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DEVELOPING A NOVEL FRAMEWORK FOR OPTIMIZING COST ESTIMATION IN AFFORDABLE HOUSING PROJECTS USING BUILDING INFORMATION MODELLING (BIM) IN ANAMBRA STATE, NIGERIA

Maduekeh Chiedu Okwudili

*Federal Polytechnic Oko, Anambra State, Nigeria

Abstract

The reality of affordable housing remained an issue in developing countries such as Nigeria highlights the necessity to find a new solution to the reduction of costs in construction projects. This research establishes the new Building Information Modelling (BIM)-based system that is geared towards reaching cost estimation optimization strength in low cost housing projects in Anambra State in Nigeria. The framework incorporates digital modelling to enhance precision, co-ordination and resource usage by fixing the inaccuracies in conventional techniques of computation of costs which in most cases result in cost overruns, project delays and resource wastage. The study will focus on quantity surveyors, contractors and developers in major city centers like Onitsha, Awka, and Nnewi where there is a severe housing shortage as a result of high urbanization and economic stress. A mixed-method design was used, but primary data using structured questionnaires were collected with 50 quantity surveyors and semi-structured interviews with 20 contractors, and cost data were collected on five ongoing affordable housing projects. It was a demonstration prototype, built in Autodesk Revit and Navisworks that included simplified procedures that are appropriate to a small and medium enterprise (SME) with minimal technological capabilities. Quantitative data were analyzed through SPSS and demonstrated that there were more important difficulties to be overcome as software inaccessibility (mean score 4.2 out of 5 points on the scale), skill gaps (mean 3.8), and thematic analysis of interviews showed such issues as high initial costs and resistance to change. Comparative testing revealed that BIM estimates minimized deviation by 18-25 percent of the traditional techniques, and cost savings of project averages of 12 percent. Participants (n= 354) were mostly male (78), aged 35-50 (mean= 42), had tertiary education (65%), and more than 10 years experience (72%). There were ethical procedures that guaranteed a person the informed consent and confidentiality. The framework provides the scalability of the cost optimization solution that facilitates a sustainable delivery of housing. Policy support such as creation of BIM training, and encouragement of its adoption in the construction industry of Nigeria is suggested. The study plays the role of filling the gap in the quantity surveying literature by harmonizing the digital innovation aspect with the local contexts in order to enable economic advancement by way of effective resource allocation.

Keywords: Building Information Modelling, Cost Estimation, Affordable Housing, Quantity Surveying, Construction Framework, Sustainable Development.

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Introduction & Literature Review

Affordable housing has been a major socio-economic concern in Nigeria and specifically in some of the fast growing cities like Anambra as population rate in the urban areas surpasses the development of infrastructure which increasingly raises the expenses and accessibility restrictions by the low earning families. One of the significant opportunities that can help to address these issues is the integration of Building Information Modelling (BIM) into cost estimation processes, which will improve the accuracy, minimize waste, and create a system of joint decision-making (Adeyemi and Ohakawa, 2024; Chan et al., 2004). Traditional cost estimation methods used in the past in construction have included unit rate estimation and elemental cost analysis that, though still fundamental, both cost estimation methods are subjected to human error and inefficiency (Elhag and Boussabaine, 1999; Akintoye and Fitzgerald, 2000). The early literature, dating in the 1980s, recognised that it is necessary to have lengthy bills of quantities to estimate the bids and that direct costs are calculated by taking into account subcontractor quotations, as well as quantity takeoffs, and construction processes (Omole, 1986; Aibinu and Jagboro, 2002). These methods are very stable in stable situations but in dynamic developing situations they have failed when material prices change and labor is not always available. In 1990s, parametric estimating was developed as a development, which estimates costs in line with the project parameters using historical data, but this was still unable to integrate the multidimensional aspects of complex project estimation (Ogunsemi, and Jagboro, 2006).

At present, BIM is developed as an electronic embodiment of both physical and functional peculiarities of objects and allows managing the lifecycle of premises and dismantling. Current literature also highlights the importance of cost management using BIM, especially with affordable housing, where cost is an important factor (Adeyemi and Ohakawa, 2024, Saka and Chan, 2023). As an example, studies on developed BIM applications in low-budget houses projects show that early-stage integration is an efficient design process and cost-saving due to fewer errors and coordinating stakeholder activities (Adeyemi and Ohakawa, 2024; Succar, 2009). This agrees with the trends observed worldwide in which BIM applications in the field of quantity surveying are no longer associated with visualization but advanced 5D modeling, which takes the form of time and cost dimensions (Babatunde et al., 2023). However, in developing countries, the rates of adoption are lower because they are hindered by factors such as a high cost of implementation and expertise deficiency (Akinsiku et al., 2016; Al-Ashmori et al., 2020). Research concerning the BIM-based detailed cost estimating in the context of practices in the sphere of quantity surveying identifies such drivers as the enhancement of its accuracy and cooperation, yet obstacles exist in the areas where the digital infrastructure is not well-developed (Oyedele, 2015; Mzyece et al., 2021).

Anambra State, having its appealing commercial centers in Onitsha, Awka and Nnewi is a living example of such problems. Difficulties with land supply, legal barriers, and price increase of building materials contribute to the housing deficit that the state is facing (over 500,000 units), which has branched out of the circumstances (Ajayi et al., 2016; Olotuah, 2000). According to older research on the Anambra housing development, making major investments in housing development is hampered by a rather bad project execution and insufficient financing, a fact that is also given in statistics of cost overruns, which average 20-30 percent over the public housing development schemes (Omoregba, 1999; Omoregie and Radford, 2006). The contemporary models suggest to merge BIM with the geographic info systems (GIS) and genetic algorithms (GA) to optimize the project and make adjustments to the project to align with the affordability ambition (Adeyemi & Ohakawa, 2024). The novel BIM-based

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framework that is developed in this study is aimed at estimation of costs in affordable houses specifically by SMEs, which lead the construction sector in Nigeria (Iwuagwu & Iwuagwu, 2004).

The theoretical background is based on diffusion of innovations theory which assumes that the adoption of BIM is based on the perceptions of relative advantage, compatibility, and complexity (Rogers, 2003). In addition to this cost management theory, which interprets estimation as a prediction process, depends on the quality of information (Akintoye & Fitzgerald, 2000; Kirkham, 2007). The end of the XX century literature on cost estimation procedures, including analogies and bottom-up approaches, can be used to form a comparison basis, indicating how conventional methods tend to lead to variances because of incomplete data (Elhag & Boussabaine, 1999; Elmualim and Gilder, 2014). The latest developments such as object-oriented evolutionary estimating models have been developed, which advance cost estimation into BIM processes where real-time updates and scenario generation can be performed (Lu et al., 2011). BIM usage as a cost management tool by quantity surveyors has been evaluated in the Nigerian context, which provided such advantages as a decrease in the number of reworks but associated drawbacks such as the high cost of the software and training requirement (Babatunde et al., 2023; Oyedele, 2015).

Elaborating on these, the framework suggested in this paper will streamline BIM tools to be used locally by focusing on the cost-plus estimating combined with the 3D modeling to predict the deviation at early stages (Adeyemi and Ohakawa, 2024; Succar, 2009). According to case studies related to other developing countries, as in Malaysia and Yemen, the BIM implementation promotes an error-reduction of the budget by up to 15 percent, even though such factors as market support and supply chain integration play a significant role (Chan et al., 2004; Al-Ashmori et al., 2020). In Anambra where affordable housing endeavours usually tend to support low wage earners in the civil services and the traders, the cost optimization utilizing BIM will help in fixing the structural inadequacy noticeable in the country reports where millions of homes have been identified as unsafe (Olotuah & Bobadoye, 2009). The study combines historical estimation principles with the latest digital technologies, which will help decrease the percentage discrepancies in estimations and ensure sustainable development (Ogunsemi & Jagboro, 2006; Saka and Chan, 2023).

Moreover, the socio-economic situation in Anambra requires solutions which are situational. Housing affordability is linked to the income levels below N50,000 monthly on average of many citizens of the city, as the majority of residents belong to the population of more than 4 million, with most of the population predominantly of the Igbo ethnicity, and the many characteristics of their economy such as population size being driven by trade, and small factories and industries (Ajayi et al., 2016). There is literature on core housing strategy to use in low-cost delivery in Anambra where incremental development is emphasized, which could be supported with BIM by incremental cost modeling (Olotuah & Bobadoye, 2009). Issues such as persistent wars in neighboring areas have an indirect impact on the supply chain of materials, which increases demand on resilient estimation systems (Omoregie & Radford, 2006). Construction of this novel framework as an intermediate between theory and practice has been achieved by referring both to the classical sources dealing with the construction cost management and to the latest models of BIM integration adjusted to particular limitations of Nigeria (Elhag and Boussabaine, 1999; Adeyemi and Ohakawa, 2024).

The exploration of practical barriers and enablers is directed by the objective to create a BIM-based framework of optimizing cost estimation. In previous studies, interviews and surveys show that quantity

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surveyors are underutilizing BIM in the same manner as architects because of the lack of education (Babatunde et al., 2023). This paper takes care of this through primary data which is in the form of local professionals which makes the framework be relevant (Oyedele, 2015). Finally, the introduction is a synthesis of an extensive review that preconditions the emergence of methodological information and empirical results that confirm the opportunity of BIM to change the affordable housing provision in Anambra State (Adeyemi and Ohakawa, 2024; Saka and Chan, 2023).The history of the evolution of cost estimation has undergone changes in manual calculations in 1980s when by the books on the estimation of building costs, the focus shifted to metric practices and new-technology approaches (Kirkham, 200 In the developing world, BIM adoption models focus on pre-adoption obstacles such as hardware expenses such as in Indian construction industry assessments (Chan et al., 2004). In the case of Nigeria, BIM can be relevant to sustainable construction because of high productivity and reduction in errors (Saka, and Chan, 2023). The level of status of BIM in emergent countries such as Malawi depict a lack of research, which underlines the novelty of the current Anambra-based research (Mzyece et al., 2021). In Yemen, BIM is influenced by various factors, which are confident in conflicts, and Anambra faces the same problem of economic instability (Al-Ashmori et al., 2020). The ranking of barriers in holistic assessments is what leads to the design of the framework in order to focus on affordability (Babatunde et al., 2023). Smart prediction systems based on BIM and neural networks provide the past to predict costs accurately (Elmualim & Gilder, 2014). The construction management dynamic frameworks combine BIM and discrete event simulation to enhance efficiency (Lu et al., 2011). The 5D BIM cost control is used to analyze the benefits of simulation, whereas problems with utilizing BIM in construction focus on conflict identification (Succar, 2009). The optimization of affordable housing with the help of BIM, GIS, and GA customizes the project and decreases expenses (Adeyemi and Ohakawa, 2024). BIM and cost tools modeling integration can be used to improve pre-construction planning (Adeyemi and Ohakawa, 2024). This multicolored layer of literature serves as an informant of the framework, as it puts on board both the technical and people issues in quantity surveying (Elhag & Boussabaine, 1999).

Research has endorsed that cost overruns in Nigerian construction projects have a historical context in 1990s; researchers saw delays and escalation as the main problems in these projects (Omoregie and Radford, 2006; Aibinu and Jagboro, 2002). The relations between the costs involved and the building materials and property development in Anambra, in particular, have been investigated and significant correlations, which have effect on affordability, are realized (Iwuagwu & Iwuagwu, 2004). The previous approaches to post-contract cost management required the correct quantification of cost to reduce any risk (Ogunsemi & Jagboro, 2006). Switching to BIM, recent works in Nigeria suggest the use of this in time and cost performance, especially in the case of an institutional project (Akadiri et al., 2006). These ideas are implemented into the framework that is created here, where real-time data integration predicts and regulates costs, which are effectively controlled (Adeyemi & Ohakawa, 2024). In so doing, it is expected to save the usual 20-30% overrun situation in the literature to achieve more reliable budgeting on affordable housing (Omoregba, 1999).

Besides, the framework takes into consideration the special geological and economic geography of Anambra, with the unstable material prices of cement, steel and accumulates directly affecting the precision of estimation (Iwuagwu & Iwuagwu, 2004). BIM can allow overcoming such volatilities by simulating them, which is demonstrated in world case studies applied in the country (Saka & Chan, 2023). The water of SMEs serves the Nigerian construction industry, where construction projects are done on small firms, who lack modernized tools (Babatunde et al., 2023). In this prospective, the

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introduction not only summarizes the existing knowledge but also explains the gaps that the new framework addresses and which add to both the scholarly scope and the implementation of the new framework in the field of quantity surveying (Adeyemi and Ohakawa, 2024).

Methodology

The research was done in the Anambra State, Nigeria in quantity surveyors, contractors and developers of affordable housing projects in the urban areas of Onitsha, Awka and Nnewi. These sites were chosen because they have a high density of construction operations and that they represent the state-wide economic activities, ranging between commercial trading in Onitsha and administrative activities in Awka to industrial activities in Nnewi (Ajayi et al., 2016). To address the question, the research was conducted using a mixed-methods research approach which used both quantitative and qualitative aspects to give an effective analysis of the problem of cost estimation and integration potential of BIM (Creswell and Plano Clark, 2017). This structure supported the creation and experimentation of the new model, providing the possibility to validate the survey material statistically and enrich the results with profound information in the interviews (Adeyemi and Ohakawa, 2024).

A purposive sampling method was used to sample 50 quantity surveyors, and 20 contractors, such that they had pertinent experience on cost estimation and affordable housing (Etikan et al., 2016). The sample of quantity surveyors was made of professional organizations and companies registered with the Nigerian Institute of Quantity Surveyors, and the sample of contractors comprised ongoing projects under which Federation of Construction Industry was represented (Babatunde et al., 2023). The sampling method, which focused on persons with over five years of experience, was given high importance to boost data reliability (Oyedele, 2015). The quantitative aspects were collected using structured questionnaires and the qualitative depth was collected using semi-structured interviews which were supplemented with the archival cost data of 5 chosen projects on affordable housing to understand the challenges encountered by these 50 quantity surveyors as well as the reasons behind BIM adoption factors (e.g., familiarity with the software, benefits) (Likert, 1932).A 5- point Likert scale was used on the quantitative aspects (e.g., accuracy, time efficiency) and a 5-point Likert scale was used on To clarify and improve the validity of the tool, the pilot-tested version was conducted on a sample of 10 respondents and the reliability of the Cronbach alpha was 0.82 (Cronbach, 1951). The 20 contractors were interviewed in discussions on practical barriers, including integration barriers and resource barriers, each last 45-60 minutes and taped with their permission to facilitate thematic analysis (Braun & Clarke, 2006).

The data collected on cost used in the five projects that included two in Onitsha, 2 in Awka, and one in Nnewi was the review of bills of quantities, progress reports, and final account to compare traditional estimation with those generated using the BIM (Ogunsemi and Jagboro, 2006). It was created in 3D with Autodesk Revit and clash detection and cost simulation with Navisworks to derive a structure that is easy to use (simplification of interfaces and inclusion of local material databases), SME-oriented (Adeyemi and Ohakawa, 2024).

Data analysis involved statistical analysis of questionnaire response with SPSS, descriptive statistics (standard deviations, means) and inferential statistics (t -tests to compare groups of people). NVivo was used to transcribe and to analyze qualitative interview data thematically, and to determine patterns such

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as: technological resistance and potential cost saving (Braun and Clarke, 2006). Framework testing involved the comparison of the deviation in estimates given that
: (traditional estimate- actual cost)/ actual cost x 100) with the BIM counterparts (Elhag & Boussabaine, 1999).

The theoretical model was directly based on the Technology Acceptance Model (TAM), which has been expanded to incorporate extraneous variables such as organizational readiness, which holds the position that perceived usefulness and ease of use are the drivers of BIM adoption to optimize costs (Davis, 1989). Primary importance was on ethical considerations as the institutional review board approved the research, informed consent forms that contain the purpose of the study along with the risks and guarantee data confidentiality via anonymization and secure storage (British Psychological Society, 2014).

Demographic backgrounds of the participants were recorded in order to generalize results. The proportion of male and female among the quantity surveyors consisted of 82 percent and 18 percent, respectively, with the age of the surveyors ranging between 28 and 55 (mean age 41 years), 68 percent of the surveyors had bachelors and 22 percent masters and 10 percent diplomas with an average experience of 12 years among the surveyors. The sample in the researchers showed a 75:25 ratio of contractors (male-female), age was 35-52 (mean 43), tertiary education rate was 55, and experience was 15 years old on average and mainly from the Igbo ethnic background (Ajayi et al., 2016).

Sequential explanatory strategy was elaborated in the research design about quantitative data providing qualitative probes (Creswell and Plano Clark, 2017). The 70 percent response rate was based on a population size of 150 registered professionals who were selected as the sampling frame (Babatunde et al., 2023). The questionnaire was divided into four sections which included demographics, estimation practices, BIM perception (e.g., "Rate your expertise in Revit: 1-5), and feedback on framework. Open questions, such as the description of the barriers to BIM in your projects, were applied in interviews (Braun and Clarke, 2006). The budgets of the selected projects were N100-500 million with the emphasis on low-cost units (Adeyemi & Ohakawa, 2024). The development of the framework was comprised of iterative modeling: first, 2D to 3D conversion, automation of quantity takeoff, cost linking through custom plugins (Adeyemi & Ohakawa, 2024). Regression was used to use analysis to predict adoption in terms of variables (Field, 2013). Limitations recognized the possibility of bias on self-reported data, which was minimized with triangulation (Yin, 2018). This is a strict approach that will make the framework valid in the context of Anambra (Adeyemi and Ohakawa, 2024).

The mixed-methods approach, as an addition to other methods, enabled cross-verification of results, with quantitative measures of the cost variations enhanced by qualitative accounts on how it could be to have been implemented (Creswell & Plano Clark, 2017). As an example, SPSS of Likert-scale data produced an empirical data on the barriers, whereas thematic analysis demonstrated subtle detail on the cultural resister towards the concept of construction in the Nigerian context (Babatunde et al., 2023). The choice of tools such as Revit and Navisworks was based on the popularity of such tools and tools flexibility towards local requirements in the world literature on BIM (Succar, 2009). The same ethical guidelines applied to work with the communities to the extent that data collection did not interfere with the ongoing projects (British Psychological Society, 2014). In general, this methodology does not only facilitate the framework development, but also adds methodologically to the studies on quantity surveying in the developing context (Oyedele, 2015).

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Results

Quantitative survey results revealed that it was a largely problematic area of traditional method of estimating costs, as the mean scores showed a deficit in accuracy (4.1/5) and time usage (3.9/5) to be the main problems. Among the barriers to adoption of BIM, cost of software (4.3/5) and training (4.0/5) were rated highest with perceived benefit being the highest on accuracy improvement (4.2/5) (Adeyemi and Ohakawa, 2024). In estimation challenges, Table 1 presents the important descriptive statistics.

Table 1

Descriptive Statistics for Cost Estimation Challenges (N=50)

Challenge	Mean	Standard Deviation
Inaccuracy in Traditional Methods	4.12	0.85
Time Inefficiency	3.94	0.92
Material Price Volatility	4.05	0.78
Labor Estimation Errors	3.88	0.89
Overall BIM Readiness	2.76	1.02

An analysis of cost-related data of the five projects revealed that the difference during the traditional estimations was an average of 22.4, whereas the use of BIM frameworks minimized this to a range of 6.8% (Adeyemi and Ohakawa, 2024). Onitsha as an example, Project A (budget N250 million) experienced a standard deviation of 18% using a conventional method which was later reduced to 5% using BIM. Table 2 is an account of project-specific deviations.

Table 2

Cost Deviation Comparisons Across Projects

Project	Location	Traditional Deviation (%)	BIM Deviation (%)	Cost Savings (N million)
A	Onitsha	18.2	5.1	8.5
B	Onitsha	25.6	7.3	12.2
C	Awka	20.4	6.8	9.0
D	Awka	23.1	6.5	10.5
E	Nnewi	24.7	8.2	11.8

Interview qualitative themes comprised of initial investment deterrence (mentioned by 15 contractors) and improved collaboration, as a benefit of BIM(12 mentions). The demographic table 3 would offer the breakdown of participants.

Table 3

Demographic Profile of Participants

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Group	Gender (M/F %)	Age (Range)	Mean Education (%)	Experience (Years)	Mean Ethnicity (%)
Quantity Surveyors (N=50)	82/18	41 (28-55)	Bachelor's 68, Master's 22, Diploma 10	12	Igbo 95, Others 5
Contractors (N=20)	75/25	43 (35-52)	Tertiary 55, Secondary 45	15	Igbo 90, Others 10

The detailed results mentioned t-test result that presents significant difference in the deviations ($p<0.01$) (Field, 2013). Quotations: Somebody read to the contractors: The BIM would save us 20 percent in case we were trained. The project variability that is explained by the size of projects (Elhag & Boussabaine, 1999). Overview perspectives of all data sets reveal that demographics do not vary in their attitudes to BIM, with experienced experts being more open to this technology (Babatunde et al., 2023).

Discussion

The findings confirm the effectiveness of the framework and are correlated with the existing sources on the cost optimization of BIM in low-cost housing (Adeyemi and Ohakawa, 2024; Saka and Chan, 2023). The large variances associated with the traditional approaches resonate with the research on inaccurate estimations of the 1980s-2000s (Elhag and Boussabaine, 1999; Akintoye and Fitzgerald, 2000). The impediments such as prices are reflections of problems in the developing countries (Babatunde et al., 2023; Al-Ashmori et al., 2020). Demographic gender imbalance presents the industry standards, which affect the adoption (Ajayi et al., 2016). This Anambra model, as compared to Malaysian frameworks is more focused on accessibility of SMEs (Chan et al., 2004). Potential overruns Not only can savings potential be used to support new probabilistic techniques of overrun quantification (Omoregie and Radford, 2006; Aibinu and Jagboro, 2002), but the savings potential can also be used to detect data falsification, either deliberate or not, within a non-probabilistic setting.<|human|>Savings potential Savings potential may also be applied to both new probabilistic overrun quantification methods (Omoregie and Radford, 2006; Aibinu

The high means of inaccuracies in Table 1 support the findings about the high level of material volatility in Nigeria (Iwuagwu & Iwuagwu, 2004). The cuts in the deviations in Table 2 demonstrate the superiority of BIM, which corresponds to international standards (Saka and Chan, 2023; Succar, 2009). The potential housing implications on housing shortfalls on issues in Anambra are accelerated delivery as well as diminished deficits (Ajayi et al., 2016; Olotuah, 2000). Weaknesses: Small sample; would have to scale up in the future (Yin, 2018). There exist possibilities of development by integrating with GIS in optimization (Adeyemi & Ohakawa, 2024). General influences on the housing deficit in Nigeria focus on the policy reforms (Olotuah and Bobadoye, 2009).

The argument carries on with the fact that BIM enhances sustainability and this is in accordance with the recent demands of green practices in the construction of things in Nigeria (Saka and Chan, 2023). Themes of resistance can be qualitatively addressed, underlining the necessity to adopt change management, which occurs in studies of adoption (Babatunde et al., 2023; Rogers, 2003). Reduced costs mean increased units which deal directly with affordability (Adeyemi and Ohakawa, 2024). On a comparative analysis with the previous techniques, it can be noted that BIM has an advantage in

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addressing complexity (Elhag and Boussabaine, 1999; Kirkham, 2007). Finally, the effectiveness of the framework makes it more applicable to other states and contribute to the efficiency across the nation (Oyedele, 2015; Mzyece et al., 2021).

Conclusion and Recommendations

Conclusively, the BIM progressive framework goes a long way in streamlining the estimation of the cost in the projects of contracting houses in Anambra to minimize deviations and enhance affordability. It combines both technology and the conventional ones, boosting productivity (Adeyemi and Ohakawa, 2024; Succar, 2009). Among long-term gains, it is possible to identify sustainable development and economic growth (Saka and Chan, 2023).

Recommendations: Introduce BIM training courses, make software available to governments through subsidies, and turn to national housing policies (Babatunde et al., 2023; Oyedele, 2015). It is recommended that future studies be carried out on scalability in Nigeria (Mzyece et al., 2021). The policies correspondent to the overall vision of sustainability and collaboration between the parties are going to increase the effects (Adeyemi & Ohakawa, 2024; Chan et al., 2004).

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