations. Additionally, 18 (12.3%) held managerial positions (head of departments, operations managers, product managers, etc.), 15 (10.3%) were co-founders, and the remaining 14 (9.6%) held junior-level positions (junior software developers and marketers).

Figure 2 presents the fields of specialization of the respondents. The majority, 49 (33.6%), were from the telecommunications sector, followed by 38 (26.0%) from software development. Additionally, 13 (8.9%) were from health sciences and computer science, 12 (8.2%) were from the field of computer networks, 7 (4.8%) were from computer maintenance, and the smallest group, 4 (2.7%), were from agriculture. This indicates that within the Silicon Mountain technology ecosystem, the telecommunications sector has the highest representation, while the agricultural field has the lowest. This result is representative of the field.

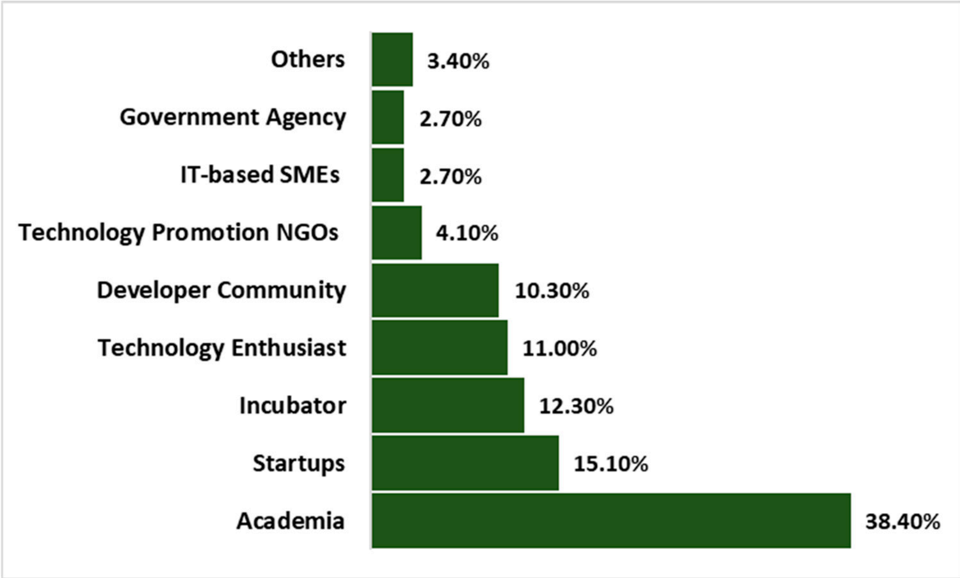

Figure 1. Respondents' affiliation within the Silicon Mountain technology ecosystem.

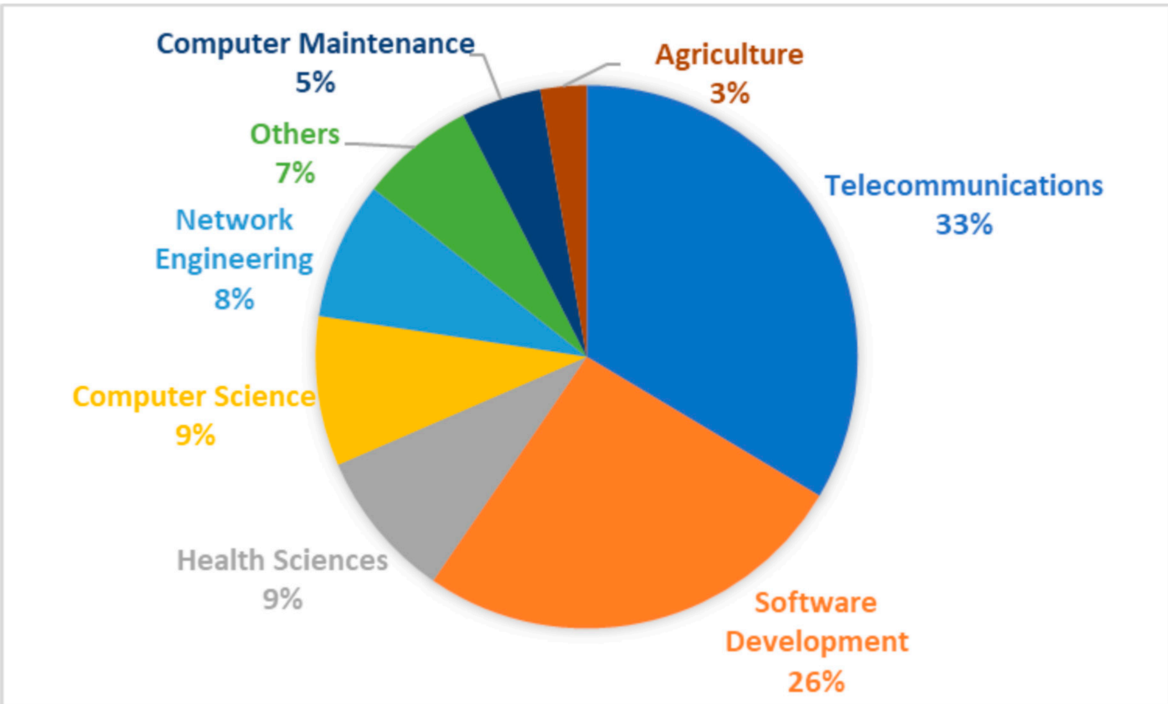

Figure 2. Respondents' field of specialization.

4.2. Reliability Analysis

Evaluating the questionnaire and its individual questions is essential to ensure the consistency of each question group supporting the respective variables and the relevance of the selected questions [44]. Reliability testing was conducted using Cronbach's Alpha statistic [45], and construct validity was assessed through the reliabilities of the individual factors, measured using Cronbach's Alpha coefficient and Exploratory Factor Analysis (EFA).

The reliability testing yielded an overall Cronbach's Alpha value of 0.821, which is considered acceptable as it surpasses the minimum acceptable threshold of 0.7 [46,47]. The Cronbach's Alpha coefficients for all five factors on the questionnaire were satisfactory, as they exceeded the recommended value of 0.7. Furthermore, the results of construct validity from EFA indicated no cross-loading constructs, leading to the identification of seven main barriers for IoT adoption. According to Park and Kim [48], factor analysis typically requires a sample size of 100 or more, but it can be performed with a minimum of 50 samples. This study's sample size exceeded that threshold.

4.3. Awareness and the Level of Knowledge About IoT in the Silicon Mountain Technology Ecosystem

When asked about their knowledge of the IoT and their sources of information, the results show that out of 146 respondents, 122 (83.6%) were familiar with the term IoT, with information acquired from various sources such as the media (59 or 81.9%), books (47 or 38.5%), and others including courses (12 or 9.8%), workshops (3 or 2.4%), and articles (1 or 0.8%). This indicates that most respondents were versed in the concept of the IoT and likely had sufficient knowledge of the challenges related to IoT adoption within the Silicon Mountain technology hub in Buea. Furthermore, more than half of the respondents, 96 (65.8%), rated their understanding of the IoT as good, 14 (9.6%) rated their knowledge as excellent, 22 (15%) had average knowledge, and 14 (9.6%) considered their knowledge of the IoT to be poor.

4.4. Potential Areas for the Implementation of Internet of Things of in the Central African Sub-Region

This study also aimed to identify potential areas and benefits of the IoT within the Central African sub-region. As illustrated in Figure 3, the results indicate that the majority of respondents (121 or 82.9%) advocated for the adoption of the IoT in smart health applications. Similarly, there was considerable support for applying the IoT to the agricultural sector (105 or 71.9%). The findings also highlighted significant interest in implementing the IoT for security and safety (74 or 50.7%), smart metering, and smart cities (99 or 67.8%). The least favored area for IoT adoption was intelligent transport systems and logistics (50 or 34.2%). Additionally, other potential areas for IoT application included environmental and weather monitoring, flexible manufacturing or industry, control of factory physical systems, and smart logistics and businesses.

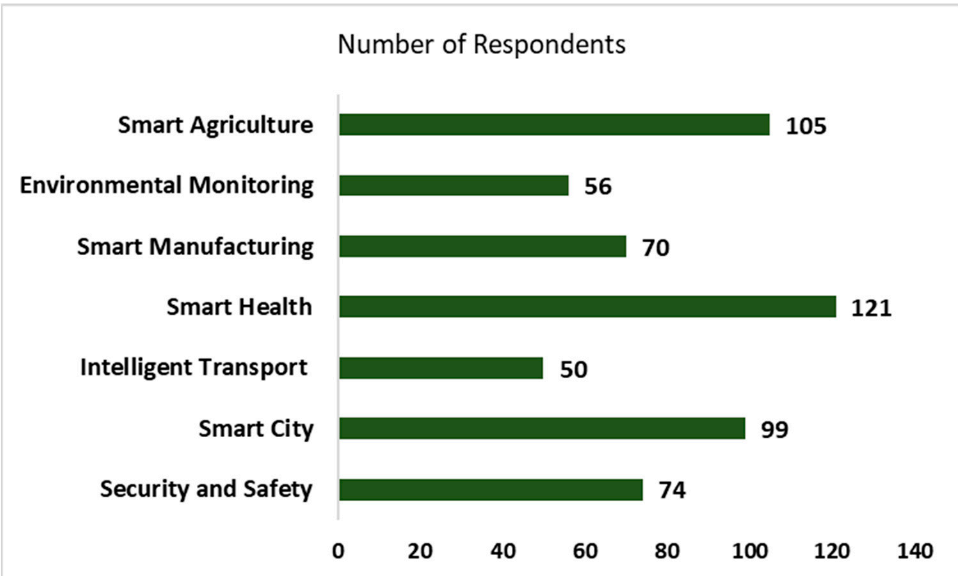

Figure 3. Respondents' identification of potential areas for the implementation of the Internet of Things in the Central African sub-region.

These results align closely with the literature on IoT adoption. For instance, data published in 2018 by IoT Analytics [49], a leading provider of market insights and strategic business intelligence for Industry 4.0 and IoT, reveal the growing importance of the IoT in sectors such as healthcare and agriculture, noting that these areas are frequently highlighted as high-potential domains for IoT applications [50]. The significant interest in smart health and agriculture observed in this study corroborates their findings, emphasizing the global trend towards leveraging the IoT for enhancing healthcare delivery and optimizing agricultural processes [51]. Furthermore, the interest in the IoT for security and safety, smart metering, and smart cities reflects the broader industry focus on urban management and infrastructure development, which has been well-documented in previous studies [52].

Other sectors (such as education, transportation, and manufacturing) also offer significant opportunities for IoT adoption in the Central African region. In higher education, the IoT can play a crucial role in smart campuses, improving operational efficiency and safety [53]. IoT sensors can optimize energy usage, monitor building security, track equipment usage, estimate room occupation, and determine student classroom attendance, leading to cost savings for educational institutions. Furthermore, the IoT can be leveraged to support research initiatives, providing real-time data collection for various academic fields. In the transportation sector, the IoT can transform public transportation by providing real-time updates on bus or train schedules and optimizing routes based on current traffic conditions to enhance commuting experience. In logistics, the IoT can streamline supply chains by enabling fleet management systems to monitor vehicle locations, fuel consumption, and cargo conditions in real time, improving efficiency and reducing costs [54]. In manufacturing, the IoT can help optimize supply chain management, tracking raw materials and finished products throughout the production and distribution processes [55]. This will lead to improved inventory management, faster response times, and enhanced coordination between suppliers, manufacturers, and distributors. The adoption of automation and robotics powered by the IoT can also improve product consistency and quality control, driving competitiveness for local manufacturers in the global market. Thus, as the Central African region seeks to improve its educational system, modernize its transportation sector, and expand its industrial base, adopting the IoT will play a key role in achieving these goals.

4.5. Challenges Impeding IoT Adoption Within the Silicon Mountain Technology Ecosystem

Table 2 presents the challenges impeding IoT adoption within the Silicon Mountain technology ecosystem. Respondents were asked to evaluate the seriousness of each challenge using the following scale: Very Serious (VS), More Serious (MS), Moderate (M), Less Serious (LS), and Not Serious (NS).

Table 2. Challenges impeding IoT adoption within the Silicon Mountain technology ecosystem.

Items	VS	MS	M	LS	NS
Poor internet connectivity and high cost of internet data	28 19.2%	5 3.4%	9 6.2%	28 19.2%	76 52.1%
Insufficient power supply and high energy costs	30 20.5%	12 8.25	5 3.4%	27 18.5%	72 49.3%
Lack of skilled labor in the field of IoT	56 40.4%	28 19.2%	36 24.7%	11 7.5%	12 8.2%
Adoption of new technologies requires an updated educational curriculum	45 30.8%	43 29.5%	33 22.3%	16 11.0%	9 6.2%
Insufficient financial resources	48 32.2%	41 28.1%	37 25.3%	13 8.9%	6 4.1%
Lack of standardization in IoT	39 26.7%	43 29.5%	40 27.4%	20 13.7%	4 2.7%
Concerns regarding data confidentiality, integrity, authentication, and ownership	33 22.6%	37 25.3%	36 24.7%	29 19.9%	11 7.5%
Potential damage resulting from a successful IoT attack	29 19.9%	38 26.0%	46 31.5%	25 17.1%	8 5.5%
Inadequate security mechanisms within IoT systems	24 16.4%	44 30.1%	45 30.8%	25 17.1%	8 5.5%

Table 2. *Cont.*

Items	VS	MS	M	LS	NS
Lack of legal recognition and a comprehensive policy framework for IoT	38 26.0%	37 25.3%	40 27.4%	24 16.4%	7 4.8%
Government interference and bureaucratic obstacles in Cameroon	25 17.1%	48 32.9%	35 24.0%	25 17.1%	13 8.9%
Conflicting and overlapping policies	46 31.5%	42 28.6%	33 22.6%	21 14.4%	4 2.7%
Increased tax burden resulting from changes in tax policy	37 25.3%	40 27.4%	44 30.1%	14 9.6%	11 7.5%
Ambiguity and lack of rigor in existing policies	47 32.2%	52 35.6%	24 16.4%	15 10.3%	8 5.5%
Prevalence of favoritism and corruption in policy implementation	47 32.2%	39 26.7%	33 22.6%	16 11.0%	11 7.5%
Potential clients are hesitant to adopt the IoT due to the need for significant infrastructure setup and upgrades	52 36.6%	42 28.8%	27 18.5%	14 9.6%	11 7.5%
Lack of understanding of commercial practices and market regulations	41 28.1%	45 30.8%	45 30.8%	11 7.5%	4 2.7%
The cost of IoT solutions and the associated payback period hinder adoption	35 24.0%	40 27.4%	42 28.8%	18 12.3%	0 00%
Difficulty in establishing cooperation with local distribution networks	25 17.1%	49 33.6%	41 28.1%	24 16.4%	7 4.8%
The high cost of marketing IoT solutions makes it difficult for startups to afford	45 30.8%	49 33.6%	31 21.2%	13 8.9%	8 5.5%
Ongoing economic crises in the country	40 27.4%	58 39.7%	33 22.6%	11 7.5%	4 2.7%
Organizations often lack understanding of the benefits of the IoT and are generally not motivated to invest in it	58 39.7%	43 29.5%	23 15.8%	16 11.0%	6 4.1%

NS = Not Serious, LS = Less Serious, M = Moderate, MS = More Serious, VS = Very Serious.

The results are as follows:

- Poor Internet Connectivity: This is not considered a serious challenge, with 52.1% of respondents rating it as “Not Serious”.
- Power Supply and High Energy Costs: Similarly, these issues are not seen as significant barriers, with 49.3% of respondents rating them as “Not Serious”.

Conversely, several factors are identified as serious challenges:

- Insufficient Skilled Labor: The lack of skilled professionals in technological areas such as data science, cybersecurity, IoT development, agriculture, etc., is considered a significant challenge by 40.4% of respondents who rated it as “Very Serious”.
- Inadequate Financial Resources: Challenges such as difficulty securing loans and limited funding support are rated as “Very Serious” by 32.2% of respondents.
- Lack of Standardization: The absence of uniform standards in IoT hardware, software, and communication protocols makes interoperability difficult. This was rated as “More Serious” by 29.5% of respondents.

Other significant challenges include the following:

- Sub-Standard Curriculum: The outdated educational curricula in most of Silicon Mountain’s academic institutions, which fail to keep up with advancements in technology, were rated as “Very Serious” by 30.8% of respondents.
- Data Security Concerns: Issues related to data confidentiality, integrity, and authentication are considered a challenge, with 30.8% rating these concerns as “Moderate”.
- Risk of IoT Attacks: The potential damage from IoT attacks, such as the 2016 IoT botnet attack, is seen as a significant risk, rated as “More Serious” by 26% of respondents.
- Inadequate Security Mechanisms: The perception of the IoT as the “Internet of Threats” due to insufficient security measures is also considered a barrier.

In terms of legal and regulatory issues, the following were stated:

- Lack of Legal Recognition and Policy Framework: The absence of a clear legal and policy framework is rated as "More Serious" by 51.2% of respondents.
- Government Interference and Bureaucracy: Overlapping and conflicting policies, increased tax burdens, and corruption are significant deterrents, with 52.7% rating tax policy changes as "More Serious" and 58.9% identifying favoritism and corruption as barriers.

Market-related challenges include the following:

- Reluctance to Adopt IoT: Potential client reluctance to invest in IoT due to the need for infrastructure upgrades and new business models was rated as "More Serious" by 64.4% of respondents.
- Lack of Understanding of Market Practices: Poor understanding of commercial practices and market regulations was also a notable challenge, rated as "More Serious" by 58.9% of respondents.
- IoT Costs and Payback Period: The high costs associated with IoT implementation and the difficulty in establishing local distribution networks were rated as significant barriers by 51.4% of respondents.

Improvement strategies for addressing the challenges in IoT adoption are detailed in Table 3. The findings were as follows:

- Tax Policy Reforms: Rated as highly influential by 87 respondents (59.6%), improving tax policies is seen as a significant factor in enhancing IoT adoption among businesses in the Silicon Mountain.
- Network Connectivity and Internet Data Costs: Improving network connectivity and reducing internet data costs were also deemed crucial, with 43.8% of respondents highlighting their importance.
- Reduction in IoT Device Prices: Lowering the costs of IoT devices was rated as a highly influential factor by 95 respondents (65.1%), which could significantly boost IoT adoption.
- Enhanced Energy Availability: Improving the availability of energy to businesses was similarly recognized as an important factor.

Table 3. Proposed improvement strategies to the challenges identified.

Improvement Strategies	GTE	GE	M	LE	NE
Improvement in tax policies to encourage the adoption of IoT businesses	60 41.1%	27 18.5%	33 22.6%	14 9.6%	12 8.2%
Enhance network connectivity and reduce internet data costs	38 26.0%	26 17.8%	20 13.7%	39 26.7%	23 15.8%
Reduction in the prices of IoT devices	64 43.8%	31 21.2%	26 17.8%	14 9.6%	11 7.5%
Enhance the availability and reliability of energy supply	65 44.5%	46 31.5%	19 13.0%	11 7.5%	5 3.4%
Enhance the security mechanisms for IoT systems	61 41.8%	52 35.6%	27 18.5%	6 4.1%	0 00%
Organize IoT workshops, seminars, and meet-ups and incorporate IoT-related courses into the curriculum to enhance skilled labor in the IoT	62 42.5%	47 32.2%	26 17.8%	9 6.2%	2 1.4%
Provide access to funding, loans, and IoT research grants for academic institutions and incubators	57 39.0%	37 25.3%	40 27.4%	12 8.2%	0 0.0%

NE = Not at all, LE = Lesser Extent, M = Moderate, GE = Great Extent, GTE = Greater Extent.

Additionally, several other strategies were proposed to improve IoT adoption:

- Enhanced IoT Security Mechanisms: Strengthening security measures for IoT systems is considered essential for fostering adoption.
- Educational Initiatives: Organizing IoT workshops, seminars, and meetups, as well as integrating IoT-related courses into academic curricula, is expected to address the skills gap and increase labor proficiency.
- Access to Funding: Providing access to funding, loans, and IoT research grants for academic institutions and incubators is identified as a key strategy to support IoT development and adoption.

4.6. Verification of the Hypothesis of the Study

In this study, Exploratory Factor Analysis (EFA) was conducted using the Principal Components Analysis (PCA) method with Varimax Rotation to investigate the challenges to IoT adoption in the Silicon Mountain technology ecosystem. To enhance the interpretability of the factor structure, the scale was refined by removing items with low cross-loadings, low factor loadings, and low communalities, following the recommendations of [41].

4.6.1. Factor Analysis

To determine if the data captured in this study were appropriate for factor analysis, we used the Kaiser–Meyer–Olkin (KMO) and Bartlett's Test of Sphericity. From the literature, a KMO value > 0.6 is acceptable for a sample size < 100, while a KMO value between 0.5 and 0.6 is acceptable for sample sizes between 100 and 200 [39,56]. In this study, the KMO measure of sampling adequacy was 0.706, and Bartlett's Test of Sphericity was significant (Sig = 0.000), with a Chi-square value of 785.296 and 231 degrees of freedom (df). Table 4 presents the results generated from the SPSS software for KMO and Bartlett's Test of Sphericity. These results demonstrate that the data set is not an identity matrix with zero correlations (i.e., the variables are indeed correlated), thereby confirming the appropriateness of applying factor analysis.

Table 4. Kaiser–Meyer–Olkin and Bartlett's Test of Sphericity.

Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.706
Bartlett's Test of Sphericity	Approx. Chi-Square	785.296
	df	231
	Sig.	0.000

determinant = 0.003.

In study, we measured 22 items related to the challenges of IoT adoption in the Silicon Mountain tech ecosystem, using a five-point Likert scale to gauge their level of seriousness. The averages of these items were calculated to provide an overview of how respondents rated the different challenges. To focus the analysis on the most significant barriers, we applied a cutoff threshold of 3.5, which allowed us to identify the factors perceived by respondents as serious impediments to IoT adoption in the Silicon Mountain tech ecosystem. After applying this threshold, 13 out of the 22 factors emerged as critical barriers to IoT adoption, and these are displayed in Table 5 along with their average ratings (mean values).

Table 5. Major factors affecting IoT adoption in the Silicon Mountain technology ecosystem.

Major Factors that Affect the Adoption of Internet of Things	Mean
Organizations often lack an understanding of the benefits of IoT and are generally not motivated to invest in it	3.8973
Ongoing socio-economic crises in the country	3.8151

Table 5. *Cont.*

Major Factors that Affect the Adoption of Internet of Things	Mean
Inadequate financial resources, difficulty in securing loans, and limited funding support from the government and other sponsors	3.8014
The loose nature of policies	3.7877
Insufficient skilled labor in the IoT, data science, and agriculture	3.7603
Potential clients are hesitant to adopt IoT due to the necessity of setting up or upgrading infrastructure and adopting new business models, which may result in a limited market	3.7534
The high cost of marketing IoT solutions poses a significant challenge, as many startups are unable to afford these expenses	3.7534
Lack of understanding of commercial practices and market regulations related to the IoT	3.7397
The mass movements of graduates from STEM (Science, Technology, Engineering and Mathematics) fields for greener pastures	3.7260
Overlapping and conflicting policies	3.7192
Lack of updated educational curricula with many academic institutions lacking dynamic curricula that integrate the latest advancements in hardware, software, and communication technologies	3.6781
Favoritism and corruption	3.6507
Lack of standardization in IoT as each vendor develops its own hardware, software, and communication protocols without adhering to common standards, making it challenging to integrate devices from different manufacturers into a cohesive IoT application	3.6370

Table 5 reveals the primary challenges to IoT adoption in the Silicon Mountain based on the mean averages. The major challenges identified include the following:

- Lack of Understanding and Motivation: organizations typically do not grasp the benefits of the IoT and are often unwilling to invest in it, with a mean score of 3.8973.
- Socio-economic Crises: the ongoing socio-economic crises in the country pose a significant barrier, scoring 3.8151.
- Inadequate Financial Resources: the inability to secure loans and the lack of funding support from the government and other sponsors are major issues, with a mean score of 3.8014.
- Loose Policies: the loose nature of policies is a critical challenge, reflected in a mean score of 3.7877.
- Insufficient Skilled Labor: there is a shortage of skilled labor in the IoT, data science, and agriculture, scoring 3.7603.
- Client Reluctance: potential clients are hesitant to adopt the IoT due to the need for infrastructure upgrades and new business models, scoring 3.7534.
- High Marketing Costs: the cost of marketing IoT solutions is high, making it unaffordable for startups, with a mean score of 3.7534.
- Lack of Commercial Understanding: there is a lack of understanding of commercial practices and market regulation, scoring 3.7397.
- Brain Drain: the mass movement of graduates from Science, Technology, Engineering, and Mathematics (STEM) fields seeking better opportunities is a significant barrier, scoring 3.7260.
- Conflicting Policies: overlapping and conflicting policies also pose a challenge, with a mean score of 3.7192.
- Outdated Educational Curricula: many academic institutions lack dynamic curricula to equip students with the latest developments in IoT technologies, scoring 3.6781.
- Favoritism and Corruption: these issues also constitute serious barriers, with a mean score of 3.6507.

- Lack of Standardization: the lack of standardization in the IoT, where each vendor develops their hardware, software, and communication protocols independently, is a hindrance, scoring 3.6370.

These challenges highlight significant barriers to the adoption of IoT in the Silicon Mountain area, as indicated by the mean scores derived from the survey.

4.6.2. Principal Component Analysis of IoT Adoption Challenges in the Silicon Mountain Technology Ecosystem

The Principal Component Analysis (PCA) method was employed, and the eigenvalues associated with each linear component (factor) before extraction, after extraction, and after rotation are presented in Table 6. Initially, 22 linear components were identified within the data set. Among these, seven primary components were extracted based on their eigenvalues, with only factors having eigenvalues greater than 1 being considered. These seven factors accounted for approximately 60.449% of the variance in the challenges to IoT adoption within the Silicon Mountain technology ecosystem. This percentage is deemed satisfactory, as it exceeds the minimum threshold of 50%. It is recommended that the proportion of the total variance explained by the retained factors should be at least 50% [39]. Consequently, about 39.551% of the variance is attributable to other challenges to IoT adoption that were not considered.

Table 6. Determination of primary components based on total variance.

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.789	21.770	21.770	4.789	21.770	21.770	2.981	13.548	13.548
2	1.788	8.127	29.897	1.788	8.127	29.897	2.173	9.878	23.426
3	1.716	7.799	37.696	1.716	7.799	37.696	1.754	7.975	31.401
4	1.396	6.344	44.040	1.396	6.344	44.040	1.752	7.963	39.364
5	1.353	6.148	50.188	1.353	6.148	50.188	1.608	7.311	46.674
6	1.176	5.345	55.533	1.176	5.345	55.533	1.520	6.910	53.585
7	1.081	4.916	60.449	1.081	4.916	60.449	1.510	6.864	60.449
8	0.948	4.310	64.759						
9	0.889	4.040	68.799						
10	0.824	3.747	72.546						
11	0.719	3.267	75.813						
12	0.711	3.232	79.044						
13	0.681	3.094	82.138						
14	0.633	2.878	85.016						
15	0.564	2.565	87.581						
16	0.543	2.467	90.048						
17	0.463	2.106	92.154						
18	0.448	2.035	94.189						
19	0.402	1.828	96.016						
20	0.352	1.599	97.615						
21	0.312	1.417	99.032						
22	0.213	0.968	100.000						

Extraction Method: Principal Component Analysis.

Table 7 provides a classification of the various challenges under the seven identified components. This classification facilitates the regrouping of the primary challenges affecting the adoption of the IoT in the Silicon Mountain technology ecosystem, as illustrated in Table 8. The categorization helps in understanding the underlying factors and how they interrelate, thereby offering a clearer perspective on the main obstacles to IoT adoption in the Silicon Mountain tech ecosystem.

Table 7. The rotated component matrix and the reclassification of components.

Rotated Component Matrix [a]							
	Component						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Loose nature of policies	0.798						
Overlapping and conflicting policies	0.654						
Favoritism and corruption	0.651						
Cameroon government interference and bureaucracy	0.631						
Increase in tax burden due to changes in tax policy	0.604						
Potential clients are reluctant adopt the IoT	0.500						
The damage that can result from a successful IoT attack		0.770					
Inadequate security mechanisms for IoT systems means that the IoT is viewed as the "Internet of Threats" despite its potential benefits		0.720					
Data confidentiality, integrity, authentication, data ownership, etc., are major concerns		0.545					
Lack of legal recognition and policy framework		0.496					
Inadequate financial resources, inability to secure loans, and little or no funding support from government and other sponsors		0.092	0.769				
Organizations do not usually understand the benefits of the IoT and are often not motivated to pay for it			0.652				
Lack of standardization in the IoT as each and every vendor is developing its hardware, software, and communication protocol without any standardization			0.526				
Ongoing economic crises in the country				0.784			
Difficult to establish cooperation with local distribution network				0.625			
The cost of marketing IoT solutions is high and startups are not able to afford this				0.578			
Technological adoption requires an updated educational curriculum but most academic institutions do not have dynamic educational curricula to equip the students with				0.102	0.844		
Could be a result of mass movements of graduates from STEM (Science, Technology, Engineering and Mathematics) fields for greener pastures.					0.524		
Lack of understanding of commercial practice and market regulation						0.828	
Insufficient power supply and the high cost of energy is one of the challenges to the adoption of IoT						−0.546	
The cost of the IoT and its payback period are a hindrance for adoption						0.444	
Insufficient skilled labor in the area of the IoT, data science, and agriculture							0.792

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. [a] Rotation converged in 9 iterations.

Table 8. Subcategorization of challenges to IoT adoption in the Silicon Mountain technology ecosystem.

Main Factors	Challenges to the Adoption of Internet of Things (IoT)	Mean	Global Mean
Government policies	Loose nature of policies	3.788	3.628
	Overlapping and conflicting policies	3.719	
	Favoritism and corruption	3.651	
	Cameroon government interference and bureaucracy	3.322	
	Increase in tax burden due to changes in tax policy	3.534	
	Potential clients are reluctant adopt the IoT	3.753	
Security and data privacy challenges	The damage that can result from a successful IoT attack	3.377	3.399
	Inadequate security mechanisms for IoT systems means that the IoT is viewed as the "Internet of Threats" despite its potential benefits	3.349	
	Data confidentiality, integrity, authentication, data ownership, etc., are major concerns	3.356	
	Lack of legal recognition and policy framework	3.514	
Standardization and Financial Resources	Inadequate financial resources, inability to secure loans, and little or no funding support from government and other sponsors	3.801	3.779
	Organizations do not usually understand the benefits of the IoT and are often not motivated to pay for it	3.897	
	Lack of standardization in the IoT as each and every vendor is developing its hardware, software, and communication protocol with any standardization	3.637	
Market Challenges	Ongoing economic crises in the country	3.815	3.662
	Difficult to establish cooperation with local distribution network	3.418	
	The cost of marketing IoT solutions is high and startups are not able to afford this	3.753	
Educational and knowledge challenges	Technological adoption requires an updated educational curriculum but most academic institutions do not have dynamic educational curricula to equip the students with	3.678	3.702
	The mass movements of graduates from STEM (Science, Technology, Engineering and Mathematics) fields for greener pastures	3.726	
Labor and power supply	Lack of understanding of commercial practice and market regulation	3.740	3.274
	Insufficient power supply and the high cost of energy is one of the challenges to the adoption of the IoT	2.322	
	The cost of the IoT and its payback period are a hindrance for adoption	3.760	
Labor Shortage in the industry	Insufficient skilled labor in the area of the IoT, data science, and agriculture	3.760	3.76

After the rotation of these factors, they were categorized into the following groups: government policies, security and data privacy challenges, standardization and financial resources, market challenges, educational and knowledge challenges, labor and power supply, and labor shortage in the industry.

In Table 8, the government policies category comprised six factors: the loose nature of policies, overlapping and conflicting policies, favoritism and corruption, Cameroon government interference and bureaucracy, increase in tax burden due to changes in tax policy, and reluctance of potential clients to adopt the IoT. This category had a global mean of 3.628.

Similarly, the standardization and financial resources category included inadequate financial resources, inability to secure loans, and minimal funding support from the government and other sponsors. It also encompassed organizations' lack of understanding of IoT benefits and their consequent lack of motivation to invest in it, as well as the lack of standardization in the IoT, with each vendor developing its hardware, software, and communication protocols independently. The mean value for this factor was 3.779.

The global mean of each category presented in Table 8 was used to rank the factors affecting the adoption of IoT in the Silicon Mountain tech ecosystem in order of importance. The results of this ranking are displayed in Table 9. This ranking provides a clear prioritization of the challenges, highlighting which areas require the most immediate attention to improve IoT adoption in the Silicon Mountain technology ecosystem.

Table 9. Mean scores and ranking of factors affecting IoT adoption in the Silicon Mountain technology ecosystem.

Main Challenges to IoT Adoption	Mean	Rank
Standardization and financial resources	3.779	1st
Labor shortage in the industry	3.760	2nd
Educational and knowledge challenges	3.702	3rd
Market challenges	3.662	4th
Government policies	3.628	5th
Security and data privacy challenges	3.399	6th
Labor and power supply	3.274	7th

An analysis of Table 9 shows that the mean scores for all barriers ranged between 3.00 and 4.00. These scores indicate an average level of concern between 'moderate' and 'serious' on the Likert scale. The most significant challenge identified was standardization and financial Resources, with a mean score of 3.779. This was closely followed by labor shortage in the industry, which had a mean of 3.760. The remaining categories, in descending order of severity, were educational and knowledge challenges, market challenges, government policies, security and data privacy challenges, and labor and power supply.

4.7. Discussion

This study identified a range of challenges hindering IoT adoption in the Silicon Mountain technology ecosystem. The challenges were categorized into the following areas:

1. Standardization and Financial Resources: issues related to the lack of standardized protocols and financial constraints.
2. Labor Shortage in the Industry: the shortage of skilled labor in the field.
3. Educational and Knowledge Challenges: inadequate educational curricula and knowledge gaps.
4. Market Challenges: difficulties related to market adoption and commercial practices.
5. Government Policies: issues arising from governmental policies and regulatory frameworks.
6. Security and Data Privacy Challenges: concerns about data security and privacy.
7. Labor and Power Supply: challenges related to the availability of reliable power and labor.

This study found that market challenges significantly impact the adoption of the IoT within the Silicon Mountain technology ecosystem. Key market challenges identified include the ongoing socio-economic crises in the country, difficulties in establishing cooperation with local distribution networks, and the high cost of marketing IoT solutions, which many start-ups cannot afford. These issues were highlighted by a high mean score of 3.662, indicating that they are considered very serious challenges.

Another significant challenge identified was data privacy and security concerns. The proliferation of IoT devices results in the generation, collection, and sharing of vast amounts of data. These data often include sensitive personal information, raising significant concerns around data privacy, including unauthorized access, data breaches, surveillance and tracking, data access and control, etc. In addition, security is also a critical concern for IoT systems due to the sheer number of connected devices, which increases the potential attack surface for cyberattacks. Inadequate security mechanisms can result in severe consequences, such as data breaches, loss of control over critical systems, and the manipulation of physical devices. This study identified security and data privacy as a significant challenge affecting IoT adoption. The results reveal that data security and user privacy are major concerns in IoT applications due to the extensive amount of data shared across platforms, increasing user vulnerability. This aligns with Iwayemi's study in Nigeria [15], which identified fraud, cyber attacks, privacy issues, and security concerns as critical challenges in IoT implementation. The primary security risk of the IoT is linked to its greatest advantage: the connection of physical objects to a global network [57]. Although the IoT has tremendous potential to drive innovation across various sectors in the Silicon Mountain ecosystem, the technical challenges of data privacy and security remain significant barriers to widespread adoption. Before the advent of the IoT, security breaches were primarily concerned with data theft and manipulation of physical entities. However, the IoT introduces the potential for direct control of these physical entities, many of which are part of critical infrastructure. Without adequate security measures, malware such as viruses and ransomware could easily spread through interconnected IoT networks, leading to potentially catastrophic global consequences. Addressing these issues is crucial to ensuring that IoT systems are secure, efficient, and capable of scaling across different industries. To address these challenges and promote IoT adoption, businesses in the Silicon Mountain ecosystem can implement mitigation strategies to minimize data privacy risks (such as end-to-end encryption, anonymization schemes, introspection, blockchain, access control, physical security, edge processing, etc.) and mitigation strategies address the security risks (such as device authentication, regular firmware updates, network segmentation, intrusion detection systems, etc.) [58].

IoT interoperability was also identified as another major challenge impeding IoT adoption in the Silicon Mountain tech ecosystem. Interoperability refers to the ability of different IoT devices and platforms to communicate and work together seamlessly. A lack of standardization in IoT hardware, software, and communication protocols makes it difficult for devices from different manufacturers to interact, posing a major challenge for IoT adoption in Silicon Mountain. The absence of interoperability can lead to fragmentation, high integration cost, and limited scalability [59]. To enhance IoT interoperability within the Silicon Mountain ecosystem, the use of open standards (MQTT, CoAP, Zigbee, etc.) and middleware solutions can be adopted [60].

The development of robust and scalable IoT infrastructure is also crucial for fostering the adoption of IoT technologies in emerging ecosystems like Silicon Mountain. In particular, leveraging innovations such as fog computing can significantly enhance the performance and scalability of IoT systems by processing data closer to the edge, thus reducing latency and improving response times. According to the research by Okafor et al. [61], the Spine-Leaf Network Topology, combined with fog computing, offers an effective approach for managing the scalability challenges of IoT datacenters. This framework facilitates the seamless integration of numerous IoT devices by decentralizing data processing and management, which can be particularly valuable for regions with limited network infrastructure, like Silicon Mountain. Given the infrastructural challenges and connectivity limitations in Central African ecosystems, adopting such scalable IoT solutions could accelerate the deployment of IoT technologies across sectors, including agriculture, healthcare, and urban management.

Digital literacy was also found to be one of the key factors inhibiting IoT adoption in developing countries due to the low-level of digital literacy within the population [62]. In this study, we consider digital literacy as the ability to effectively use digital technologies, including understanding how IoT devices function and how to leverage them for personal, professional, or industrial purposes. Based on this definition, the level of digital literacy in the Silicon Mountain tech ecosystem is low as many individuals in the region lack the necessary skills or understanding to fully engage with IoT technologies. This study identified labor shortage resulting from this low level of digital literacy in the region as a major challenge to IoT adoption, with a mean score of 3.760. This challenge is closely related to inadequate education on the IoT and the absence of specialized university courses in this emerging technology within the region [63]. These findings are consistent with the results of Morrissey [64], who noted that a shortage of skilled labor in the IoT, data science, and other technical fields could contribute to the migration of STEM (science, technology, engineering, and mathematics) graduates seeking better opportunities elsewhere. The scarcity of formal IoT programs in universities exacerbates this issue, as companies are hesitant to adopt new technologies without the assurance of having access to qualified personnel for operation, maintenance, and support. Improving digital literacy is crucial for expanding IoT adoption across sectors such as agriculture, healthcare, transportation, and education. Educational institutions, governments, and private sector stakeholders must collaborate to offer digital literacy training programs tailored to specific industries. Equipping individuals with the necessary skills to understand and interact with IoT technologies will foster greater innovation and lead to more efficient IoT integration across various sectors in the Silicon Mountain tech ecosystem [65]. In addition to the challenges posed by low digital literacy, societal resistance to technology can hinder IoT adoption [27]. Societal resistance is often driven by cultural norms, fear of job displacement, privacy concerns, costs, or skepticism about the benefits of emerging technologies [66]. Although this aspect was not deeply explored in the current paper, we believe that addressing societal resistance will enhance IoT uptake in the ecosystem and the region at large. Addressing societal resistance will require not only community engagement but also public awareness campaigns that demystify IoT and highlight its potential benefits, particularly for economic growth and improved service delivery. Policymakers and business leaders need to actively promote IoT solutions as tools that enhance productivity and job creation, ensuring that public concerns are mitigated through clear communication. Beyond digital literacy and societal resistance, other socio-cultural factors such as language barriers, traditional beliefs, convenience, social influence, habits, etc., will also influence IoT adoption [67].

Government policies also emerged as a significant barrier to IoT adoption. The rotated component factor model revealed that challenges related to government policies—including the loose nature of regulations, overlapping and conflicting policies, favoritism and corruption, government interference and bureaucracy, and increased tax burdens—accounted for 13.55% of the obstacles to IoT implementation in Cameroon. Research by Cole et al. [68] highlights a similar issue across the African continent, where cyber security initiatives are scarce and existing efforts often focus solely on cybercrime legislation with minimal implementation. This lack of supportive legislation and policies impedes technological advancement and scientific research. The high vulnerability of IoT systems, coupled with inadequate regulatory frameworks, may deter many African businesses from adopting the IoT due to perceived risks and potential threats to their systems.

The results of this study indicate that various challenges have impeded the adoption of the IoT within the Silicon Mountain technology ecosystem and the broader Central African region. Nevertheless, several improvement strategies were proposed to address these issues. These strategies include the following:

- Enhancing Tax Policies: revising tax regulations to better support IoT businesses.
- Improving Network Connectivity: expanding network infrastructure and reducing internet data costs.
- Reducing IoT Device Prices: making IoT devices more affordable.

- Increasing Energy Availability: ensuring a more reliable energy supply for IoT operations.
- Strengthening IoT Security: enhancing security mechanisms to protect IoT systems.
- Organizing IoT Workshops and Seminars: hosting events to raise awareness and build expertise in IoT.
- Updating Educational Curricula: integrating IoT-related courses into academic programs to address labor shortages and improve skill levels.

These measures aim to address key barriers such as government policies, labor shortages, and insufficient IoT knowledge, ultimately leveraging the numerous benefits of IoT applications to foster adoption and innovation in the region.

4.8. Future Trends in IoT Adoption in Silicon Mountain and Central Africa

While this study primarily focuses on current challenges in IoT adoption, it is equally important to consider longer-term trends that could significantly influence IoT uptake in the Silicon Mountain tech ecosystem and the broader Central African region. These trends include future technological advancements, evolving workforce skills, and policy changes, all of which are important for shaping the future of the IoT in the region.

The development of technologies such as 5G and edge computing will play a transformative role in enhancing IoT infrastructure and capabilities. In terms of this, 5G will provide the high-speed, low-latency connectivity necessary to support large-scale IoT deployments across sectors such as healthcare, smart cities, and agriculture. Moreover, the advent of artificial intelligence (AI) and machine learning (ML) integration with IoT devices will enable more intelligent automation, predictive analytics, and real-time decision-making, offering immense potential for innovation in sectors like manufacturing and transportation. Edge computing will also mitigate data privacy concerns, thereby positively influencing IoT uptake. Preparing for these advancements will be key to ensuring the successful scaling of IoT applications in the Silicon Mountain tech ecosystem.

One of the significant barriers to IoT adoption in the region identified by this study is the lack of skilled labor in fields such as IoT development, data science, and cybersecurity. However, as IoT technologies continue to evolve, there will be an increasing demand for a workforce proficient in managing and maintaining complex IoT systems. Educational institutions will need to adapt by incorporating the IoT, AI, and data analytics into their curricula, while industry partnerships can play a vital role in providing hands-on training and certifications. Government and private-sector initiatives to foster IoT skill development will be critical to ensure that the workforce is equipped to meet the demands of an IoT-driven economy. This training of next-generation IoT professionals will facilitate IoT uptake.

For IoT adoption to thrive in the Central African region, supportive regulatory frameworks are essential. Governments must develop policies that address data privacy, cybersecurity, and interoperability to create a stable environment for IoT deployment. Additionally, policymakers can incentivize IoT innovation by providing tax breaks, grants, and funding opportunities for startups. The establishment of IoT regulatory bodies to oversee compliance with global standards and to facilitate public–private collaboration will also help accelerate IoT adoption across various industries.

4.9. Limitations and Recommendations for Future Work

This preliminary study on IoT adoption in the Central African sub-region provides valuable insights into the Silicon Mountain ecosystem. However, it is not without limitations. In this sub-section, we discuss some of the study's key limitations and propose areas for future research that could offer more comprehensive insights into the factors influencing IoT adoption in the Central African sub-region.

This study is limited to the Silicon Mountain tech ecosystem, and the sample of 146 usable responses may not fully capture the broader diversity of stakeholders across the Central African region. Consequently, the findings may not be generalizable to all tech ecosystems within the region. Additionally, the high concentration of entry-level positions

(67.8%) and the gender imbalance (64.4% male respondents) may have influenced the results, particularly with respect to gender representation and experience levels. In future research, we plan to extend this study to include a wider range of stakeholders across different tech ecosystems in the Central African region, ensuring a more balanced gender representation and a broader distribution of respondents across various experience levels, including mid-level and senior management roles. This will provide a more comprehensive understanding of the challenges and opportunities related to IoT adoption in the Central African region.

Another limitation of the study is that it relies primarily on questionnaire responses, which may introduce certain biases, resulting from social desirability or limited depth in participants' understanding of complex topics like IoT technology. To address the limitations of self-reported data, we propose the adoption of a mixed-methods approach in future work. Combining quantitative survey data with qualitative methods (e.g., expert interviews, focus groups, or case studies) would allow for triangulation and a more comprehensive exploration of IoT adoption challenges. Additionally, we are developing a smart agriculture Proof of Concept (PoC) that focuses on determining the levels of key macronutrients (Nitrogen, Phosphorus, Potassium) in the soil. This PoC aims to provide farmers in the region with real-time information on soil fertility, enabling them to make informed decisions about crop selection to improve yields. This PoC will address key challenges identified in the study, including infrastructure limitations, regulatory barriers, and skills gaps by testing the feasibility of deploying IoT solutions in the region. These approaches will offer deeper insights into the complex issues that may have been overlooked or simplified in the survey responses.

The study also found the high rating of poor internet connectivity (52.1%) and unreliable power supply (49.3%) as "Not Serious" by respondents to be usual. This is because these are common infrastructural challenges in sub-Saharan Africa that significantly impede IoT uptake in the region, as reported in earlier IoT adoption studies [15,16]. Thus, it is important to note at this point that the "Not Serious" rating for poor internet connectivity and unreliable power supply reflects the perceptions of respondents who are part of the Silicon Mountain technology ecosystem, which benefits from relatively better infrastructure compared to other regions in Cameroon and Central Africa. As a result, these challenges may not have been perceived as immediate barriers for IoT adoption within this specific ecosystem. However, in the broader context of the Central African region, internet connectivity and power supply are indeed significant impediments, especially in more rural areas and less developed tech hubs. Thus, generalizing the findings of this study beyond the Silicon Mountain ecosystem may risk downplaying the severity of these issues. There is need for future research to focus on tech ecosystems within the Central African region where internet connectivity and power supply issues are more acute. A more in-depth analysis of how these infrastructure limitations affect IoT adoption outside of established tech ecosystems will provide a more comprehensive understanding of IoT adoption challenges in the region.

5. Conclusions

This study examined the adoption of the IoT in tech ecosystems within the Central African sub-region, focusing specifically on the Silicon Mountain technology ecosystem. The primary objectives were to identify the potential areas for IoT implementation and to uncover the challenges impeding IoT uptake in the Silicon Mountain tech ecosystem and, by extension, other tech ecosystems in the Central African sub-region. Utilizing a survey research design, the study analyzed data using both descriptive and inferential tools.

The findings suggest significant potential and numerous opportunities for IoT adoption in the Silicon Mountain tech ecosystem. The key areas of benefit identified include intelligent transport systems, smart health facilities, smart metering and smart cities, environmental and weather monitoring, security and safety, flexible manufacturing or industry control, IoT-driven agriculture, logistics, and smart businesses. The study highlighted a substantial market gap, indicating a high potential for the IoT to enhance SME performance, stimulate economic activities, and improve business connectivity in the tech ecosystem.

The study also identified numerous challenges impacting IoT adoption in the Silicon Mountain tech ecosystem. Issues related to standardization and financial resources, labor shortages in the industry, educational and knowledge gaps, market challenges, government policies, security and data privacy concerns, and inadequate labor and power supply were key among these challenges. These obstacles have collectively hindered the adoption of IoT, resulting in a slow uptake rate.

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Appendix A

Table A1. Measurement scale.

1	2	3	4	5
Not serious Not at all	Less serious Lesser extent	Moderate Moderate	More serious Great Extent	Very serious Greater Extent

Table A2. Questionnaire items.

	Operating Barriers	1	2	3	4	5
1	The implementation of THE IoT requires organizations to upgrade and adopt new business models.					
2	IoT applications need a higher infrastructure to support them, which most business cannot afford.					
3	Fragmentation of standards with new ones evolving every day makes it difficult for IoT practitioners.					
4	Increase in businesses' operating costs.					
5	IoT adoption because most of the services are delivered to mobile users.					
6	Limited skilled workforce in Cameroon as compared to developed countries.					
7	Poor internet connectivity.					
8	Varying accessibility of internet connection across the nation.					
	Information/Security Barriers	1	2	3	4	5
9	Personal privacy issue (data ownership) is a major concern in employing IoT networks as the connected objects and devices can be easily traced and hacked.					
10	Billions of devices are connected through the IoT which necessitates efficient security mechanisms that not only help in protecting the information but also enable data sharing over IoT-based smart city networks.					
11	Lack of knowledge on production costs of IoT systems.					
12	Unsecure provenance data may result in the exposition of sensitive Information.					

Table A2. *Cont.*

	Operating Barriers	**1**	**2**	**3**	**4**	**5**
	Legal/Bureaucracy Barriers	1	2	3	4	5
13	Lack of legal recognition and policy framework.					
14	Cameroon government interference and bureaucracy.					
15	Overlapping and conflicting policies.					
16	Increase in tax burden due to changes in tax policy.					
17	Loose nature of policies.					
18	Favoritism and corruption.					
	Market challenges					
19	IoT applications employ a huge number of sensing and actuating devices.					
20	Lack of understanding of commercial practice.					
21	IoT costs and its payback period are a hindrance for adoption.					
22	Difficult to establish cooperation with local distribution network.					
23	Difficulty in locating supply lines for local raw materials.					
24	Ongoing economic crises in the country.					
25	Global misinformation systems.					
	Impact of challenges on IoT adoption	1	2	3	4	5
26	Improvement in tax policies for adoption of IoT businesses.					
27	Increase in network connectivity.					
28	Regularizing prices for materials.					
29	Improvement in information flow and communication systems.					
30	Improvement in the security of information systems.					

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