

Factors influencing the adoption of information and communication technology in public building construction projects: insights from Mekelle city



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Highlights:

- ICT Adoption is low in developing cities, especially in developing countries.
- A theoretical framework is developed to improve ICT Adoption in construction.
- A deficiency of commitment by company management towards ICT was identified as the main factor.

Abstract: The adoption of Information and Communication Technology (ICT) in construction projects enhances competence, fosters partnership, and promotes innovation. However, challenges related to ICT implementation persist, particularly in emerging nations. This study investigates the factors of ICT adoption in public building construction projects in Mekelle City, Ethiopia. Using a questionnaire, 75 construction professionals were surveyed, and 8 respondents were purposively selected for in-depth qualitative interviews. Key factors recognized using linear regression include lack of commitment by company management towards ICT ($B = 1.152$, $p = 0.040$), security concerns/privacy fears ($B = 0.818$, $p = 0.005$), cost of training ICT professionals ($B = -0.676$, $p = 0.044$), and limited benefits return on investment in ICT ($B = -0.480$, $p = 0.023$), respectively. Quantitative outcomes were verified with qualitative perceptions, providing an inclusive understanding of the factors. Even though the same factors have been recognized in other emerging nations, this study examines how these obstacles work within the public construction sector, branded by regional construction procurement activities and official resource restrictions. By linking known factors with different previously known stages of the construction project lifecycle, this research recommends a framework for the public construction project delivery system in Mekelle city. The research output provides empirical, context-specific evidence on the relative importance and ranking of factors influencing ICT adoption in public building construction projects, where such evidence is currently scarce despite ongoing public infrastructure development. The outcomes deliver actionable recommendations for policymakers, professionals, and researchers. Limitations include dependence on self-reported data, a cross-sectional design, and a limited geographic scope. Future studies should emphasize longitudinal evaluations and comparative studies across Cities to assess the influence of involvement.



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1. Introduction

A construction business is a basis of commercial growth, and Information and Communication Technology (ICT) has the capacity to transform its practices. It's important to develop a generally accepted definition of ICT before discussing its use in the construction sector. According to [1], ICT is defined as “technologies involved in the collection, transport, retrieval, storage, access, presentation, and transformation of all forms of information”, and this applies to any self-governing device capable of providing communication, like telephones, faxes, and laptops. Similarly, according to [2], ICT is defined in terms of its importance, as adequate use of ICT in infrastructure, as well as other construction-related activities, can benefit from a variety of platforms for business operations, and it increases project efficiency in terms of time and expense. Thus, in the context of a construction project, ICT refers to any device or product that stores, retrieves, processes, transmits, or receives project-related information electronically. As a result, ICT is becoming a significant component of the economy.

Internationally, ICT adoption in building construction has led to developments in competence, partnership, and project results. But the degree of ICT incorporation differs across regions, with emerging countries facing unique challenges. Numerous global investigations have underlined obstacles to ICT adoption in the construction industry. Deficiency of training on ICT content of the construction process, satisfaction with traditional working methods and tools, the problem of ICT integration or compatibility with work, poor interoperability among diverse uses, and a low level of telecommunication setup in Iraq [3]. In the same way, a study on ICT adoption for the circular economy in Ghana revealed that financial constraints, data security concerns, and regulatory gaps delay implementation [4].

Additionally, the main factors influencing the use of ICT in Nigeria's construction industry are: “budget limit for investment, inadequate knowledge about the profit of ICT investment, high cost of employing professionals, lack of staff with appropriate skill and knowledge in ICT and cost of training professionals” [5]. Furthermore, according to [6], in Saudi Arabia discovered that the main reasons impacting faculty members' decisions to accept and use ICT in teaching practice were “a lack of time, a lack of training, and a lack of institutional support”.

In Africa, ICT adoption in construction and interconnected businesses is hindered by infrastructural and socioeconomic challenges. According to [7], building contractors in Kenya have encountered four main barriers to their use of ICT: “High cost of employing ICT professionals; Lack of qualified personnel to handle ICT adoption; High cost of training professionals in ICT, and Satisfaction with the existing method of working”. Similarly, as per [8] in Ghana, the primary hindrances to contractors' utilization of ICT are: “Budget constraints for ICT investments, Lack of commitment by the firm's management towards ICT, Lack of training and technical support for professionals in ICT, Inadequate ICT content of construction education, and Majority of construction clients not interested in firms ICT base”.

In the same way, the study conducted by [9], found that the following significant factors affected ICT usage among building contractors in the Democratic Republic of the Congo: “budget constraints, highly charged costs in employment of ICT experts and low return on investment (financial factor), inadequate construction ICT content, concerns for losing ones employment, and satisfaction with existing working technique (human factor), technological (ICT) changes, hardware and software

problems related to reliability, security concerns, high ICT obsolescence rate and access to relatively cheap workforce (technical factor) and risks of liability, lack of legal support of use of ICT and security implications of use of ICT”.

Furthermore, Research in Namibian rural communities establishes that lack of awareness, inadequate infrastructure, and high costs of devices and internet services meaningfully limited ICT interest [10]. These outcomes resonate with factors seen in other sub-Saharan republics, where digital readiness is irregular.

One of the Least Developed Countries (LDCs) recognized by the United Nations, Ethiopia is among the least developed nations in terms of the advancement and uptake of ICT. The country has one of the lowest Internet penetration rates in the world, with approximately 0.5 consumers for every 100 people and 6 phone lines per 100 people [11]. The country has significant cost fluctuation, poor schedule performance, and completion time delays in construction projects [12]; so, in order to reduce such issues, research is required. ICT improves the efficiency of construction projects in terms of time required to complete, additional costs, and any variation to the type of work required due to technological advancements.

In Ethiopia [13], 91.75% of public projects were not completed as per their schedule, and the remaining projects were only executed on time. There are construction industry projects that process information and data saving using old-style ways of records and telecommunications, like the exchange of documents, like drawings, specifications, site instructions, and face-to-face meetings [8].

Ethiopia’s 2020 Digital Conversion Plan aims to power technology for comprehensive economic development. Until now, the adoption of ICT within the construction sector has remained slow because of insufficient infrastructure, inadequate financial resources, and a lack of skilled professionals [14]. Nationwide confirmation proposes that such obstacles delay project finishing, escalate costs, and decline overall competitiveness.

Even though the transformative possibilities of ICT in construction are broadly adopted, obstacles to its adoption in Mekelle city have not been sufficiently explored. This research addresses this gap by scientifically recognizing and analyzing these factors, intending to provide evidence-based recommendations to improve ICT adoption. Such visions are vital for officials, industry stakeholders, and educational institutions looking to improve competence, sustainability, and modernization in Ethiopia’s construction industry. There is a limited study addressing ICT adoption in the Ethiopian context. However, due to a lack of time and money, the study was limited to Mekelle City. As a result, the difficulty to be solved through this research is time overrun (delay) in completing a construction project with the required quality and cost by increasing awareness on using ICT throughout the life cycle of a construction work.

While previous studies in Congo, Nigeria, Ghana, and other countries have recognized similar factors affecting ICT usage, this research contributes theoretically by suggesting that barriers to ICT adoption in growing construction sectors are dominated by the government, in addition to being context-dependent. In the public construction sector, administrative commitment functions as a structural determinant variable rather than only an organizational attitude variable. This governance-sensitive weighting view extends conventional ICT adoption models, which were mainly developed in private-sector backgrounds. This study’s influence lies in contextual systematic improvement. Mekelle’s public building construction sector operates within a government-dominated procurement system where administrative autonomy, budget distribution, and digital investment decisions are officially regulated. This organizational

background varies from mainly private-sector contexts observed in the previous studies. Consequently, this research examines how commonly identified ICT adoption factors are obvious, related, and strengthen within the public construction sector. By linking the research findings with project lifecycle stages, the study delivers a framework for public building construction project delivery systems. This study broadens existing ICT adoption research by introducing a governance-sensitive and context-specific perspective, where adoption is influenced not only by organizational and technical barriers but also by institutional, political, and cultural factors unique to public-sector environments. Unlike earlier studies that mainly focus on private-sector dynamics, this research highlights how consolidated decision-making structures, policy implementation gaps, and socio-cultural tensions reshape ICT adoption in government-led construction projects. By explicitly incorporating these Mekelle-specific realities, the study offers a framework for understanding ICT adoption that is both locally grounded and extends old-style ICT adoption models by integrating context-specific institutional and socio-political dimensions prevalent in Ghana, Nigeria, or private-sector contexts.

1.2. Objectives of the study

1.2.1. General objective

The general objective of this research was to identify the factors affecting the use of ICT in public building construction projects, insights from Mekelle city, and to draw conclusions in accordance with the outcome of the research.

1.2.2. Specific objectives

(1) To assess the current practice of ICT applications in public building construction projects, and to gain insights from Mekelle city.

(2) To identify and evaluate the factors affecting ICT management in the public building construction projects.

(3) To design and develop a framework based on the research findings from Mekelle City public building construction projects, aimed at guiding and evaluating ICT adoption in practice.

2. Materials and methods

2.1. Research design

Study design aids in the accomplishment of the study's goal and helps researchers narrow down on methodologies appropriate for the topic. The outline of the study methodologies and procedures selected by the investigator to carry out this study is summed up in Figure 1, which represents the overall research design. The process begins with the selection of the study problem, followed by a literature and document review, and data analysis. Finally, the study concludes with the development of a framework and a summary of the findings. Figure 1 is provided below to guide readers through the complete research process.

The plan of the study involved different stages as listed in Figure 2. The stages include: (1) questionnaire and interview design, (2) sample selection, (3) sample size selection, (4) pilot questionnaire and interview,

(5) administration of the main questionnaire and interview, and (6) data analysis. This figure provides a clear visual representation of the sequence and interconnection of each stage of the research design.

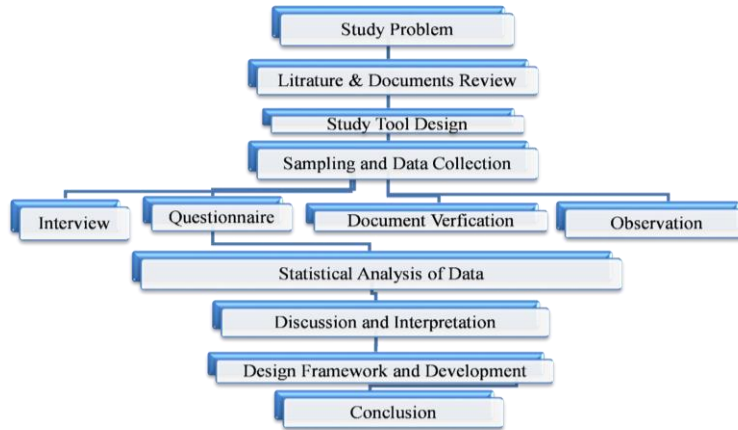


Figure 1. Research methodology.

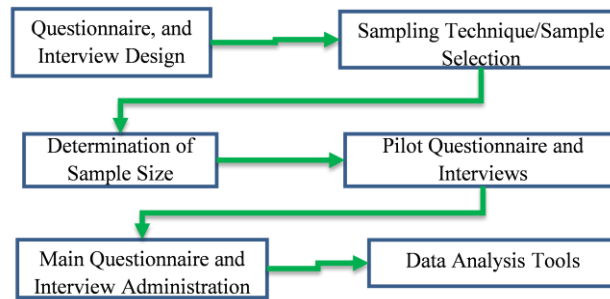


Figure 2. Research design steps.

This study used a progressive questionnaire and interview design to confirm procedural rigor and contextual relevance. The quantitative survey was conducted first to identify and statistically evaluate the factors affecting ICT adoption in public building construction projects. Linear regression analysis was used to assess the relative explanatory strength of the factors. Then, semi-structured interviews were used to confirm and contextualize the statistical results, specifically within Mekelle’s governance-dominated public construction projects. Total-population sampling was acceptable because the number of active public construction projects during the study period was limited and well defined, ensuring complete coverage of appropriate stakeholders. This progression from quantitative evaluation to qualitative interpretation confirmed the coherence of the research objectives, methods, and analysis.

2.2. Study area description

The study was conducted on construction projects of varying scales with diverse purposes and characteristics in Mekelle City, located in the northern part of Ethiopia. As Mekelle is the capital city of the Tigray region, many public construction projects and offices are located there. Therefore, it became a good source of data for the study. Mekelle city was established in the 1880s, and during the reign of Emperor Yohannes IV, it became the capital city of Tigray. It is located at 39.4670E, 13.4830N, and it is found at 780 kilometers from Addis Ababa city [15].

2.3. Sample size determination

The selected construction projects vary in size and purpose, including healthcare and educational buildings, administrative offices, and public service facilities. Most projects are medium-scale and publicly funded through government budgets. The projects are at different stages of completion, such as ongoing construction and near-final phases, reflecting variability in ICT usage contexts. Interview candidates were chosen from organizations of various sizes, such as small and medium enterprises and public client institutions. Most respondents had over five years of experience and had been involved in their respective projects for a significant period, ensuring they are familiar with project processes and ICT adoption practices. Relevant data have been collected from professionals employed with clients, contractors, and consultants who were contributing to the construction projects and were considered in the study. The investigator made a primary survey in the study area to find the sample size before deciding to use the entire population using the total population sampling method, which is used when the target group is small and has well-defined characteristics and is not overly large in number. During an assessment, there were 25 public building construction projects in Mekelle City, with 25 client representatives, 25 contractors, and 25 consultants, as summarized in Figure 3. To compile quantitative scope and qualitative depth, a hybrid of questionnaire and interview techniques was adopted. Using total-population sampling, full coverage of all 75 experts across the 25 projects was ensured, ensuring representation of all participant sets.

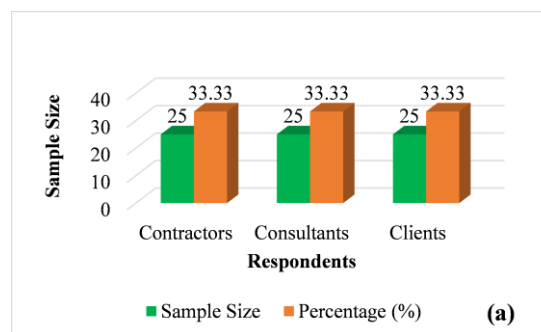


Figure 3. Sample size of respondents. (a) Number of contractors, consultants, and clients.

Figure 3 indicates that the sample size of 25 contractors, 25 consultants, and 25 clients (75 total respondents) was considered the sample of the study. The targeted population of the study consisted of all experts who met the inclusion conditions (employed on the project for many years, directly involved in scheduling, implementation, supervision, or ICT-related jobs) and agreed to participate across selected construction projects in Mekelle city during the study ($N = 75$). For the reason that the population was limited, well-defined, and available, a total population (census) sample method was assumed to maximize coverage and reduce sampling mistakes. Hence, 75 questionnaires were prepared and distributed.

2.4. Data collection instrument

Primary and secondary sources were applied in the statistics collection process. The research has been conducted through questionnaires, interviews, observation, and document verification. A questionnaire survey was done from September 30, 2024, up to November 30, 2024. Next to preliminary statistical analysis, the interview was carried out from December 15, 2024, up to December 30, 2024. Contractors,

consultants, and clients participating in the public building construction projects in Mekelle city were the target group for questionnaires, interviews, observation, and document verification used to gather primary data from field surveys. Books, journals, and various items in published publications were also sources of secondary data. Many techniques for gathering data have been employed so that information gathered from one source can be strengthened by information gathered from others.

2.4.1. Questionnaire

A questionnaire is defined as a research tool consisting of a list of questions or prompts intended to collect data from respondents [16].

Preparing the questionnaire is almost straightforward. With a word processor, it is possible to design one in a short time. But developing a questionnaire that yields honestly valuable data is much harder than one might think, and useful research does require effective data. This study's questionnaires were adapted and comprised general information, ICT platforms, and their extent of usage, and variables influencing the usage of ICT.

The common value for the options starts with Never at 1 point and Always at 4. A four-point scale survey was employed when the respondents must provide a clear opinion without being neutral, and is suitable to collect opinions for recently used products or services. To calculate the interval, maximum value minus minimum value, then divide by the maximum value, and it becomes 0.75 as shown in Table 1 below [17].

Table 1. Interpretation of four-point Likert Scale [17].

No	Rank level	Likert point	Interval value
1	Never	1	1.00 to 1.75
2	Sometimes	2	1.76 to 2.50
3	Often	3	2.51 to 3.25
4	Always	4	3.26 to 4.00

The questionnaire used for data collection was evaluated for validity in two steps. In the first step, it was evaluated by research members for the logical and linguistic clarity of distribution, in addition to its fitness with the objective of the study, and was well supported through a literature review. The second step was made after the relevant data was collected as part of the data analysis.

2.4.2. Interview

To supplement the assessment results, eight interviewees were selected for in-depth qualitative interviews. Eight key informants were purposively chosen for interviews based on their roles in construction projects and ICT usage, including office engineers, site engineers, supervisors, and surveyors, covering companies of different sizes and project responsibilities. This sample size was enough to reach thematic saturation in qualitative analysis. While the quantity of interviewees was restricted to eight, this sample was enough to reveal various viewpoints through diverse professional parts, allowing for thematic capacity to be extended. According to [18], an interview is a more effective instrument for gathering data than further techniques like questionnaires because it can generate narrative data that enables researchers to look deeper into people's perspectives and facilitates the direct explanation of human behavior through in-depth speech interactions.

2.5. Method of data analysis

Information is just raw data; to make that data expressive, it has to be organized, filtered, and analyzed. Whereas information examination is a process used by researchers to reduce data to a story and interpret it to derive insights [19].

The information for this research has been examined using Statistical Product and Service Solution (SPSS). Validity of the questionnaire was checked using factor analysis to evaluate the relationship between each item or factor after all the relevant data were collected.

Exploratory factor analysis using principal axis factoring with orthogonal Varimax rotation was conducted. The correlation of each factor was also determined. Multiple linear regression remains an essential method for modeling the connection between a dependent variable and several independent factors. Previous studies related to the construction sector have developed useful regression models to estimate the effect of several predictors on key outcomes. These methods validate the strength of regression modeling even with small sample sizes and many variables [20]. So, linear regression among the dependent and independent variables was conducted.

There are two statistical measures, Kaiser-Meyer-Olkin (KMO) sampling adequacy ratio and Bartlett Sphericity test, to assess the factorability of the data, and the average amount for KMO for sample size < 100 of valid data can be greater than 0.6, whereas the amount for the Bartlett Sphericity test can be less than 0.05. This was done by the mathematically represented below [21];

$$KMO_j = \frac{\sum_{i \neq j} R_{ij}^2}{\sum_{i \neq j} R_{i+j}^2 + \sum_{i \neq j} U_{ij}^2} \quad (1)$$

Where R_{ij} is the correlation matrix between the i^{th} and j^{th} variable, and U_{ij} is the partial covariance matrix between the i^{th} and j^{th} variable.

To quantify the general relation among the variables, the determinant of the correlation matrix $|R|$ is calculated. The average amount for the Bartlett Sphericity test can be less than 0.05. According to [21], the formula for Bartlett's test of Sphericity is calculated as follows.

$$X^2 = - (n - 1 - \frac{2p+5}{6}) \times \ln|R| \quad (2)$$

Where, p = number of variables, n = total sample size, and R = correlation matrix of variables.

Reliability test represents the degree of accuracy or the degree of being free from any error of the research instrument, and the internal consistency is confirmed by calculating Cronbach's alpha to test the instrument's accuracy and reliability, and the value of Cronbach's alpha is > 0.7 [21].

The variables in this study were tested with the Kaiser-Meyer-Oklin measure of sampling adequacy and Cronbach's Alpha value at a significance level of 5%. The value confidence level 95% is the preferred significance level with a minimal level of statistical error. And also, the study used a popular formula to create a ranking of the factors of concern based on the marks allocated by the assumed respondents. The method is given as follows [22];

$$I = \frac{\sum(F_i + S)}{N} \quad (3)$$

Where, I = mean score, F_i = frequency of each Likert scale score (number of respondents), S = Likert item score (1 to 4), N = total number of respondents.

To minimize social attraction bias, respondents were assured that they would not write their name or address and that their responses would remain confidential. We recognize that the cross-sectional

design captures ICT adoption at a single point in time; a high sample size, and longitudinal research is recommended to assess dynamic changes in acceptance patterns.

3. Results and discussions

3.1. Questionnaire response rate

A total of 75 inquiry forms were circulated to the main contracting parties or their representatives. Before analysis, all returned questionnaires were checked for completeness and consistency. Questionnaires with significant missing replies were omitted using listwise deletion to avoid presenting bias in the statistical examination. After that, 65 questionnaires were gathered, and 54 of them were valid and correctly completed. The total valid response rate was 72%. As described by [23], a minimum reply degree of 50% or greater is often measured to be brilliant, and further analysis can be made. Since the response rate is above the minimum requirement (which is 72%), further analysis was made in the following sections. To assess potential non-response bias, responses from early and late participants were compared, and no significant differences were found in key variables, establishing that non-response bias is unlikely to significantly affect the results.

3.1.1. Questionnaire of respondents' profile

Questionnaire respondent professionals of varying experience and role were directly considered as a population with different categories that 33% consultants, 33% also clients, and the remaining 34% of the respondents are contractors, as summarized in Figure 4a.

About 84% of the questionnaire respondents were bachelor's degree holders, and 10% of the respondents had a diploma, while the remaining 6% of the respondents were M.Sc. holders, as in Figure 4b. This large percentage representation of B.Sc. was good as it shows a good educational status of respondents in order to answer the investigator's questionnaire effectively.



Figure 4. Questionnaire respondent with different (a) categories and (b) education status.

Additionally, the questionnaire respondents were also of varying responsibilities and job positions. From Figure 5, 48.1% of the respondents were site engineers. The high representation of site engineers (48.1%) was vital as they are the main aim of this investigation, as they are directly involved in construction work execution, and the availability of other experts shows a good scattering.

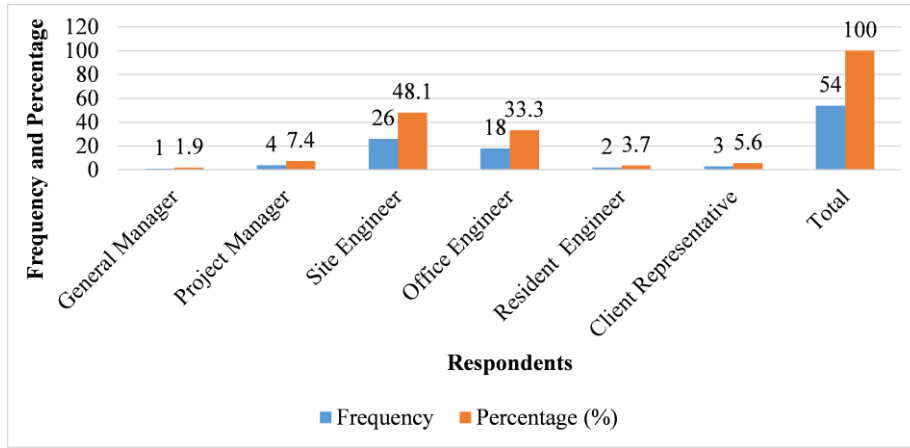


Figure 5. Questionnaire respondent responsibilities and job positions.

Figure 6 shows the personal experience of questionnaire respondents of different construction experts.

As stated in Figure 6, majority of professionals have enough work experience and this be located critical as they are the main aims of this investigation as mainly involved in construction task execution for a long period of time.

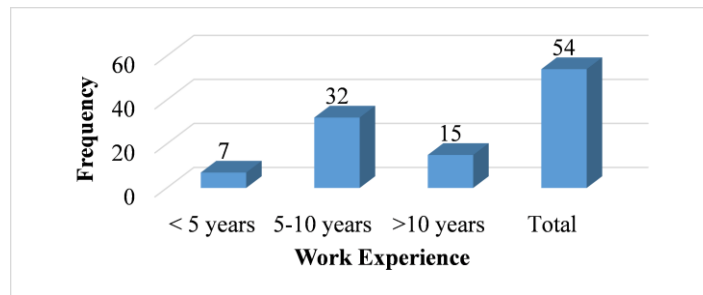


Figure 6. Questionnaire respondent work experience.

3.1.2. Questionnaire of company profile

Figure 7 shows that the companies covered in this study were grouped by the year of their involvement in the construction sector (a) and their computer access (b) in the office and at the project site.

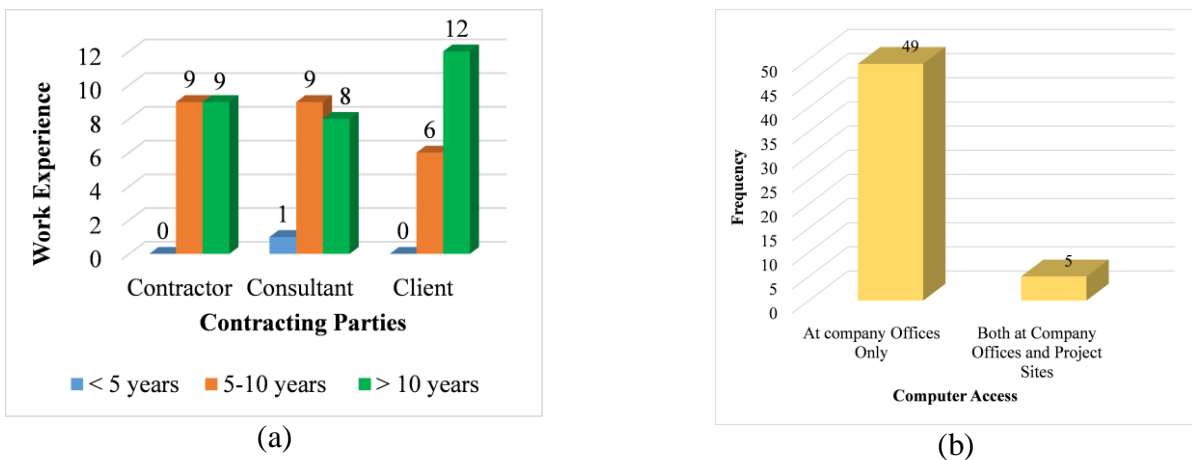


Figure 7. Work experience and computer access of the company profile. (a) Work experience; (b) computer access.

The presence of computer access in a company, or the presence of someone responsible for information management, can help to use ICT efficiently. As shown in Figure 7, computer access in the companies was available only at company offices (90.7%) and at both company offices and project sites (9.3%).

3.2. Interview respondents profile

As the reason stated in the methodology part, 8 interviewees who were directly partaking in the construction of ongoing public building projects in Mekelle city were selected. According to Figure 8, 2 of the interviewees were supervisors, 4 office engineers, 1 survey professional, and 1 site engineer.

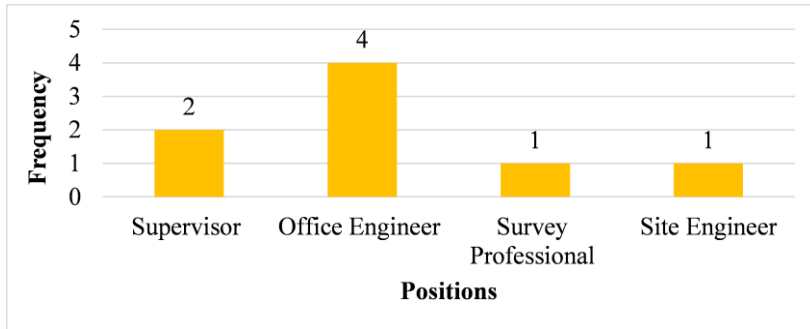


Figure 8. Interview respondents’ profession.

Respondents in the interview also had diverse experiences in the construction sector over many years, as summarized in Figure 9a. Additionally, 62.5% of the respondents had 5 to 10 years of experience, indicating strong knowledge. Similarly, 37.5% of respondents were CoTM, while the remaining 62.5% were Civil Engineers (Civil E.), as shown in Figure 9b. Interview respondents also had varying experiences and roles.

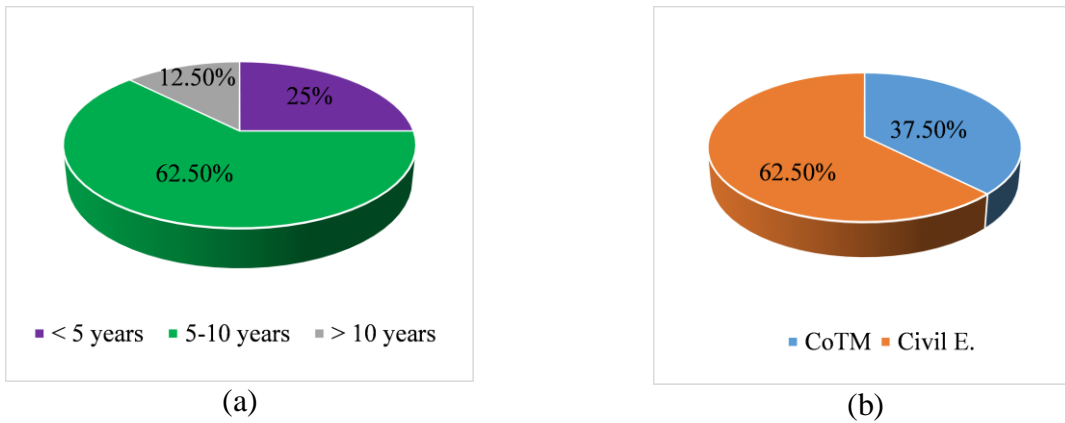


Figure 9. Experience of the Interview Respondents (a) experience and (b) field.

3.3. Factorial analysis and validity test

Validity tests were analyzed using the average value of KMO and Bartlett’s Sphericity, whereas reliability tests were analyzed using Cronbach’s alpha. According to [21], the accepted values for KMO, Bartlett’s Sphericity, and Cronbach’s alpha were > 0.6, < 0.05, and > 0.7, respectively. For ICT platforms responses, the value of KMO and Bartlett’s test of Sphericity was 0.654 and 0.000 consecutively as stated in Table 2 below, so those values confirm the required criteria which shows the data’s was

suitable for factor analysis, and Table 2 confirms that the value of KMO for frequency of ICT applications was 0.686 which is > 0.6 and the value of Bartlett's test of Sphericity was 0.000 which is < 0.05 . Therefore, both values were accepted as they show the variables of frequency of ICT applications were valid.

Similarly, the assessment of KMO for factors affecting the use of ICT was 0.673, which is > 0.6 , and the value of Bartlett's test of Sphericity was 0.000, which is < 0.05 ; both values were accepted as they indicate the variables influencing the use of ICT were valid as stated in Table 2.

Table 2. Result of Factorial analysis and validity test.

Serial Number	KMO and Bartlett's test value		Constructs		
			ICT platforms	Frequency of ICT Applications	Factors affecting the use of ICT
1	Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.654	0.686	0.673
2	Bartlett's Test of Sphericity	Approximate Chi-square	178.573	656.119	916.773
		df	28	153	210
		Sig.	0.000	0.000	0.000

Whereas, "a construct is reliable if the Cronbach's alpha (α) value is greater than 0.70" [21]. The results discovered that the ICT platforms with eight items ($\alpha = 0.708$), the frequency of ICT applications with eighteen items ($\alpha = 0.829$), and the factors affecting the use of ICT with twenty-one items ($\alpha = 0.754$), show all constructs were reliable as summarized in Figure 10. Therefore, the factorial analysis was made on the collected questionnaires, and further data analysis can be made.

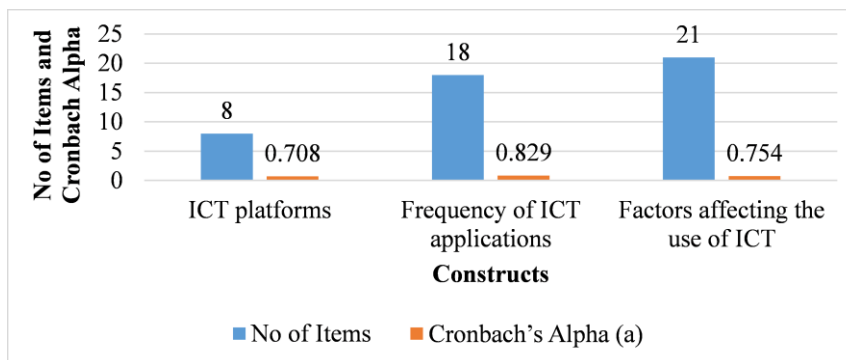


Figure 10. Reliability statistics.

3.3.1. Factor analysis and correlation for ICT applications

An exploratory factor analysis using principal axis factoring with orthogonal Varimax rotation was conducted, excluding several factors with items that have factor loadings below 0.40, significant cross-loadings, or lacking conceptual consistency were eliminated. The number of factors retained was based on eigenvalues greater than 1 and confirmed through scree plot analysis. Then, 18 ICT application frequencies were retained for the final investigation, yielding a fixed five-factor solution with a strong conceptual understanding.

The frequency of ICT applications lists was appropriate for factor analysis, as indicated by the Kaiser-Meyer-Olkin (0.686) measure of sampling adequacy and a significant Bartlett's test of Sphericity

(χ^2 (153) = 656.119, $p < 0.001$). Five factors remained, based on eigenvalues above 1, theoretical interpretability, and the scree plot, clarifying 61.73% of the cumulative variance after extraction, which is satisfactory for research. All factor loadings were greater than 0.40, with no cross-loadings, as shown in Table 3. The five grouped factors were theoretically distinct. The factors were factor 1 (Project Planning and Scheduling), factor 2 (Making Project Drawings), factor 3 (General Project Administration), factor 4 (Project Cost Control), and factor 5 (General Communication).

Table 3. Rotated factor matrix of ICT applications.

	Factor				
	1	2	3	4	5
Primavera	0.802				
Microsoft Project	0.794				
Power Project	0.451				
ArchiCAD		0.751			
AutoCAD		0.810			
Revit		0.481			
Microsoft Office PowerPoint			0.476		
Microsoft Office Word			0.736		
Microsoft Office Excel			0.876		
Microsoft Office Access			0.452		
spread sheet			0.757		
Esti-mate				0.622	
Resource cost sheet				0.528	
Master bill				0.865	
E-mail service					0.606
Internet (Website, telegram, skype)					0.655
Teleconferencing					0.559
Mobile Phones					0.566

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization ^a.

^a Rotation converged in 9 iterations.

Among the five factor scores, Pearson correlations were used for the usage of ICT applications, and the values were small (ranging from 0.033 to 0.114) and non-significant, as $p > 0.05$, as shown in Table 4. This indicates that the factors extracted using principal axis factoring with Varimax rotation were critically independent, and this shows that each factor represents a distinct dimension of ICT Usage levels.

Table 4. Correlations of ICT applications.

		REGR factor score (Project Planning and Scheduling)	REGR factor score (Making Project Drawings)	REGR factor score (General Project Administration)	REGR factor score (Project Cost Control)	REGR factor score (General Communication)
REGR factor score (Project Planning and Scheduling)	Pearson Correlation	1	-0.006	0.114	0.002	0.066
	Sig. (2-tailed)		0.964	0.414	0.986	0.634
	N	54	54	54	54	54
REGR factor score (Making Project Drawings)	Pearson Correlation	-0.006	1	0.040	-0.031	0.071
	Sig. (2-tailed)	0.964		0.775	0.823	0.609
	N	54	54	54	54	54
REGR factor score (General Project Administration)	Pearson Correlation	0.114	0.040	1	0.045	0.011
	Sig. (2-tailed)	0.414	0.775		0.746	0.938
	N	54	54	54	54	54
REGR factor score (Project Cost Control)	Pearson Correlation	0.002	-0.031	0.045	1	-0.033
	Sig. (2-tailed)	0.986	0.823	0.746		0.813
	N	54	54	54	54	54
REGR factor score (General Communication)	Pearson Correlation	0.066	0.071	0.011	-0.033	1
	Sig. (2-tailed)	0.634	0.609	0.938	0.813	0.921
	N	54	54	54	54	54

3.3.2. Factor analysis and correlation for ICT adoption factors

Similarly, in ICT adoption factors, an exploratory factor analysis using principal axis factoring with orthogonal Varimax rotation was generated by excluding those with low factor loadings (< 0.4), cross-loadings, or single-item factors, which compromised the stability and understandability of the factor structure. Finally, ICT adoption factors were retained for the final investigation, resulting in a fixed five-factor solution with strong conceptual understanding.

Factors affecting ICT adoption lists were appropriate for factor analysis, as indicated by the Kaiser-Meyer-Olkin (0.673) measure of sampling adequacy and a significant Bartlett's test of Sphericity ($\chi^2 (210) = 916.773, p < 0.001$). Five factors remained, based on items with factor loadings below 0.40, significant cross-loadings, or lacking conceptual consistency, were eliminated. The number of factors retained was based on eigenvalues greater than 1 and confirmed through scree plot analysis, clarifying 67.51% of the cumulative variance after extraction, which is satisfactory for research. The five grouped factors were theoretically distinct. The factors were the first seven items as factor 1 (Human Factors), the next three items as factor 2 (Technical Factors), the next three items as factor 3 (Financial Factors), the next four items as factor 4 (Legal Factors), and the next two items as factor 5 (Environmental Factors), as shown in Table 5. All factors had acceptable loadings and were conceptually different, which shows a coherent five-dimensional part of the ICT adoption factors.

Table 5. Rotated factor matrix of ICT adoption factors.

	Factor				
	1	2	3	4	5
Lack of commitment by company management towards ICT	0.931				
Lack of staff with appropriate skills and knowledge in ICT	0.908				
Inadequate ICT content in construction education	0.656				
Inadequate knowledge about the return on ICT investment	0.656				
Satisfaction with the existing method of working	0.665				
Fear of job losses/making professionals redundant	0.616				
Lack of time available to learn	0.43				
Lack of training	0.688				
Problem of ICT integration in the organization		0.824			
Security concerns/privacy fears		0.813			
Access to a relatively cheap workforce		0.707			
Software and hardware reliability problems		0.931			
Cost of training professionals in ICT			0.927		
Limited benefits return on investment in ICT.			0.718		
High cost of employing ICT professionals			0.721		
Budget constraint for ICT investment			0.669		
Lack of legal support for the use of ICT				0.734	
Risks for liability/obligations				0.81	
Security implications of ICT transactions				0.413	
Lack of adequate jobs in the market					0.91
The majority of client not interested in the company's ICT-based services					0.424
Extraction Method: Principal Axis Factoring.					
Rotation Method: Varimax with Kaiser Normalization ^a .					

^a Rotation converged in 6 iterations.

Similarly, among the five factor scores, Pearson correlations were used for ICT adoption factors, and the values were small (ranging from -0.012 to 0.023) and non-significant as $p > 0.05$, as shown in Table 6. This indicates that the factors extracted using principal axis factoring with Varimax rotation were critically independent, and this shows that each factor represents a distinct dimension of ICT usage levels. The factors were the first seven items as factor 1 (Human factors), the next three items as factor 2 (Technical Factors), the next three items as factor 3 (Financial Factors), the next four items as factor 4 (Legal Factors), and the next two items as factor 5 (Environmental Factors), respectively.

Table 6. Correlations of ICT adoption factors.

		REGR factor score (Human factors)	REGR factor score (Technical Factors)	REGR factor score (Financial Factors)	REGR factor score (Legal Factors)	REGR factor score (Environmental Factors)
REGR factor score (Human factors)	Pearson Correlation	1	0.005	0.000	0.018	-0.007
	Sig. (2-tailed)		0.973	1.000	0.895	0.962
	N	54	54	54	54	54
REGR factor score (Technical Factors)	Pearson Correlation	0.005	1	0.019	-0.004	-0.008
	Sig. (2-tailed)	0.973		0.894	0.978	0.956
	N	54	54	54	54	54
REGR factor score (Financial Factors)	Pearson Correlation	0.000	0.019	1	0.023	-0.012
	Sig. (2-tailed)	1.000	0.894		0.870	0.929
	N	54	54	54	54	54
REGR factor score (Legal Factors)	Pearson Correlation	0.018	-0.004	0.023	1	0.007
	Sig. (2-tailed)	0.895	0.978	0.870		0.959
	N	54	54	54	54	54
REGR factor score (Environmental Factors)	Pearson Correlation	-0.007	-0.008	-0.012	0.007	1
	Sig. (2-tailed)	0.962	0.956	0.929	0.959	0.84
	N	54	54	54	54	54

3.4. Questionnaire of ICT platforms and their extent of usage

Herein, the defendants demonstrated the ICT Setup platforms in use within their companies. The mean index score was used for statistical analysis to find the grade of ICT usage by the main contracting parties. A grouping based on a four-point type Likert ordinal scale was employed to measure the level of usage by respondents from Never to Always. ICT platforms were assumed as a single category, as each platform works as a complete tool in itself and does not need a more specific category. The symbol was “1 = Never, 2 = Sometimes, 3 = Often, and 4 = Always,” and the responses of ICT platforms were summarized in Figure 11.

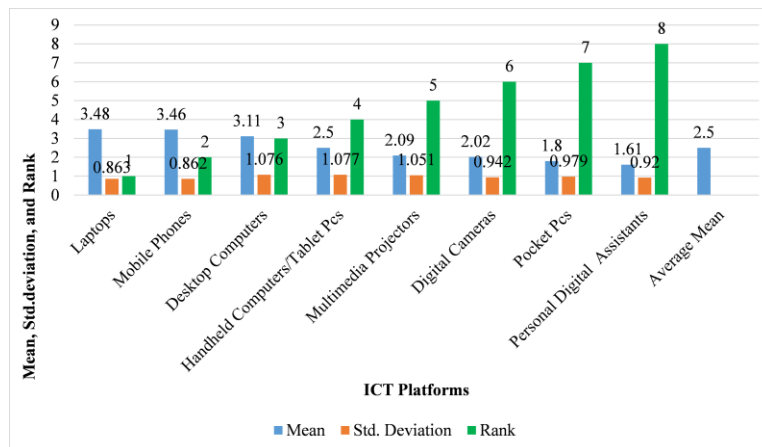


Figure 11. Responses of ICT platforms.

According to Figure 11, more than half of the platforms identified had a standard deviation of below 1.00; this shows that more than half of the respondents had no differences in the ranking of their level of usage. The findings of this research show that the ICT platform with the maximum grade of usage was laptops (with a mean of = 3.48). ICT platforms used by the main contracting parties have an average of 2.50, showing a minimum grade of usage (sometimes) of those recognized ICT platforms. From this finding, it can be summarized that the greatest construction companies contained laptops, mobile phones,

and desktop computers as devices of work. However, construction companies are unmoving to contain additional existing tools like personal digital assistants, pocket PCs, and other digital tools as well.

According to the factor analysis result, the five grouped factors were Factor 1 (Project Planning and Scheduling), Factor 2 (Making Project Drawings), Factor 3 (General Project Administration), Factor 4 (Project Cost Control), and Factor 5 (General Communication), as shown in Table 7. The average table mark of the defendants was also considered.

Table 7. Responses for ICT applications.

No	ICT applications	Mean	Standard Deviation	Rank	Overall Rank	
1	Project Planning and Scheduling	Primavera	1.78	0.904	2	14
		Microsoft project	1.87	0.778	1	12
		Power project	1.61	0.763	3	17
2	Making Project Drawings	ArchiCAD	2.13	1.065	2	9
		AutoCAD	2.89	0.904	1	3
		Revit	1.83	1.005	3	13
3	General Project Administration	Microsoft Office PowerPoint	1.74	0.915	4	15
		Microsoft Office Word	2.54	0.840	3	7
		Microsoft Office Excel	3.09	0.853	1	2
		Microsoft Office Access	1.65	1.012	5	16
		Spread sheet	2.63	0.853	2	6
4	Project Cost Control	Estimate	1.54	0.693	3	18
		Resource cost sheet	2.70	0.792	2	5
		Master bill	2.74	0.935	1	4
5	General Communication	Email service	2.41	0.962	2	8
		Internet (skype, telegram)	1.93	0.949	3	10
		Teleconferencing	1.91	1.103	4	11
		Mobile phones calls	3.15	0.899	1	1
6	Average mean	2.23				

Total number of respondents (N) is 54.

As stated in Table 7 above, most of the ICT applications identified required a standard deviation of below 1.00. This shows that over half of the defendants required no differences in the ranking of their grade of usage. From overall rank of ICT application in construction projects, the top five highest level of usage was mobile phones calling (mean = 3.15), Microsoft office Excel (mean = 3.09), AutoCAD (mean = 2.89), master bill (mean = 2.74) and resource cost sheet (mean = 2.70) consecutively, and ICT application used by main contracting parties have an average mean with 2.23, shows a little usage (sometimes) from that recognized ICT application software's. It can be summarized after the outcome that most construction companies practice Mobile phone calling, Microsoft Office Excel, AutoCAD, mater bill, and resource cost sheet as tools of work. But construction companies still need to have additional available tools as well to facilitate their performance in construction project administration.

3.5. Questionnaire of factors affecting the use of ICT

In this part, a one-sample t-test was employed to analyze the factors affecting the use of ICT in public building construction projects. A sample t-test numerical instrument was engaged to identify the important and selected factors by the main contracting parties. "A one-sample t-test reports on the mean of the test group, degrees of freedom for the test, the t value, which was an indication of the strength of the test, and the p value, which was the probability value that the test was significant" [24]. When the sample

size is more than 30, a normal distribution can be assumed by the central limit theorem [25]. The test value of 3 was chosen because it marks the threshold of ‘often’ on the four-point Likert scale, indicating that respondents view the factor as a significant obstacle. This approach aligns with previous research that employs ordinal Likert scales to identify key factors. A significant t-value ($p < 0.05$) indicates that the mean score of the factor varies from the test value, suggesting that respondents perceive it as a barrier to ICT adoption in public building construction projects. Conversely, a non-significant t-value ($p > 0.05$) indicates that the factor is not considered a major barrier.

As per [25], “A high standard deviation means that the values within a dataset are generally positioned far away from the mean, while a low standard deviation indicates that the values tend to be clustered close to the mean”. Table 8 indicates that the amount of the normal error for all the averages was close to zero, which indicates that the sample selected was an exact image of the people as shown below, and more than half of the identified factors had a standard deviation of below 1.00. This shows that over half of the respondents had no differences in the ranking of their grade of factors. Based on the result of factor analysis, the factors were the first seven items as Factor 1 (Human Factors), the next three items as Factor 2 (Technical Factors), the next three items as Factor 3 (Financial Factors), the next four items as Factor 4 (Legal Factors), and the next two items as Factor 5 (Environmental Factors), respectively.

Table 8. Results of one-sample statistics.

One-sample statistics				
No	Factors affecting the use of ICT in public building construction projects	Mean	Standard Deviation	Standard Error Mean
1	Deficiency of commitment by company management towards ICT	3.43	1.002	0.136
2	Deficiency of staff with appropriate skills and knowledge in ICT	3.30	1.039	0.141
3	Inadequate ICT content in construction education	1.63	0.760	0.103
4	Inadequate knowledge about the return on ICT investment	3.37	0.938	0.128
5	Satisfaction with the existing method of working	3.28	0.834	0.113
6	Fear of job losses/making professionals redundant	1.94	0.998	0.136
7	Deficiency of time available to learn	1.44	0.538	0.073
8	Deficiency of training	3.41	0.880	0.120
9	Problem of ICT integration in the organization	3.35	0.805	0.109
10	Security concerns/privacy fears	1.26	0.705	0.096
11	Access to a relatively cheap workforce	1.63	0.760	0.103
12	Software and hardware reliability problems	1.15	0.596	0.081
13	Cost of training professionals in ICT	1.22	0.664	0.090
14	Limited benefits return on investment in ICT	2.87	1.133	0.154
15	High cost of employing ICT professionals	3.22	0.984	0.134
16	Budget constraint for ICT investment	2.44	1.093	0.149
17	Deficiency of legal support for the use of ICT	3.33	0.801	0.109
18	Risks for liability/obligations	1.61	0.787	0.107
19	Security implications of ICT transactions	1.30	0.537	0.073
20	Deficiency of adequate jobs in the market	2.22	1.298	0.177
21	The majority of clients are not interested in companies’ ICT-based	3.24	0.930	0.127

Total number of respondents (N) is 54.

Using SPSS software, a statistical analysis based on Table 9, with a total number of respondents (N) of 54, utilizes a two-tailed test on each factor and a mean test value of 3 to determine the significance of each factor influencing ICT usage by main contracting parties.

Table 9. Results of a one-sample test.

Factors affecting the use of ICT in public building construction projects	One-sample test					
	t	df	Sig. (2-tailed)	Mean Difference	Test Value = 3	
					95% Confidence Interval of the Difference	Upper
Deficiency of commitment by company management towards ICT	3.124	53	0.003	0.426	0.15	0.70
Deficiency of staff with appropriate skills and knowledge in ICT	2.095	53	0.041	0.296	0.01	0.58
Inadequate ICT content in construction education	13.255	53	0.000	1.370	1.58	1.16
Inadequate knowledge about the return on ICT investment	2.903	53	0.005	0.370	0.11	0.63
Satisfaction with the existing method of working	2.449	53	0.018	0.278	0.05	0.51
Fear of job losses/making professionals redundant	7.769	53	0.000	1.056	1.33	0.78
Deficiency of time available to learn	21.252	53	0.000	1.556	1.70	1.41
Deficiency of training	3.402	53	0.001	0.407	0.17	0.65
Problem of ICT integration in the organization	3.213	53	0.002	0.352	0.13	0.57
Security concerns/privacy fears	18.135	53	0.000	1.741	1.93	1.55
Access to a relatively cheap workforce	13.255	53	0.000	1.370	1.58	1.16
Software and hardware reliability problems	22.840	53	0.000	1.852	2.01	1.69
Cost of training professionals in ICT	19.689	53	0.000	1.778	1.96	1.60
Limited benefits return on investment in ICT	0.840	53	0.404	0.130	0.44	0.18
High cost of employing ICT professionals	1.659	53	0.103	0.222	0.05	0.49
Budget constraint for ICT investment	3.735	53	0.000	0.556	0.85	0.26
Deficiency of legal support for the use of ICT	3.058	53	0.003	0.333	0.11	0.55
Risks for liability/obligations	12.967	53	0.000	1.389	1.60	1.17
Security implications of ICT transactions	23.333	53	0.000	1.704	1.85	1.56
Deficiency of adequate jobs in the market	4.402	53	0.000	0.778	1.13	0.42
The majority of clients are not interested in companies ICT base	1.902	53	0.063	0.241	0.01	0.49

Figure 12 summarizes the overall global factors affecting the use of ICT in public building construction generated from this study.

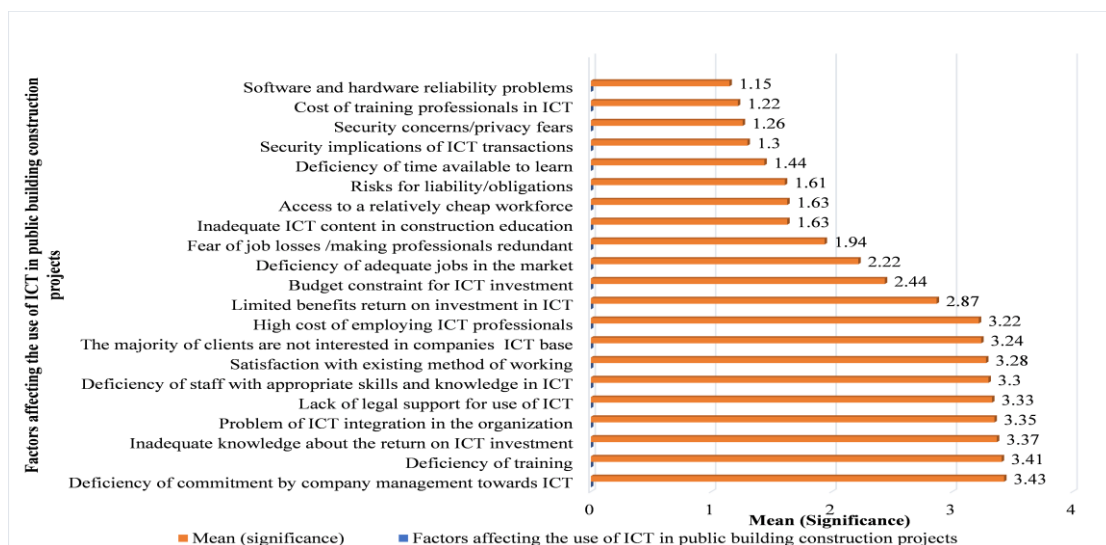


Figure 12. Ranking of factors affecting the use of ICT.

3.5.1. Regression analysis

To examine the influence of 21 human, technical, financial, legal, and environmental factors on ICT adoption in public construction projects, linear regression analysis was performed. Even though factor analysis recognized five different dimensions of ICT application usage, the construct is theoretically conceptualized as a complete and combined situation. The identified factors represent sub-sections of the broader ICT usage group rather than independent endings. Using the significant theoretical overlap among the constructs and their satisfactory internal consistency, an overall mean score was calculated to characterize the overall ICT applications. This method decreases model difficulty and aligns with the research objective of investigating factors of overall ICT adoption through diverse ICT applications. So, the dependent variable, the overall mean of 18 items of ICT application usage as a single variable, was used. All 21 individual items as independent variables were used in linear regression to determine specific ICT adoption factors affecting the outcome, which is consistent with the research objective. Before interpreting the regression results, diagnostic tests were performed to verify the model assumptions. Multicollinearity was assessed using the variance inflation factor, and all variables had acceptable values below 10. Residual analysis showed an approximately normal distribution and no severe heteroscedasticity, confirming that the linear regression assumptions were sufficiently met.

Based on the linear regression result, the model was statistically significant as F-value $(21, 32) = 2.80$, $p = 0.004$, showing that the independent variables collectively describe variation in ICT adoption, with an R^2 of 0.648, and the adjusted R^2 was 0.416, which shows that 41.65% of the variance in ICT adoption was described by the predictors as stated in Table 10. And also, the standard error of the estimate was 0.36.

Table 10. Model summary and ANOVA of variables. (a) Model summary; (b) ANOVA.

Model	R	R Square	Adjusted R-Square	Standard Error of the Estimate	Sum of Squares	df	Mean Score	F	Sig.
(a) Model Summary									
1	0.805 ^a	0.648	0.416	0.35954					
(b) ANOVA									
1	Regression				7.601	21	0.362	2.800	0.004 ^b
	Residual				4.137	32	0.129		
	Total				11.738	53			

^a Predictors: (Constant), All 21 items.

^b Predictors: (Constant), All 21 items.

Dependent Variable: Overall Mean of the 15 ICT applications.

To measure the influence of factors on the outcome, a coefficient table was generated from the linear regression. Among the 21 factors identified, the primary influential factors were lack of commitment by company management towards ICT ($B = 1.152$, $p = 0.040$), security concerns/privacy fears ($B = 0.818$, $p = 0.005$), cost of training ICT professionals ($B = -0.676$, $p = 0.044$), and limited benefits return on investment in ICT ($B = -0.480$, $p = 0.023$) respectively as shown in Table 11. Additional factors, such as lack of staff skills ($B = -0.806$, $p = 0.087$), ICT integration problems in the organization ($B = 0.575$, $p = 0.093$), and lack of training ($B = -0.532$, $p = 0.054$), indicate moderate effects on ICT adoption. The positive beta amount shows factors related to higher levels of ICT adoption, and the negative beta amount shows factors whose increase minimizes ICT adoption.

Table 11. Coefficients of variables ^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.917	0.843		3.461	0.002
Lack of commitment by company management towards ICT	0.541	0.253	1.152	2.137	0.040
Lack of staff with appropriate skills and knowledge in ICT	-0.365	0.206	-0.806	-1.768	0.087
Inadequate ICT content in construction education	-0.147	0.133	-0.237	-1.104	0.278
Inadequate knowledge about the return on ICT investment	-0.253	0.165	-0.505	-1.540	0.133
Satisfaction with the existing method of working	-0.062	0.093	-0.109	-0.666	0.510
Fear of job losses/making professionals redundant	0.126	0.116	0.267	1.087	0.285
Lack of time available to learn	-0.124	0.133	-0.141	-0.927	0.361
Lack of training	-0.285	0.143	-0.532	-1.997	0.054
Problem of ICT integration in the organization	0.336	0.194	0.575	1.733	0.093
Security concerns/privacy fears	0.546	0.180	0.818	3.028	0.005
1 Access to a relatively cheap workforce	-0.085	0.186	-0.138	-0.460	0.649
Software and hardware reliability problems	0.286	0.255	0.362	1.125	0.269
Cost of training professionals in ICT	-0.479	0.228	-0.676	-2.098	0.044
Limited benefits return on investment in ICT	-0.199	0.084	-0.480	-2.383	0.023
High cost of employing ICT professionals	0.006	0.098	0.014	0.066	0.948
Budget constraint for ICT investment	0.133	0.078	0.310	1.705	0.098
Lack of legal support for the use of ICT	0.161	0.110	0.274	1.462	0.153
Risks for liability/obligations	-0.164	0.139	0.275	-1.181	0.246
Security implications of ICT transactions	-0.081	0.147	-0.092	-0.550	0.586
Lack of adequate jobs in the market	0.052	0.058	0.144	0.892	0.379
The majority of clients are not interested in the company's ICT-based services	-0.163	0.095	-0.323	-1.721	0.095

^a Dependent Variable: Overall Mean of the 15 ICT applications.

3.5.2. Interpretation of results

This study investigated factors affecting the use of ICT in public building construction projects in Mekelle city using a one-sample t-test with a test value of 3 as a benchmark. According to the analysis of perception results in Table 8, Table 9, and Figure 12, the top five factors that were identified based on a significant t-value ($p < 0.05$) indicate that respondents perceive the factor as a barrier to ICT adoption as having the greatest impact on the use of ICT in public building construction projects are listed below. Deficiency of commitment by company management towards ICT (Mean = 3.43, $t = 3.124$, $p = 0.03$), insufficient training (mean = 3.41, $t = 3.4$, $p = 0.001$), inadequate knowledge about return on ICT investment (mean = 3.37, $t = 2.9$, $p = 0.005$), problem of ICT integration in the organization (mean = 3.35, $t = 3.2$, $p = 0.002$), and lack of legal support for use of ICT (mean = 3.33, $t = 3.058$, $p = 0.003$). According to the study's findings, as indicated in Figure 12 above, the factors influencing ICT usage at a higher level of significance ranged from the main factor, which had an average of 3.43, to the smallest important element, which had an average of 1.15.

Based on the result of linear regression (actual impact), the primary influential factors were lack of commitment by company management towards ICT ($B = 1.152$, $p = 0.040$), security concerns/privacy fears ($B = 0.818$, $p = 0.005$), cost of training ICT professionals ($B = -0.676$, $p = 0.044$), and limited benefits return on investment in ICT ($B = -0.480$, $p = 0.023$) respectively as shown in Table 11. This demonstrates that management commitment could serve as an antecedent factor affecting other elements, such as training availability and ICT integration capability. The positive beta amount shows factors related to higher levels of ICT adoption, and the negative beta amount shows factors whose increase minimizes ICT adoption. The ranking of factors differs between the t-test and regression analysis. The t-test reflects respondents' agreement on factors, the weight that factors are measured significantly.

Whereas, regression analysis quantifies the actual influence of each factor on ICT adoption, controlling for other variables. This change specifies that some factors may be agreed as significant but have a smaller actual influence, while others with moderate agreement can have a strong impact on ICT usage. Even though the set of factors we detect is consistent with the wider literature, the relative ranking of these factors in Mekelle city varies from some previous studies.

In our study, the deficiency of commitment by company management towards ICT, insufficient training, inadequate knowledge about return on ICT investment, the problem of ICT integration in the organization, and the lack of legal support for the use of ICT were ranked highest; Security implications of ICT transactions, Security concerns/privacy fears, Cost of training professionals in ICT, and Software and hardware reliability problems were important but ranked lower. This arrangement confirms the overall outcomes of previous work while enlightening an indigenous weighting that redirects Mekelle's specific conditions [14].

The results of our findings recognize the similar broad categories of ICT factors as those reported in previous investigations [5–9,14]. But the relative importance attributed to these factors confirms some important differences. Differences in factor rankings compared with previous studies highlight the importance of location-specific administrative, educational, and operational conditions shaping ICT adoption in Mekelle city.

In our study, the deficiency of commitment by company management towards ICT developed as the top-ranked factor, whereas in [8] this one was located second, and in [6] this one was located third. A reasonable explanation for this difference lies in the organizational and administrative structure of public institutions responsible for building projects in Mekelle city, where ICT-related decisions are typically centralized and require approval from senior management levels. Centralized administrative procedures and limited managerial decisions reduce proactive leadership in promoting ICT adoption, thereby increasing the significance of this factor in the local context. Regarding enterprise structure, Ghana and Saudi Arabia's construction sectors include a high percentage of competitive private firms operating in market-driven environments. In this context, ICT adoption is often linked to competition and client needs. However, public building construction projects in Mekelle city are mainly executed within government-regulated procurement systems, where administrative autonomy and decision-making authority are limited. Consequently, insufficient management commitment in Mekelle city reflects organizational attitudes and institutional restrictions embedded in public sector governance structures. Similarly, obstacles like irregular power supply and limited internet capacity create unique functioning restrictions that strengthen the importance of specific factors compared to other contexts.

This difference can be understood within the unique socio-economic, political, and cultural context of the city. In Mekelle city, most construction companies are small to medium-sized with limited financial capacity and high dependence on traditional construction practices. Additionally, limited exposure to digital construction tools and insufficient policy incentives from government offices reduce awareness of ICT usage in construction. Political instability influences ICT adoption in construction projects. And culturally, construction managers often like traditional practices of construction, and they have limited ICT literacy, which enables resistance to change. When compared with previous studies in Ghana and Nigeria, where larger organizations and stronger ICT support policies exist, management commitment ranks lower because organizations there may have formal ICT systems and more trained individuals. Methodologically, our combination of quantitative surveys and qualitative interviews

provides a better understanding of the mechanisms underlying each factor, rather than simply ranking them. Moreover, the framework established in this study translates these visions into practice and offers project-stage-dependent recommendations, making it more operational and contextually adapted than current universal ICT adoption frameworks. Therefore, our results both complement and expand existing studies by explaining not only which obstacles are significant but also why they are serious in Mekelle City and how they can be addressed in practice.

In this study, security concerns ($B = 0.818$, $p = 0.005$) became a contextual innovation as it was the second most significant factor affecting ICT usage. Even previous studies have acknowledged it, but they have rarely noticed it as the main factor. In Mekelle city, the government-dominated public construction sector and centralized administration control appear to increase sensitivity toward data protection and system reliability. This indicates that in government-dominant public sectors, digital trust works as an official determinant of ICT adoption.

In the same way, while the insufficient training was ranked second based on perception in our results, it was described as the first in [3], second in [6], third in [7,8], and the fifth factor in [5]. This result shows that professionals engaged in public building projects in Mekelle city face limited institutional support for structured ICT training. As a result, even when ICT tools are available, insufficient learning opportunities affect effective utilization.

And also, though the inadequate knowledge about return on ICT investment was ranked third based on perception in our results, it was described as the second in [5]. This difference can be explained by the characteristics of public building construction projects in Mekelle city, where project performance is evaluated primarily based on compliance with budget and schedule rather than long-term efficiency gains. As a result, construction professionals place relatively less emphasis on assessing the economic returns of ICT investments.

Similarly, while the problem of ICT integration in the organization was found to be statistically significant, ranked fourth based on perception in our results, it was described as the third in [3] and the sixth factor in [9]. This reflects fragmented workflows and weak coordination between technical, administrative, and financial units involved in public building projects in Mekelle City. Unlike project environments where integrated digital systems are standard practice, local public organizations often rely on disconnected processes, making ICT implementation more complex and less effective.

Additionally, while the deficiency of legal support for the use of ICT was ranked fifth based on perception in our results, it was described as the thirteenth in [9]. The absence of clear and project-relevant legal guidelines governing electronic records and digital communication creates uncertainty among stakeholders. This uncertainty discourages the widespread adoption of ICT tools, particularly in contractual and administrative processes.

Furthermore, Limited benefits return on investment in ICT was moderately less highlighted in Mekelle city, ranked tenth; however, it was described among the top three in another study [9].

In addition to contextual variations, this study aligns methodologically with prior research by combining quantitative ranking analysis with qualitative validation interviews. Although numerous previous studies rely mainly on survey-based numerical ranking, the triangulated method adopted here enables a deeper explanation of the institutional constraints underlying factor ordering. This procedural incorporation enhances the explanatory depth of the results. Overall, the observed differences in factor ranking between this study and previous research are not incidental but reflect measurable differences

in organizational structure, training opportunities, labor market conditions, and decision-making mechanisms specific to public building construction projects in Mekelle city. These findings suggest that ICT adoption factors are highly context-dependent and that strategies that are successful in other environments may not be directly transferable without adaptation.

Apart from the factors identified statistically, this research shows that ICT adoption in Mekelle is heavily influenced by specific institutional and infrastructural challenges that traditional models do not fully capture. In the city, political instability has affected infrastructure reliability, especially power supply and internet connection, which indirectly discourages long-term ICT adoption. Additionally, cultural practices related to traditional building methods limit experts' willingness to adopt ICT, even when it is accessible. Moreover, although Ethiopia has implemented national digital transformation policies, gaps in local government enforcement, such as delayed implementation of ICT guidelines and poor monitoring, reduce their actual impact on construction projects. These findings establish that ICT adoption in public construction projects is not just a technical or organizational issue but also a socio-political and institutional one.

3.5.3. Mechanism of ICT adoption

The results of this study indicate that ICT adoption in public building construction projects is driven not by individual factors but by an interconnected system of influencing factors with hierarchical links. Based on the regression results and qualitative insights, a mechanism-based explanation is proposed. Management commitment appears to function as a key upstreaming driver, affecting many downstream elements. When company management commitment is low, organizations typically allocate fewer resources for ICT-related training, resulting in insufficient staff skills and limited technical motivation. This creates challenges for ICT integration at different stages of the construction project.

In this framework, training and staff competence can be interpreted as mediating factors between management commitment and ICT adoption. Additionally, ICT integration issues represent operational constraints, turning organizational hurdles into practical obstacles during project execution. Moreover, contextual conditions in Mekelle City influence these connections, either strengthening or weakening them. The predominance of small and medium-sized enterprises limits their financial capacity, making organizations more vulnerable to training costs and investment risks. The limited inclusion of ICT topics in construction sector education sustains a skills gap, maintaining reliance on traditional construction methods.

Furthermore, institutional factors such as autonomous decision-making and inadequate policy enforcement act as moderating variables, affecting how strongly management commitment influences actual ICT adoption. Therefore, ICT adoption in this context is a multi-layered process where governance-level factors shape organizational willingness, which then impacts operational implementation.

3.6. Results of the interview

Interviews were conducted using a semi-structured guide designed to identify the main themes from the questionnaire, including commitment in management, security concerns, problems with ICT integration, and limited return on ICT investment insights. Open-ended questions were used to allow respondents to focus on contextual obstacles influencing ICT use while confirming alignment with the quantitative

variables. All interviews were transcribed and analyzed using thematic analysis. A primary coding framework was established based on the survey factors, followed by open coding to identify frequent patterns in the responses. Codes were grouped into broader themes aligned with the key influencing factors. Thematic saturation was considered achieved when no new themes emerged in the final interviews. The qualitative results were used to triangulate and support the interpretation of the regression outcomes.

While the questionnaire provides a quantitative ranking of factors affecting ICT usage in public building projects in Mekelle city, the qualitative interviews offer deeper insights into the mechanisms and contextual nuances behind these factors. The following section integrates these narratives to validate and enrich the survey findings. A thematic analysis of the interview data was conducted to provide deeper insights into the factors affecting ICT usage identified in the survey. Eight main themes were created, each question offering explanations for the quantitative findings that surveys alone could not capture.

Table 12, regardless of the order, almost all factors of ICT were also selected here, the same as the questionnaire result, and it shows evidence on the main factors. And with this outcome, a solid framework for when and how to use ICT throughout the lifetime of construction projects can be developed.

Table 12. Interview questions with their answer.

Respondent Number	Interview Question			
	Factors affecting the use of ICT in Public Building Construction Projects	Mechanisms that are used to overcome the factors	When and how to use ICT in any construction project lifecycle	Recommendation for other contracting parties to use ICT
1	“Deficiency of staff, lack of electronic devices, and lack of legal support”	“Recruit enough staff, and fulfill enough computers.”	“Assume ICT usage in the whole project in the initiation phase.”	“Should use ICT as well, as it saves everything.”
2	“Low commitment, lack of training, budget constraint, and lack of staff”	“Solve the budget constraint and prepare training sessions.”	“Match the ICT type with each project stage.”	“Better to use ICT as it makes everything easy.”
3	“Low benefits return, and clients are not interested in ICT-based.”	“Clients must consider ICT usage in the tender.”	“Select which ICT to use in which stage of construction.”	“It is good to use ICT because it saves time and cost.”
4	“Low commitment and ICT integration of the management body”	“Well, integration and commitment of ICT in the management body.”	“Analyze each stage of the project with its required ICT.”	“They should use it to become a competitive advantage.”
5	“Cost of training, budget constraint, and lack of staff”	“Prepare training and budget, and recruit professionals.”	“Remember to use the required ICT in each project stage.”	“Prepare enough professionals to use ICT as well.”
6	“Satisfied with the existing method, the lack of training.”	“Use ICT in a timely manner rather than satisfying.”	“Select ICT in each project stage.”	“Use ICT to complete any project safely.”
7	“Low-quality jobs and low time available to learn”	“Prepare enough time to learn.”	“Select the best software for each stage.”	“Using ICT saves time and cost.”
8	“Deficiency of ICT integration in the company as a whole, and a lack of legal support.”	“Prepare incentives to use ICT and support the legal use of ICT.”	“Put design software in the design phase.”	“Should use ICT as it’s an alarm to help complete the project on time.”

3.7. Development of a framework to expand ICT usage

The construction project lifecycle is defined by the Construction Management Association of America (CMAA) as having five phases: “predesign, design, procurement, construction, monitoring, and post construction” [26]. According to the study reported in [27], states the process of a construction project within five phases: “initiation phase, preconstruction phase, procurement phase, construction phase, and post-construction or closeout phase”.

In this study, ICT tools are plotted to particular construction project stages: project initiation, design, procurement, construction, monitoring, and closeout according to their purpose and involvement in project efficiency. The foundation for this location is described under:

Project initiation stage: Management commitment to ICT is essential and should be established at the start of the project to ensure ICT adoption throughout the lifecycle of the construction project.

Design stage: design tools focus on visualizing and coordinating project designs. In this phase, it is critical to assign security concerns as it often affects ICT tool selection and configuration.

Procurement stage: ICT tools used under the procurement stage help to organize the acquisition of materials and services needed for construction. In order to solve system compatibility and procurement of hardware, the problem of ICT integration issues should be emphasized at this stage.

Construction and monitoring stage: As this stage is actual, it is good to consider whether ICT tools are providing the expected efficiency and benefit. So, Limited benefits return on ICT investment should be given an emphasis.

Closeout stage: Even though training assumptions are ended earlier, outcomes of insufficient training become clear at project closeout after staff are expected to use ICT tools effectively. Here are some of the required activities: use a digital documentation platform, and finalize all required activities and documents as per the schedule.

The selection of ICT tools within the proposed framework considers local implementation challenges. Many construction companies in Mekelle operate with limited financial and technical resources; therefore, priority is given to low-cost, widely accessible tools such as mobile communication and basic project management software. Additionally, tools that can work in low-bandwidth areas or have offline capabilities are more suitable given the unreliable internet connection in the city. The complexity of using the latest tools may require extra training, which should match organizational capacity. Language barriers and the lack of localized software interfaces also present practical challenges for ICT adoption in the study area. The suggested framework to expand ICT usage in construction projects is structured in standard project phases, confirming alignment with established construction management practices. While the phases themselves are conventional, the framework is contextually applied to solve the specific factors identified in the Mekelle city construction sector. For example, in the planning stage, it emphasizes with selecting software to use which addresses the top-ranked factors from the study. By using Mekelle city-specific findings in each phase, the framework suggests a practical, actionable instrument that matches familiar construction management structure with reaction to the local socio-economic, cultural, and institutional context, which facilitates significant ICT usage in the construction sector.

Different generic ICT adoption models that highlight firms' willingness within private organizations are used. The following planned framework integrates ICT involvement plans with the lifecycle stages of public building construction projects. This framework shows governance-driven restrictions in the outcomes and aligns remedial plans with stages where institutional blockages are most pronounced. This lifespan-dependent and governance-sensitive grouping is the main critical development of this study. The framework was built based on statistically significant regression determinants instead of a common charting of ICT factors to project phases. Each dominant factor recognized in the regression analysis is linked to the phase in which operational involvement can actually amend its effect on ICT adoption. For example, lack of commitment by company management towards ICT ($B = 1.152$, $p = 0.040$), the

strongest determinant, is assigned during the project initiation phase through administration, addition, and managerial-level ICT oversight mechanisms. Also, negative determinants like cost of training ICT professionals ($B = -0.676$, $p = 0.044$), assigned at design phase, and limited benefit return on ICT investment ($B = -0.480$, $p = 0.023$), were solved through training policies and actual performance monitoring during construction and monitoring stages. Moreover, the framework integrates an iterative comment mechanism whereby quantifiable outcomes from the monitoring stage notify strategic modifications in the following project beginning phases. This converts the framework from a constant stage-tool arrangement into a data-based, lifecycle-grounded intervention model grounded in observed indication. Based on the findings, the researcher incorporates the platforms as a conceptual framework in order to expand the ICT usage level, as stated in Figure 13.

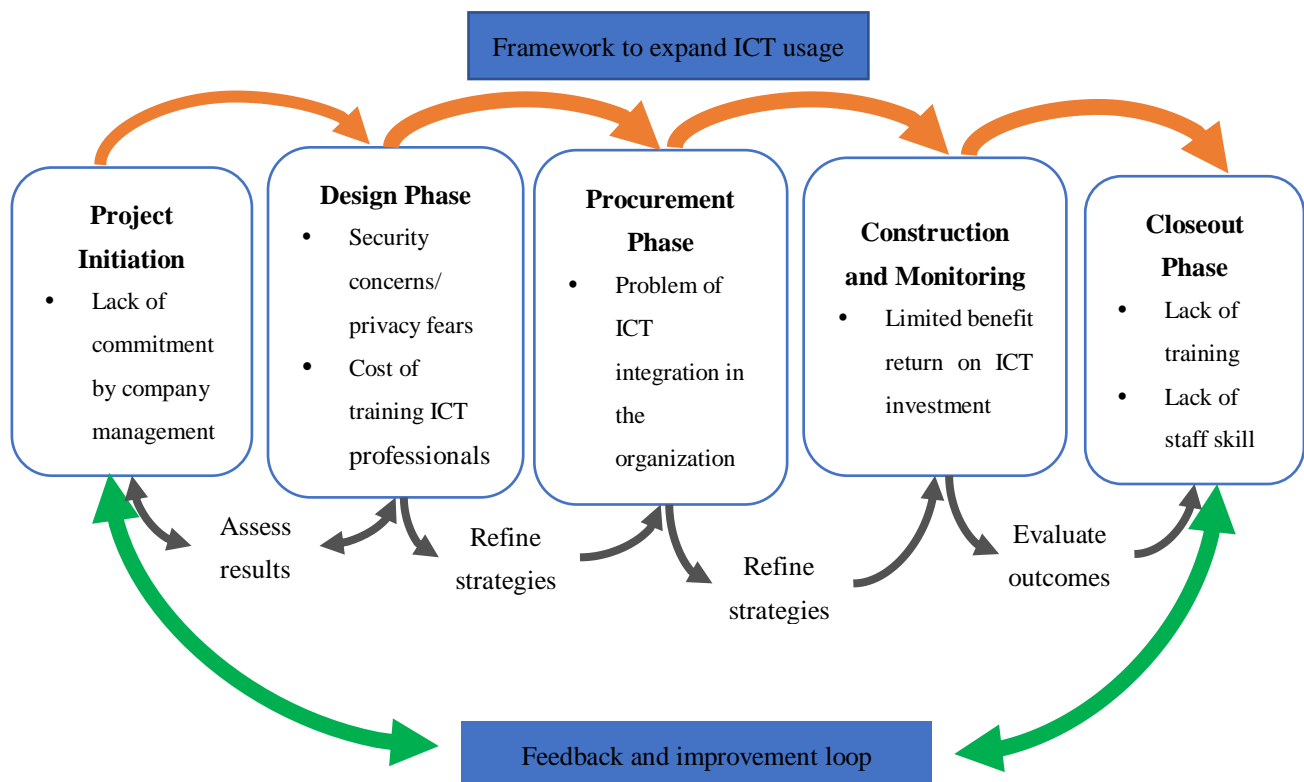


Figure 13. Conceptual framework to expand ICT usage.

The developed framework clearly addresses the top-ranked factors: lack of commitment by company management towards ICT, security concerns/privacy fears, cost of training ICT professionals, and limited benefits return on investment in ICT, respectively. Additional factors include a lack of staff skill, the problem of ICT integration in the organization, and a lack of training. This supports the network among research outcomes and practical applications. The planned framework includes not only lifecycle stages but also institutional restrictions and specific drivers based on context, making it adaptable for government-controlled construction projects.

Although the recommended ICT framework provides clear guidance for adoption, its implementation must account for costs and operational feasibility within the local context. Numerous construction companies in Mekelle are medium- and small-sized firms with limited economic and technical capacity. Therefore, low-cost ICT tools such as mobile communication platforms and cloud-based construction management applications with minimal infrastructure requirements are advisable as initial adoption

steps. More advanced systems, including integrated building information modeling platforms, may require staged implementation, supported by government training and policy incentives. Furthermore, concerns about internet permanency, cybersecurity, and implementation policies should prioritize data protection measures and offline-compatible solutions where possible. These considerations enhance the practical significance of the framework in governance-sensitive and resource-constrained contexts.

4. Conclusion

This investigation aims to improve the understanding of how widely documented factors operate within the public construction sector. By empirically examining Mekelle's public building construction projects, the study validates that administrative structures, centralized procurement structures, and institutional resource constraints significantly shape ICT adoption patterns. The process- or lifecycle-aligned framework provides a structured system for integrating digital plans into public construction project delivery systems. This study examined the main factors of ICT usage in public building construction projects in Mekelle city, Ethiopia, with the purpose of recognizing the most critical difficulties and providing practical recommendations to improve adoption. The principal findings are: lack of commitment by company management towards ICT, security concerns/privacy fears, cost of training ICT professionals, and limited benefit return on investment in ICT. The researcher provided the following actionable recommendations: stronger leadership involvement for ICT implementation, being committed by company management towards ICT adoption, trust building for security concerns/privacy fears during ICT tool selection and configuration, training ICT professionals, assuming limited benefits return on investment in ICT will improve over time, having well-integrated ICT in the organization, and addressing staff skills by preparing enough training programs.

This investigation contributes to the literature by moving beyond traditional factor-ranking perspectives and proposing a mechanism-based understanding of ICT adoption in public construction projects. By including administrative structures, organizational dynamics, and contextual constraints, the study shows that ICT adoption is not just a technical decision but also a multi-level process shaped by institutional, cultural, and economic factors. This perspective provides a foundation for future research to develop more complex causal models and policy-specific strategies. Also, this cross-sectional study captures awareness at one point in time and depends on projects and construction professionals within Mekelle City. So, the severity of obstacles may vary across cities, construction project sizes, and over time. Future longitudinal or multi-site studies should assess how factor rankings change following targeted interventions to develop complex causal relationships and study probable mediating systems among ICT adoption factors. Experts should pilot the recommendations above in the listed activities, and officials should cross-check initial results to refine incentive and support mechanisms, like training opportunities, and recognition for ICT use, to encourage adoption of ICT and measure the most effective procedures.

Supplementary data

The supplementary data include the questionnaire and interview materials used in this study.

Data availability statement

The data or datasets that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of generative AI and AI-assisted technologies

During the preparation of this manuscript, the authors used generative AI tools (ChatGPT and Grammarly) only to improve language and readability. The authors take full responsibility for the content of the manuscript.

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Authors' contribution

Teklay Berhe: formal analysis, investigation, methodology, resources, software, writing—original draft preparation, writing—review and editing. Zeru Tariku: supervision, conceptualization, validation, and visualization. Gebrehiwet Teklemariam: data curation and project administration. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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