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Adoption and Integrating Industrialised Construction Technology to Small and Medium Construction Enterprises in Tanzania

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ABSTRACT: Industrialization has recently eased and cleared the path to mitigate numerous challenges within the construction industry as a consequence of adopting and integrating industrialized construction technologies. Hence, the objective of this paper was to develop a framework of critical strategies towards adoption and integration of industrial construction Technologies to Small and medium Construction Enterprises (SMCE) in Tanzania. Using a structured questionnaire, one-hundred-fifty-nine questionnaires well attended were administered through online media to experienced construction industry professionals. The findings acknowledged nine motivational factors and twelve critical factors including promoting the use of BIM to enhance collaboration and ease communication between project participants, developing educational and training initiatives pertaining to ICT for developers, contractors, and policy makers; Optimization of local building materials usage, and promoting Rand D that geared towards the application of ICT. This study provides fundamental insights for future research in this field aimed at informing the construction industry about the importance of adopting ICT in the construction projects.

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The Construction industry has been witnessed globally to be among the substantial sector of the economy that plays a fundamental role in any countries' social-economic development (Otsil *et al.*, 2024). It contributes significantly to raise the economy by providing infrastructures and other physical structures such as roads, bridges, railways, water projects, sewage systems and different public buildings. It creates an employment opportunities and consequently contribute to the country's Gross Domestic Production (GDP) (Ertuğrul and Pirgaip, 2021). The Tanzania construction industry is among the fastest growing sector encompassing both small and medium; private and public construction and or engineering enterprises/firms working or categorized as contractors and sub-contractors; consultants, merchants, engineers and technicians, suppliers, plants and equipment. Recently, The United Republic of Tanzania has witnessed a steady annual growing in government budget expenditure on new infrastructure development and old maintenance and renovation including residential and commercial real estate, construction of roads, highways, railways, water systems, telecommunications, and air transport networks to name a few. The construction of aforementioned infrastructures has acted as a stimulant for a sustained inflows of investments in the construction industry that contributed to14.4% of the country's Gross Domestic Product (GDP) in 2022 behind agriculture that contributed about 26.9 percent

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of the total GDP (Kajumulo *et al.,* 2024). Despite the significance of the construction industry, it faces numerous challenges including delays, health and safety issues, disputes, corruption and late payments (Mwemezi *et al.,* 2023). Moreover, construction time and cost variations, poor quality of the competed project, occupational injuries and illnesses, low profit gain to contractors. Furthermore, the industry has lagged behind compared to other industries in adopting, integrating and implementing new technologies that has eventually contributed to poor image of the construction sector (Haian *et al.,* 2024). While it is believed that the use of industrialized construction technology has transformed and revolutionized the construction industry by improving abundant project development and management aspects, encompassing design accuracy, effective resource optimization, enhancing collaboration efficiency, streamlining the project workflows, and providing a holistic view of projects, The marginal adoption and application of industrial construction technology has made difficulties to focus on generating smart construction processes integration and automation, procedures, and products and thus failed to generate diverse economic, environmental, and social benefits (Julia *et al.,* 2024). The situation has become more difficulty to move away from conventional construction entailing low manufacturing or construction capabilities mainly for the construction industry made up of a high volume of small and medium construction companies for most n developing countries including Malaysia and Tanzania (Al-Hussein, 2022). Numerous literatures have acknowledged various strategies such as industrialized construction technology (ICT) encompassing off-site construction, prefabrication, pre-assembly, modular construction, factory assembly and other smart construction methods as an emerged and a promising construction methods strategy to address most of the construction industry challenges by speeding up delivery with less time, reducing labor costs, eliminating unnecessary waste and attaining better and improved quality (Menegon *et al.,* 2022). Generally, adopting the ICT have been noted as the best game-changer within the dynamic construction industry (Babatunde and Clinton, 2024). Despite that the ambition for adoption, integrating and successful implementation of industrialized construction technology for emerging country is high, its application, implementation and integrating promptness has been informed to be still lagging, very minimal almost to negligible in developing countries. This has made the construction industry in many places globally to be slow due to difficulties in new technology adoption. However, in developing countries the difficulties and challenges are extreme. Many studies undertaken on ICT have concentrated on identifying the critical factors for enhancing the use, the applicability potentials and implementation of ICT on various construction companies (Al-Hussein, 2022). Even though previous studies have investigated the imperative aspects of ICT in developed countries, there is a lack of similar studies in developing countries focusing specifically on identifying and developing strategies for adoption and integrating ICT to small and medium construction enterprises from developing countries. Thus, this study was conducted to fill this gap. This study employed a mixed-method approach to manifest and investigate the critical success factors for adoption and implementation of ICT from the literature based on Tanzanian construction industry experts through an interview and then develop from the questionnaire interview the strategies to be adopted by SMCE in integrating the ICT. This study aims to expands the body of knowledge regarding the strategies that contribute to enhance application and integrating the industrialized construction technology which may be considered a potential base point for future studies in different contexts and project types. Practically, the study findings can be viewed as a direction that can contribute valuable insights to industrialized construction technology project managers and construction industry stakeholders, policymakers, and researchers facilitating them to development of tailored strategies to accelerate the integration of ICT in the construction sector. Industrialized Construction Technology refers to the use of modern or advanced and automated methods, processes, and equipment in construction activities in the construction industry. It involves the application of modern techniques such as prefabrication, modular construction, robotics and digitalization to enhance efficiency, productivity and quality in construction projects (Meng *et al.,* 2020). The Industrialized Construction Technology (ICT) has long been reported to reshape the construction sector as an effective unconventional construction method with extensive benefits such as reductions in construction cost and time, defects, health and safety risks, environmental impact, increase in predictability, improving efficiency during productivity, it embraces an extensive design flexibility, visualization, it facilitates a collaborative efforts and profitability (Jiawang, 2024). Thus, as recognized by various scholars and following its importance, the ICT needs to be adopted for improvement of industry performance. The concept of ICT in Tanzania like in other emerging countries is not new, although its adoption is still to the infant stage. Various initiatives by government and scholars in Tanzania have attempted to promote the adoption of ICT. It was in 1971 when the government decided to establish the National Housing and Building Research unit (NHBRU) department charged with the responsibility of improving the housing conditions in Tanzania by promoting the construction of decent houses using affordable local building materials and technologies and imparting technical skills to the community on the supreme utilization of local available resources to reduce the construction costs. Later, in 2001 NHBRU was changed to National Housing and Building Research Agency (NHBRA) and charged to facilitate the technological growth of building technology and housing construction techniques (NHBRA, 2017). various initiative to promote the use of ICT includes organizing various meetings where several topics regarding ICT were discussed, publishing various papers including the one that measured the benefits of ICT adopting in Tanzania. Furthermore, in 2010 the private firm was not left behind on the ICT adoption agenda including Africa Prefabs LTD company in Dar es Salaam and Yafei Construction Company, a Chinese firm operating prefabricated houses in Tanzania (Kalokola, 2024). Despite the long history of initiatives since 1970s, (Msilamgunda and Casmir, 2024) observed that the Tanzania construction industry is the guilt of delays in accepting new technology. Therefore, proper strategies are still compulsory to ensure that ICT is adopted and integrated (Msilamgunda; Casmir, 2024).

It is undeniable that the construction industry players do not unconditionally accept innovations. However, as new innovations in construction industry are always being offered to benefit the industry, it is essential to apprehend the factors that could influence or increase the likelihood of adopting the new technologies (Fakhira *et al.*, 2023). Literatures have identified multiple factors necessary to influence the decision to choose, adoption, integrate and implementation of ICT. A study by Al-Hussein *et al*. (2022) acknowledged the initial investment cost for automated machinery, and software systems versus the long-term savings as among the critical and privileged factor when the construction firm intends to adopt and implement the ICT in the construction project (Al-Hussein *et al.*, 2022). Besides, Abioye (2021) stressed that the construction firms needs to establish and justify the initial required cost before embarking to adopt and implement it (Abioye *et al.*, 2021). He argued on the development of the financial models that will help to highlight the long-term economic benefits and a comprehensive scrutiny of the financial consequences, including a potential rate of return on investment. Moreover, training for skill acquisition and employee’s adaptability was mentioned. Lack of capabilities necessary to successfully adopt and deploy ICT by many workers in developing countries was also mentioned. A study conducted by Zhang *et al.* (2021) informed that training and education expenditures are crucial for creating a workforce with the necessary skills to use technologies like Building Information Modeling (Zhang *et al.*, 2021). In the same vein, a study by Wang (2020) admitted several factors hindering the adoption and implementation of ICT. Factors including lack of government incentives, extra costs related to green construction technology (GCTs), dependence towards traditional construction technology, shortage of technological training and conflicts of interest among stakeholders were revealed (Wang *et al.,* 2021). Furthermore, technology awareness and organizational characteristics such as facility, Government involvement in the project, Impact on project duration and quality, readily availability of technology, Impact on data security, presence of external incentives such as from government and construction project expert’s preferences (Fakhira; Rahman, 2021) as well as Management's approach in making decisions, construction project team's previous experience and Communication process (Fakhira *et al.*, 2023) were also revealed from multiple literatures. Ultimately, a study by Qian (2024) cemented on the factors essential for promoting the adoption of ICT factors encompassing unfamiliarity with the technology, limited suppliers, lack of standardized procedures and rules of control, tight timelines that does not allow quality delivery, immature and company’s capabilities on prefabrication products productivity, technical complexity incorporating structural errors, technical delays, maintenance and operations, and assembly processes as well as market factors, were exposed (Qian *et al.*, 2024).

Small and medium-sized businesses (SMEs) have taken the focus point in the private sector, acting as fundamental to the economies of both developed and developing nations as they contribute expressively to the income generation, job creation and development of entrepreneurial skills (Sara, 2014). The scale of an enterprise ranges from micro to large. The global economies have begun to place much emphasis on small and medium-sized businesses. This is mostly due to the fact that efforts to advance economic development by establishing sizable companies have typically not succeeded in improving the quality of life for the vast majority of populations, especially in developing nations (Yahya and Mutarubukwa, 2015). The majority of SMCE owned by the Tanzanian are grounded into seven classes as per Contractors

Registration Board (CRB) of Tanzania based on registration class limit defined by the project's contract value to be tendered (Safa *et al.*, 2015). The class range targets to describe the enterprise capabilities in terms of owned resources and assets. Local SMCE are allowed to register from class I-VII. Foreign firms are allowed to register to only two higher classes (I and II) for civil, building, electrical and mechanical works and to only three classes (I-III) under the specialist contractor group (Tekka, 2021). Conversely, under building construction category, restriction was imposed that class five are limited to construct up to four (4) story structure, class six are limited to three (3) story structure while class seven are strongly restricted not to build any story structure (CRB, 2020).

Most SMCE are confronted with unpredictable and varying business challenges emanating from communication rather to documentation, problems on resources allocation and utilization, failure to access the loan for the project, confronting an exceedingly competitive environment from foreign firms (Khanyisa *et.al.,* 2023), failure to strengthen their operations, market recognition that lead to minimization of profits and hence fail to grow (Tekka, 2021). On top of that, majority of SMCE works in rural and regional locations with poor infrastructure, including expensive and subpar workspaces, communication and transportation networks, serviced land warehouses, power outages with insufficient supply, and unreliable and exorbitant prices (Kazungu *et al.*, 2014). SMCE in Tanzania have been confronted with a serious challenge of failing to adopt and use of modern technology services. The situation has led to SMCE failure to access the new business opportunity and hence failing to stimulate the creativity and innovations as among the most entrepreneurship characteristics. Furthermore, the SMCE are characterized with lack of technical and competent staff, lack of resources, lack of management expert, and information sharing problems as well as shortage of technical and competent labor (Lara *et al.*, 2019). The aforementioned factors have hindered influencing construction technology adoption and delayed the SMCE from ICT adoption and hence continue to attain underperformances and low competitiveness compared to foreign firms (Mohammed *et al.,* 2022)

MATERIALS AND METHODS

Data Collection: Using a quantitative research design, this study determined and assessed the critical strategies (CS) necessary for effective adoption and integration of industrialized construction technology. Two criteria were used in selecting the targeted construction industry professionals: (1) the professional should have occupy theoretical and research experience in construction projects and (2) the professional should have acquired a satisfactory hands-on- skills with enough experience of not less than five years. Two hundred fifty (250) experienced experts in construction projects were used as the sampling frame. In order to gather opinions for the study, a standardized questionnaire consisting of three sections was given to respondents. Part one of the questionnaire aimed to gather the demographic data from the respondent. Part two was meant to get opinions on critical factor for adoption of ICT by SMCE. Part three was purposely intended to gather opinion on critical strategies for adoption of ICT. To show the numerical ranks solely, a 5-point rating Likert scale was opted represented as: 1=not critical, 2=fairly critical, 3=critical, 4=very critical and 5=extremely critical. The questionnaire written in English and translated in Swahili language was distributed on 9^{th},11^{th} and 14^{th} May 2024. The distribution was made through a combination of personal emails by attaching the QR-code and Web link and WhatsApp social network. Following multiple reminders, 159 well attended questionnaires were gathered from respondents within three weeks provided to finish the survey. The study acknowledges that issues with data quality and reliability are key disadvantages for online questionnaire surveys; thus, the risk was considerably reduced by enlisting more registered professionals with extensive practical experience within the construction industry.

Data Analysis: The collected sample data were coded, edited, analyzed, and descriptively analyzed. SPSS was used to conduct several statistical tests comprising construct validity, reliability analysis test, mean score analysis, and significance analysis. Construct validity was executed to measure the extent to which all items on a scale measure the same construct. Data reliability was scrutinized to test the internal reliability of the 5-point Likert scale. The examination intended to check if the questionnaire survey tool provides equivalent results at different sets of tests. Besides, AMOS was used to perform the confirmatory factor analysis (CFA) whose result facilitated to test for a convergent and discriminant validity. However, using SPSS-AMOS, a structural Equation Modelling (SEM) was used to develop the model.

RESULTS AND DISCUSSION

Tables 2 present the descriptive statistics of the respondents' demographic characteristics collected by the survey. The basic information collected in this study includes age, education level, working experience, profession carrier and leadership position. The findings show that the majority of respondents (120=75.4%) were aged between 35 to 45 years followed by (26=16.4%) aged between 26-34 years and minor respondents (13=8.2%) aged between 18-25. This implies that majority of the respondents were mature enough to understand and address issues under investigation. Most of respondents (139=87.42%) are graduates to master's levels. This portray that questionnaires were responded with knowledge people. It also shows that the study opinions were given with people having enough knowledge, skills and understand on construction industry issues. More than three quarters (131=82.39%) of respondents had an experience of more than ten years in the construction industry that made then to have enough understanding of various operations and the challenges facing the industry. Moreover, (50=31.4%) of the sample consists of top management leaders including director and project manager who make up the majority. This suggests that the majority of the viewpoints collected came from people who probably play a big part in the operations and leadership of their firms. Additionally, departments are well-represented, with the most prevalent being engineer (65=40.9%), followed by architects (42=26.4%) and quantity surveying (26=16.4%).

Table 1: Respondent's Demographic Information

Item	Class	Frequency	Percentage (%)
Respondent's Age (Years)	18-25	13	8.2
	26-35	26	16.4
	35-45	60	37.7
	Above 45	60	37.7
Educational Level	Diploma	11	6.9
	Degree	97	61.0
	Masters	42	26.4
	PhD	9	5.7
Working Experience (Years)	0-10	28	17.6
	10-20.	76	47.8
	21-30	29	18.2
	Above 30	26	16.4
Profession	Engineer	65	40.9
	Architects	42	26.4
	Quantity Surveyor	26	16.4
	Surveyor	13	8.2
	Procurement officer	8	5.0
	HR officer	5	3.1
Leadership	Director General /GM	19	11.9
	Project Managers	31	19.5
	Departmental managers	50	31.4
	Foremen/Supervisor	59	37.1

Motivational Factors for Industrial Construction Technology Adoption in Tanzania: In the current research, understanding the motives for adoption and integration of ICT among SMCE was important and a key for the construction industry dramatic change and encouraging the SMCE to embrace adoption of ICT and can help the country achieve the sustainable development goad (SDGs) 9. The relative importance index (RII) equation (1) below was applied to compute and rank the respondent's opinion on the adoption of ICT. The findings (Table 2) below have recognized the drivers motivating the adoption and integration of ICT in the Tanzania construction Industry.

$$\text{Relative Importance } Index\ (RII) = \frac{\Sigma W}{A * N}\ (0 \leq RII \leq 1) \quad (1)$$

Where RII= Relative Importance Index; W = Weighting given to each factor by the respondents (ranging from 1 to 5), A= Highest weight (i.e. 5 in this case), N =Total number of respondents.

The findings (Table 2) have documented that "improvement of construction project quality" was ranked number one with RII 0.777. Number two was given to "lessening the overall construction project time"; RII=0.776 and number three is "ensuring cost saving" with RII=0.766**Table 2**. The ranking difference between rank 1 and 2 is minimal as the two factors can be caused by the fact that poor quality and time overrun are often resulted to cost overrun. Factors M4-M7 has explained the need for efficiency and productivity increases (RII=0.761) on construction projects, the timely decision making due to real-time data collection and analysis (RII=0.746), an increased desire for higher performance from the client's (RII=0.741) as well as the need for attaining the reduced health and safety risks (RII=0.738). The top seven factors were identified by the respondents to facilitate the adoption and integration of ICT in the Tanzania construction industry environment.

Table 2: Factors Motivating the Adoption of ICT

Motivation Factors	Rating Scale					∑W	RII	Rank
	1	2	3	4	5			
MF1- Improvement of construction project quality	12	14	21	45	67	618	0.777	1
MF2- Lessening the overall construction project time	8	16	25	48	62	617	0.776	2
MF3- Ensuring cost saving	10	17	23	49	60	609	0.766	3
MF4- Increase the construction efficiency and productivity	9	17	29	45	59	605	0.761	4
MF5- Enable Real-time data collection, analysis and decision making	12	20	26	42	59	593	0.746	5
MF6- increased client's higher performance demands	14	17	20	59	49	589	0.741	6
MF7- Reducing health and safety risks	13	27	19	37	63	587	0.738	7
MF8- Lowering construction material waste	20	19	36	31	53	555	0.698	8
MF9- Ensuring environmental construction sustainability	20	21	42	48	28	520	0.654	9
MF10- Lowering labor shortage and skilled gap	36	19	38	35	31	483	0.608	10
MF11- Improved teamwork, communication and information flow	29	37	31	38	24	468	0.589	11

Manifested Critical Strategy: various strategies to assist in adoption of ICT by SMCE were identified and manifested from various literatures. Initially on strategies data analysis, SPSS-24 was chosen to calculate the Cronbach's alpha coefficient test in order to measure the reliability and or internal consistency of the identified dimensions The computed Cronbach's alpha coefficient yielded the value (Table 3) within the acceptable threshold value of 0.7 (Tavakol; Dennick, 2011). However, all item had a homogeneity index significantly of above 0.2; neither item was removed. Secondly, the Kaiser-Meyer-Olkin (KMO) was computed using the Principle Component Analysis (PCA) method to measure the Sample adequacy. The findings exposed the chi-square of approximately ($\chi 2$ =2173.85), (DF=796.5) and KMO (0.842) and $p < 0.01$ for the significance of Bartlett's test of sphericity. The model saturated have explained 78.13% of the total variance, corresponding to the dimensions defined a priori. The result designates a non-identical correlation matrix which recommends the appropriateness of the samples for factor analysis (Theodoros, 2018). Thus, the mean indexes (μi) for every critical strategy were computed using the provided equation (2).

$$\mu_i = \frac{\sum(S * F)}{N}, (1 \leq \mu_i \leq 5) \quad (2)$$

Where S signifies a score assigned to each critical strategy (CS) ranging from 1 to 5 (1=Not critical to 5=Extremely critical); F symbolizes the frequency for each CS rating from (1–5) and N represents the total number of responses for a given CS. However, the mean indices interval scale was used to easier interpretation: μi ≤ 1:4 defined "not critical"; 1:5 ≤ μi ≤ 2:4 defined "fairly critical; 2:5 ≤ μi ≤ 3:4 defined "critical; 3:5 ≤ μi ≤ 4:4 defined "very critical; and μi ≥ 4:5 was considered "extremely critical (Osei-Kyei and Albert, 2017).

Furthermore, the Relativity Index (RI) for each CS was calculated so as to develop the unity-based normalization of the mean indices. The computed RI intended to help to rank the CS with higher relative weights. Equation (3) below was opted to compute the unit of the sum of the mean indices which were compared to the mean indices of all the CSF (Ibrahim *et al.*, 2020)

$$RI_i = \frac{\mu_i}{\sum_{i=1}^{N}(\mu_i)} \quad (3)$$

Where: RI represents the relative weightings of each CS; N represents the number of CS and μi symbolizes the mean index of the CS.

Besides, the significance index (Si) of every CS was computed using equation (4) below. The linear fuzzy linguistic alternatives of the 5-point grading scale (1–5) used in measuring the CS in the questionnaire were transformed to a percentage scale ranging between 20 to100 with 20 representing the lowest and 100 the highest significance. However, the significance indices of 20, 40, 60, 80 and 100 where correlated to "1," "2," "3," "4" and "5" Likert scale values respectively (Zhang, 2005)

$$Significance\ index\ (Si) = \frac{1 * R_{i1} + 2 * R_{i2} + 3 * R_{i3} + 4 * R_{i4} + 5 * R_{i5}}{R_{i1} + R_{i2} + R_{i3} + R_{i4} + R_{i5}}$$

$$= \frac{20 * R_{i1} + 40 * R_{i2} + 60 * R_{i3} + 80 * R_{i4} + 100 * R_{i5}}{R_{i1} + R_{i2} + R_{i3} + R_{i4+} + R_{i5}} \quad (4)$$

S_i represent the significance index for the i^{th} Critical strategy; R_{i1} symbolize the number of responses for the grading alternative "1" for the i^{th} CS; and Ri5 represent the number of responses for the grading alternative "5" for the i^{th} CSs. Generally, the scores form the foundation for ranking the CSs to be adopted and integrating the industrial construction technology.

The findings) indicates the three computed indices namely; the mean score index (μ_i), the significance index (S_i) and the relativity index (R_i). The findings of the mean score after analysis have produced the indices values greater than 3.0 on the 5-point Likert scale adopted. Referred on the previous definition of the fuzzy linguistic variables (e.g. 3 5 critical) of the 5-point Likert scale, all attained critical strategies (Table 3were considered critical.

Table 3: Critical strategies for Adoption of ICT

Code	Critical Strategies	MI	STD	RI	SI	RA
CS1	Promoting the use of BIM to enhance collaboration and ease communication between project participants.	3.97	0.94	0.121	78.34	1
CS2	Developing educational and training initiatives pertaining to ICT for developers, contractors, and policy makers.	3.85	0.83	0.118	77.62	2
CS3	Optimization of local building materials usage	3.77	1.02	0.117	77.48	3
CS4	Promote Rand D that geared towards the application of ICT.	3.70	0.89	0.114	77.13	4
CS5	Provide low-cost loans and government financial/grants supports on ICT adoption and implementation.	3.69	0.93	0.113	77.09	5
CS6	Conducting capacity building to develop the ICT skilled workforce.	3.64	0.86	0.111	76.82	6
CS7	Focusing on sustainability and environmental Impact.	3.56	0.90	0.110	76.81	7
CS8	Providing better information on cost benefits analysis before ICT adoption.	3.51	0.81	0.108	76.38	8
CS9	Acknowledging and rewarding professionals who are ICT pioneers.	3.72	0.93	0.107	75.91	9
CS10	Establishing construction technology transfer and development centers.	3.82	1.00	0.105	75.23	10
CS11	Promoting industry alliances and collaboration to have a joint programme.	3.47	0.85	0.102	75.02	11
CS12	Developing obligatory policies and regulations to enforce adoption of ICT	3.75	0.87	0.101	74.67	12

Note: STD= Standard Deviation; RI= Relativity Index; SI=Significance Index; RA= Ranking

Small and Medium Construction Enterprises (SMEs) in Tanzania face significant challenges in adopting and integrating Industrial Construction Technology (ICT), which could help enhance efficiency, reduce costs, and improve project delivery times. The findings of the study (Table 3) have admitted that, for effective adoption of ICT in Tanzania's construction sector, the SMCEs should develop the critical strategies that focus on improving access to financing, upgrading skills, and promoting a favorable regulatory environment. The first ranked critical strategy is to promoting the use of BIM to enhance collaboration and ease communication between project participants (M=3.97, RI=0.121, SI=78.34); followed by developing educational and training initiatives pertaining to ICT for developers, contractors, and policy makers (M=3.85, RI=0.118, SI=77.62); and Optimization of local building materials usage (M=3.77, RI=0.117, SI=77.48); as well as promoting Rand D that geared towards the application of ICT (M=3.70, RI=0.114, SI=77.13). The findings concur with the study by Marceau and Mustafaa (2020) who cemented that training for upskilling the workforce in new technologies, creating a conducive regulatory environment, cooperation between academic research institutions, technology suppliers, and construction companies as well as focusing on sustainability and environmental impact can lead and facilitates the development of tailored ICT solutions (Marceau and Mustafaa, 2020). Providing low-cost loans and government financial/grants supports on ICT adoption and implementation was ranked the fifth with (M=3.77, RI=0.117, SI=77.09). The provision of financial support tailored to SMCEs was identified among the critical strategies to help them overcome the barrier of high initial costs associated with ICT adoption. The Tanzanian government and financial institutions can offer low-interest loans, grants, and subsidies to encourage the purchase of modern construction equipment, as well as to help SMCEs invest in training programs for their workers. Such financial schemes could ease the burden of high upfront costs and allow SMCEs to incorporate technologies like Building Information Modeling (BIM), prefabrication, and robotics into their operations (Walid *et al.*, 2023). In addition, SMCEs can collaborate with larger firms or international companies that have the financial resources and technical expertise to introduce ICT solutions, enabling knowledge transfer and partnership-based growth in the sector. Moreover, Capacity building and the development of a skilled workforce was the sixth ranked critical strategy scoring MI=3.64, RI=0.111 and SI=76.82) towards promoting the adoption of ICT among SMCEs in Tanzania. SMCEs in Tanzania often face challenges related to a lack of skilled labor capable of operating advanced construction technologies. To address this, educational institutions, professional training organizations, and construction industry bodies need to offer specialized courses and certification programs focused on industrialized construction methods. Public-private partnerships could be formed to establish training centers where workers can gain hands-on experience with ICT tools such as BIM, 3D printing, and prefabrication techniques. Additionally, SMCEs could form alliances with technology providers to offer on-the-job training to workers, which would reduce the learning curve associated with new technologies. The last six critical strategies mentioned to be opted to facilitates adoption of ICT encompasses focusing on sustainability and environmental Impact (M=3.56, RI=0.110, SI=76.81), recognizing and rewarding professionals who are ICT pioneers (M=3.72, RI=0.107, SI=75.91), establishing construction technology transfer and development centers (M=3.82, RI=0.105, SI=75.23), sustainability and environmental Impact (M=3.56, RI=0.110, SI=76.81), Promoting industry alliances and collaboration to have a joint programme (M=3.47, RI=0.102, SI=75.02), and Developing obligatory policies and regulations to enforce adoption of ICT (M=3.75, RI=0.101, SI=74.67).

It is clearly noted that, creating a conducive regulatory environment is essential for the successful adoption and integration of ICT in Tanzania’s small and medium construction enterprises. The government plays a key role in fostering an environment where SMCEs can operate efficiently and adopt modern construction methods. One strategy is simplifying regulatory processes related to the use of new construction technologies, such as building codes and permits. For example, the Tanzanian government could create fast-track approval processes for projects that use industrialized construction technologies, incentivizing SMCEs to adopt these methods. Additionally, policies that encourage research and development (Rand D) within the construction sector, such as tax breaks or innovation funds, would support the growth of ICT and the wider construction ecosystem.

Conclusion: This study has established twelve critical strategies required for adoption of ICT by SMCE encompassing the use of BIM to enhance collaboration and ease communication between project participants, developing educational and training initiatives pertaining to ICT for developers, contractors, and policy makers, optimization of local building materials usage, promoting R and D that geared towards the application of ICT, providing low-cost loans and government financial or grants supports on ICT adoption and conducting capacity building to develop the ICT skilled workforce. This study provides a theoretical importance of recognizing the motivational factors and practically establishing an exclusive framework of critical strategies desired for adoption and integration of ICT by SMCE to improve the construction industry performance. This study recommends the future needs of the study to develop the structural model to indicate the correlation and interdependences between the identified critical strategies.

Declaration of Conflict of Interest: The authors declare no conflict of interest

Data Availability: Data are available upon request from the corresponding author

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