Texila International Journal of Management
ISSN: 2520-310X
DOI: 10.21522/TIJMG.2015.11.02.Art006

Project Management Information Systems (PMIS) Effect on Sustainability Assessment and Management: A Case of Construction Companies in the Greater Accra Region of Ghana

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Abstract

This study explores the application of Project Management Information Systems (PMIS) for sustainability assessment in Ghanaian construction companies. Construction activities significantly impact the environment, peoples and places and effective PMIS may facilitate their sustainable practices. The research aims to evaluate the effectiveness of PMIS use in sustainable construction project management by adopting a document review approach. A thorough review of 252 construction companies using probability random sampling and convenient sampling in the greater Accra regional area is conducted. With these documents, 211 of them integrated PMIS in their project sustainable management plan, focusing on its role in enhancing transparency, accountability, and decision-making. The resulting data is analyzed with the application of Odd Ratio Test, Relative Risk, Sensitivity analysis, Specificity analysis and chi square test of independence. The results revealed that PMIS tools adoption is not related to project sustainable management success in greater Accra region even though, it significantly improves data accuracy and timelines, enabling a proactive sustainable monitoring and reporting, timely identification and the mitigation of adverse effects. The study concludes that although, the strategic use of PMIS can contribute to sustainable construction practices as suggested by the relative risk value (RR=0.8494), ultimately supporting the achievement of sustainability goals, its use is not related to the successful assessment and management of construction projects in the greater Accra region of Ghana since the chi square test statistic of 7.716 is less than the critical statistic of 18.301at p = 0.05.

Keywords: *Compliance, Environment, Implementation, Sustainable Practice.*

Introduction

The construction industry significantly impacts people and the environment, contributing to pollution, resource depletion climate change and societal issues in terms of both benefits and loses. These are pressing concerns and effective project management is crucial to mitigate these effects and achieve the benefits for sustainable development [1-4]. Over the years, the construction industry has faced challenges in assessing and managing sustainability due to its perceived expensiveness to implement [5] and poor end-user perceptions of the project deliverables [6] by stakeholders together with inadequate stakeholder engagement. Traditional project management methods have also often overlooked sustainability considerations [7], leading to unsustainable practices and negative environmental impacts. The objective of this study is to investigate the effect of PMIS tools adoption on the successful assessment and

Received: 07.06.2025 ***Accepted: 18.06.2025*** ***Published on: 29.08.2025***
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management of sustainability in construction projects in the greater Accra region of Ghana. Current solutions include manual tracking of sustainability metrics before implementation and environmental impact assessments with sustainability reporting for further action. Consequently, these approaches are often time-consuming, prone to errors, and lack real-time monitoring [8] capabilities. The adoption of PMIS tools offers a promising solution to address these challenges as they can facilitate real-time monitoring, data-driven decision-making, and stakeholder engagement, enabling more effective sustainability assessment and management. The study therefore, aims to contribute to the existing body of knowledge on sustainable construction project management by investigating the impact of PMIS tools adoption on the project sustainability assessment and management and developing a framework [9] for integrating PMIS with sustainable projects. This study, apart from developing a new framework to integrate PMIS into sustainable construction projects, will provide insights into the impact of PMIS tools adoption on sustainability assessment and management which will in turn, contribute to the existing body of knowledge. The study focuses on the construction industry and may not be generalizable to other sectors. Additionally, the study is limited to the greater Accra metropolis and the results may not be generalized to other cities in the country. By exploring the potential of PMIS tools in enhancing sustainability in construction projects, this study aims to provide valuable insights for industry practitioners, policymakers, and researchers.

Materials and Methods

Literature Review

Sustainable project management [10-13] is an approach to managing projects that integrates environmental, social, and economic considerations to ensure long-term viability and minimize negative impacts. It consists primarily of 3 phases.

1. Environmental sustainability: this ensures that the construction minimizes the environmental impact [14], such as reducing waste, conserving resources, and promoting eco-friendly practices.
2. Social sustainability: this also ensures that the project benefits stakeholders [15], including local communities, employees, and customers, while promoting social justice and human rights and
3. Economic sustainability: which ensures the construction project's financial viability [16], while considering the long-term economic impacts on stakeholders and the environment.

To be able to achieve these sustainable goals, the project manager and the team are expected to integrate sustainability into the project planning by involving key stakeholders in the project planning and implementation process to ensure their needs and expectations are met. The execution phase is then regularly monitored and reported on sustainability performance to ensure transparency and accountability.

Since the goal is to deliver projects that are environmentally responsible, socially equitable, and economically viable, the review here takes a snap-shot look at literature on sustainability assessment in construction.

Deshvena (2024), explores the best practices and strategies to improve environmental sustainability in construction projects with a focus on waste management, efficient energy usage and materials management with compliance by using a mixed-methods approach of data analysis. Findings revealed that projects that apply sustainable construction practices can reduce their environmental degradation by 30%. This emphasized a proactive approach to sustainability with regulatory compliance and continuous improvement for innovation. He recommended the need to increase investment in sustainable technologies, and the use of life cycle assessment approaches with collaborative works in the construction industry to promote a sustainable future.

Mavi et al, (2021), identified the major concepts studied in the literature of sustainability in construction projects using bibliometric analysis tools. Namely. BibExcel and Gephi to visualize and analyze their interrelations. The research focused parallelship network (RFPN) analysis which clustered the studies into three categories to evaluate sustainability, sustainable project management, and sustainable drivers in construction and keyword cooccurrence network (KCON) analysis for the research themes discovery. Analysis shows that each paper had a different focus with sustainability and its evaluation as the underlying concept. Hence, sustainability concept should be added to construction projects beginning at the feasibility and design stages and monitored throughout the project entire life cycle.

Whilst these researches and others explored the assessment of sustainability in construction projects, little study was conducted to determine whether PMIS tools adoption has an effect on the assessment and management of a construction project sustainability. This is necessary to make recommendations on its applications during construction projects and Hence, the need for this study.

Research Hypothesis

In the determination of the relationship between PMIS tools adoption and the successful sustainable management of the construction projects in the country, the application of the chi square test of independence demands the statement of research hypothesis.

H1: The use of PMIS significantly improves the management of environmental sustainability during construction projects.

H0: The use of PMIS does not improves environmental sustainability management during construction project.

H2: PMIS implementation leads to real-time environmental impacts assessment during construction projects.

H0: PMIS implementation does not lead to a real-time environmental impact assessment during construction projects.

Conceptual Framework

Technology tools [19] such as the Project Management Information Systems (PMIS) emerged as a potential solution to enhance sustainable management in construction projects as its adoption can enable the integration of sustainable management practices into project planning, monitoring, and control. PMIS tools provide features such as data management, tracking, reporting, collaboration, and analytics, which can be leveraged to support sustainable construction project management. This is seen in the conceptual framework in figure 1, the adoption and application of PMIS tools in construction projects can assist to better manage project sustainability. This management when properly conducted, can lead to a successful sustainable metrics assessment and management that will results in its successful management. On the contrary, improper sustainable management will lead to unsuccessful sustainable metrics assessment and hence, poor sustainable outcome.

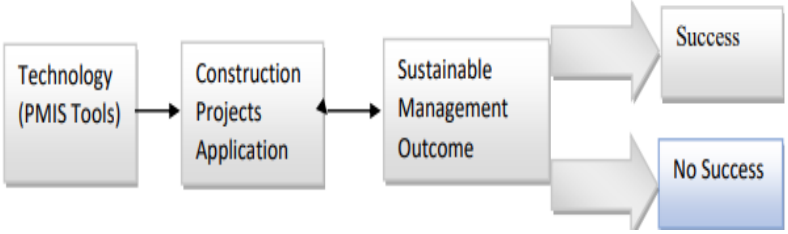

Figure 1. The Conceptual Framework

The adoption of software tools [20] such as the PMIS tools has the potential to significantly impact project sustainable management outcome in construction projects by integrating these management practices into PMIS tools.

Data Collection

In this phase of the research, 252 construction companies consisting of road construction companies and building construction firm's documents were reviewed using a combination of probability random sampling and convenient sampling. This method was chosen over survey opinion data collection as it results in concrete evidence based on real facts. The table of recorded values are shown in table 1. In table 1, contraction companies that utilized PMIS tools in their construction project activities and have achieved sustainable development goals are those with sustainable management success. Project sustainable management here is not limited to only the proper environmental management but also includes the addition of skills and values to the working staff and other stakeholders for their future self-development [21]. To be able to qualify for moderate sustainability, the construction company must achieve between quarter to half of the sustainability metrics. The companies that did not achieve any sustainability goals are those that scored below quarter of the sustainability measurement success. The table of values of the review is shown below in Table 1.

Table 1. Contingency Table of Observed Values (Number of Companies that Adopted PMIS Tools against those that did not)

PMIS Tools Adoption	Sustainable Management Success (Yes)	Moderate Sustainable Management (Moderate)	Unsuccessful Sustainable Management (No)
MS Projects	22	16	13
ERP	15	13	9
MS Excel	31	19	17
Gantts	12	9	8
Primavera	9	7	11
No PMIS Tool Adopted	17	18	6

Data Analysis

Given a matrix A, with entries Ai j, where i and j are positive integers.

$$Aij = \begin{pmatrix} A1,1\ A1,2\ A1,3\ A1,4 \\ A2,1\ A2,2\ A2,3\ A2,4 \\ A3,1\ A3,2\ A3,3\ A3,4 \\ A4,1\ A4,2\ A4,3\ A4,4 \end{pmatrix} \text{Sum of Columns} = \begin{pmatrix} \Sigma A1,j \\ \Sigma A2,j \\ \Sigma A3,j \\ \Sigma A4,j \end{pmatrix} \text{and}$$

Sum of Rows = $(\Sigma Ai, 1\ \Sigma Ai, 2\ \Sigma Ai, 3\ \Sigma Ai, 4)$

Total Sum of Rows and Columns = $(\Sigma Ai, j)$

The sum of the rows and columns and their totals in the matrix A, a representative of Aij modelled through the data collection is in table 2.

Table 2. Sustainable Management Outcome

PMIS Tools Adoption	Sustainable Management Success (Yes)	Moderate Sustainable Management (Moderate)	Unsuccessful Sustainable Management (No)	Total
MS Projects	22	16	13	51
ERP	15	13	9	37
MS Excel	31	19	17	67
Gantts	12	9	8	29
Primavera	9	7	11	27

No PMIS Tool Adopted	17	18	6	41
Total	106	82	64	252

The contingency table of expected values for each entry in the matrix A, is then given by the relation.

$$E_ij = \frac{R_i \times Cj \cdot}{\Sigma A_{ij}} \qquad (1)$$

Where Ri and Cj and the sum of rows and columns respectively and ΣAij is the total sum of all the entries in the matrix.

Table 3. Contingency Table of Expected Values

PMIS Tools Adoption	**Sustainable Environmental Management Success (Yes)**	**Moderate Sustainable Environmental Management (Moderate)**	**Unsuccessful Sustainable Environmental Management (No)**	**Total**
MS Projects	21.45	16.60	12.95	51
ERP	15.56	12.04	9.40	37
MS Excel	28.18	21.80	17.02	67
Gantts	12.20	9.44	7.37	29
Primavera	11.36	8.78	6.86	27
No PMIS Tool Adopted	17.25	13.34	10.41	41
Total	106	82	64	252

Equation (2) calculated results are also shown in table 3. These results of the expected values are now used to determine the chi square test of independence to achieve table 4.

The chi square test, denoted by χ^2, is given by the relations.

$$\chi^2 = \frac{\sum_{\cdot}\left(O_{iJ} - E_ij\right)^2}{E_{ij}} \qquad (2)$$

Where

χ^2 = the chi square test

Oij = observed frequency in the ith row and jth column and

Eij = expected frequency in the ith row and jth column.

The chi-square test of independence uses the contingency table 3 to determine whether there is a significant association between the two categorical variables and is calculated using the observed and expected frequencies:

To determine if there is any relationship between the variables namely, PMIS tools adoption and the successful management of sustainability during construction projects in Ghana, a chi square test of independence is conducted. This is illustrated using table 4 below.

Table 4. The Chi Square Test Contingency Table

PMIS Tools Adoption	**Sustainable Environmental Management Success (Yes)**	**Moderate Sustainable Environmental Management (Moderate)**	**Unsuccessful Sustainable Environmental Management (No)**	**Total**
MS Projects	0.0141	0.0217	0,000193	51
ERP	0.0202	0.0765	0.0170	37

MS Excel	0.2822	0.3596	0.000023	67
Gantts	0.00328	0.02051	0.05385	29
Primavera	0.4903	0.3609	2.4985	27
No PMIS Tool Adopted	0.003623	1.6279	1.8682	41
Total	106	82	64	252

By considering table 4 and applying the chi square statistic (χ^2) test which is achieved by summing the squared differences between observed and expected frequencies, divided by the expected frequencies, for each cell in the χ^2 contingency table, the resulting value is compared to a critical value from the χ^2 distribution to determine the p-value. This p-value helps in determining the significance of the association between the variables being tested.

χ^2 is the sum of all the values in the last table

$$x^2 = 7.7186$$

To determine the critical statistic, the degrees of freedom is first calculated.

$$Let\ df = the\ degrees\ of\ freedom$$

$$df = (R-1) \times (C-1) = (3-2) \times (6-1) = 10$$

Where C = Number columns and R = Number of rows.

The obtained statistic is then compared to the critical statistic found in the chi-square table. As it can be seen, for an alpha level of 0.05 and 10 degrees of freedom, the critical statistic is 18.307, which is greater than the obtained statistic of 7.7186.

In order to concretized the results, the odds ratio, relative risk, sensitivity and specificity are estimated using the given data in table 1 or table 2.

Odd Ratio

The odds ratio (OR), is determined by comparing the odds of a sustainable outcome with PMIS adoption versus the odds of sustainable outcome without PMIS adoption.

$$\text{0dd Ratio (PMIS Adopted)} = \frac{\text{Number of projects with PMIS adoption and sustainable outcome}}{\text{Number of projects with PMIS adoption without sustainable outcome}}$$

$$Odds(PMIS\ adopted) = \frac{153}{58} = 2.6379$$

$$\text{0dd Ratio (PMIS not Adopted)} = \frac{\text{Number of projects without PMIS adoption with sustainable outcome}}{\text{Number of projects without PMIS adoption and no sustainable outcome}}$$

$$\text{0dd Ratio (PMIS not Adopted)} = \frac{35}{6} = 5.833$$

$$\text{0dd Ratio (OR)} = \frac{\text{Odds (PMIS adopted)}}{\text{Odds(PMIS not adopted)}}$$

$$\text{0dd Ratio (OR)} = \frac{2.6379}{5.833} = 0.452.$$

Relative Risk

This is the measure of the ratio of the probability of an event occurring in the exposed group as against the non-exposed group. In the context of the study, it is the ratio of the probability of achieving sustainable management outcome when PMIS is adopted, compared to the probability of achieving sustainable management outcome when PMIS is not adopted.

Risk (PMIS Adopted) = (Number of projects with sustainable outcome)

(Total number of projects with PMIS adoption)

$$\text{Risk (PMIS Adopted)} = \frac{\text{Number of projects with Sustainable outcome}}{\text{Total number of projects with PMIS adoption}}$$

$$\text{Risk (PMIS Adopted)} = \frac{153}{211} = 0.7251$$

$$\text{Risk (PMIS not Adopted)} = \frac{\text{Number of projects with sustainable outcome}}{\text{Total Number of projects without PMIS adoption}}$$

$$\text{Risk (PMIS not Adopted)} = \frac{35}{41} = 0.8537$$

$$\text{Relative Risk (RR)} = \frac{\text{Risk(PMIS Adopted)}}{\text{Risk (PMIS not adopted)}}$$

$$\text{Risk (PMIS Adopted)} = \frac{0.7251}{0.8537} = 0.8494$$

Sensitivity and Specificity

Sensitivity and Specificity are measures used to evaluate the performance of a predictive model. They can be applied to evaluate the performance of PMIS in predicting or identifying sustainable project outcomes. For instance, Sensitivity is the proportion of sustainable projects that are correctly predicted by PMIS adoption to achieve sustainability. whiles Specificity is the proportion of non-sustainable projects that are correctly predicted by lack of PMIS adoption or ineffective PMIS implementation.

Sensitivity and specificity can be calculated by using the formulae.

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}} = \frac{188}{(188 + 36)} = 0.8392$$

$$\text{Sensitivity} = \frac{\text{TN}}{\text{TN} + \text{FP}} = \frac{6}{(6 + 58)} = 0.1111$$

Where;

True Positives (TP): Projects with PMIS adoption and sustainable outcome (188).

False Positives (FP): Projects with PMIS adoption but no sustainable outcome (58).

True Negatives (TN): Projects without PMIS adoption and no sustainable outcome (6).

False Negatives (FN): Projects without PMIS adoption but with sustainable outcome (35).

Results

The odds ratio is 0,452, indicating that projects with PMIS adoption have lessor times the odds of achieving a sustainable outcome compared to projects without PMIS adoption.

The relative risk is 0.85, indicating that projects with PMIS adoption are 85% times more likely to achieve a sustainable outcome compared to projects without PMIS adoption. The sensitivity is 0.84. this indicates that 84% of projects with sustainable outcomes were correctly predicted by PMIS adoption whiles the specificity is 0.11 which implies that 11% of projects without sustainable outcomes were correctly predicted by lack of PMIS adoption. The summary results are shown in table 5 below.

Table 5. Table of Parameter Estimates

Parameter	Value
Chi Square Test of Independence	7.7186
Sensitivity Analysis	0.8392
Specificity Analysis	0.1111
Odd Ratio Test	0.4520
Relative Risk	0.8494

Discussion

Project Management Information System (PMIS) is a vital tool for assessing and managing construction projects. This discussion highlights the role of PMIS in sustainable assessment and management. As PMIS collects, stores, and analyzes data [22], enabling informed decisions and facilitating real-time tracking of relevant information, allowing for prompt corrective actions. This study shows that it does not have a significant impact on construction project sustainable management. The Chi-Square test of independence is used to determine if there is a significant association between these two categorical variables. Namely PMIS adoption and sustainable project assessment and management. Since the calculated Chi-Square statistic (7.716) is less than the critical statistic (18.301), the null hypothesis cannot be rejected in favor of the alternative hypothesis. There's insufficient evidence to suggest a statistically significant association between PMIS and sustainable project management at $\alpha = 0.05$ in the greater Accra Region of Ghana.

An Odds Ratio (OR) of 0.452 for PMIS tools adoption and sustainable project management implies that the odds of achieving sustainable

project management are lower for projects that adopt PMIS tools compared to those that do not. Specifically, the odds are 54.8% lower $(1 - 0.452 = 0.548)$.

for projects with PMIS adoption. This implies that PMIS adoption might not be associated with increased likelihood of sustainable project management. Other factors might be influencing the relationship between PMIS adoption and sustainable project management. The OR therefore, suggests a potential negative association, but further investigation is needed to understand the relationship.

A Relative Risk (RR) of 0.8494 for PMIS tools adoption and sustainable project management also implies that the risk of not achieving sustainable project management is lower for projects that adopt PMIS tools compared to those that do not adopt them. Specifically, the risk is 15.06% lower $(1 - 0.8494 = 0.1506)$ for projects with PMIS adoption and hence, PMIS adoption might be associated with a reduced risk of not achieving sustainable project management. PMIS adoption could be a protective factor for sustainable project management, reducing the risk of unsustainable outcomes. Hence, the RR suggests a potential positive association between PMIS adoption and sustainable project management, but further investigation is needed to confirm the relationship.

Given the sensitivity value of 0.8392, The test only correctly identifies 83.92% of projects that are truly sustainable (true positives), suggesting that the model is fairly sensitive to detecting sustainable projects but not the relationship between the two. The specificity value of 0.1111 suggests that the test correctly identifies 11.11% of projects that are truly not sustainable (true negatives) which further suggests that the model has low specificity meaning it may generate many false positives and identifying non-sustainable projects as sustainable. This is quite impracticable as the percentage is low.

Base on the results, it is highly recommended that further research be carried out by using confounding variables such as the project team experience and their training needs including the project size and complexity and their effects in the application of PMIS tools in projects.

Conflict of Interest

The authors declare that there is no conflict of interest in the creation of this article.

Acknowledgement

I would like to express my profound gratitude to all those who contributed in diverse ways to the success of this script. Firstly, to Professor B. Elamurugan as the project idea started under his guidance. I also wish to thank Mr. Andrews Clocanas of the Ghana government housing project at Seglemi for his immense support during data collection. Finally, to the members of PMI -Ghana chapter for the immense knowledge acquired through training sessions.

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