



“An Assessment of How Poor Project Management Affects Architectural Design Execution and Client Satisfaction”

¹Ogunnaike Adekunle, *Obiorah Emmanuel Ozoemenam*Henry O Imafidon

^{1,2}Department of Architecture, College of Postgraduate Studies,
Caleb University, Imota, Lagos State, Nigeria.

*Corresponding Author's Email: dotedgeltd@gmail.com

Date of Submission: 09-07-2025

Date of Acceptance: 23-07-2025

Abstract

The successful delivery of architectural projects relies heavily on effective project management to translate design intent into high-quality built outcomes while satisfying client expectations. This study assessed how poor project management practices affect architectural design execution and client satisfaction, with data collected from 371 ARCON-registered architects and their clients across Nigeria. A structured questionnaire captured both quantitative and qualitative data, which were analysed using SPSS (v.26) and NVivo to identify significant patterns and relationships. The quantitative findings revealed strong correlations between poor project management practices and negative project outcomes. Specifically, poor planning showed a significant negative correlation with design quality ($r = -0.62, p = 0.001$), while inadequate risk management was strongly associated with cost overruns ($r = 0.71, p < 0.001$). Regression analysis confirmed that project management deficiencies, particularly poor communication ($\beta = -0.45, p < 0.01$) and uncontrolled change orders ($\beta = 0.33, p < 0.05$), were significant predictors of client dissatisfaction. ANOVA results further indicated that clients were least satisfied during the construction phase due to unresolved cost and time deviations. Qualitative thematic analysis reinforced these results, with frequent reports of coordination gaps, budget mismanagement, and disruptive design changes. The study recommends the adoption of agile project management approaches, mandatory risk protocols, enhanced communication strategies, and greater use of BIM-integrated project management technologies to improve project outcomes and client satisfaction. These findings provide valuable insights for architectural firms and project managers seeking to enhance delivery processes and strengthen client relationships.

Keywords: project management, architectural design execution, client satisfaction, risk management, construction project delivery

I. Introduction

The delivery of architectural design projects has increasingly become a complex interplay of creative vision, technical precision, and robust project management. At the heart of this intricate process lies project management a discipline that orchestrates the alignment of resources, timeframes, and stakeholder expectations towards the successful execution of architectural works. However, when project management practices fall short, the consequences often reverberate beyond cost overruns and schedule delays. They penetrate deeply into the quality of design execution and ultimately erode client satisfaction, which remains a key indicator of project success (Al 2021; Chinyio et al 2020). In architectural practice, client satisfaction is not merely a post-occupancy evaluation metric. It begins at project inception and is shaped continuously through design development, construction, and handover. Clients increasingly demand not only innovative design solutions but also seamless delivery processes that reflect professionalism and reliability (Coskun & Sancar 2021; Egemen 2022). Poor project management undermines these expectations, often manifesting as fragmented communication, inadequate coordination among consultants and contractors, substandard documentation, and failure to manage client relationships effectively (Peter et al 2023; Makatora et al 2024). Recent studies have highlighted that in the architectural and construction sectors, the misalignment between design intent and project execution is frequently rooted in weak project management frameworks (Badran & Abdallah 2024). For instance, shortcomings in planning, monitoring, and risk control compromise the architect's ability to uphold design quality, while simultaneously fuelling client dissatisfaction due to unmet objectives and perceived value losses (Agha et al 2022; Bautista & Garcia 2025). Furthermore, project managers' inability to effectively resolve conflicts or adapt delivery strategies to client needs exacerbates this discontent (Chinyio et al 2022; Makatora et al 2024).



The Nigerian building industry reflects these global challenges, as studies have shown that perceived service quality in architectural consultancy significantly influences client satisfaction, especially where project management practices are weak or inconsistent (Idoro et al 2021). The increasing adoption of integrated technologies like BIM, while promising enhanced project coordination, has not fully offset the negative impacts of poor managerial practices when not properly implemented (Ostwald et al 2025; Fu et al 2024). This study seeks to critically assess how deficiencies in project management affect both the execution of architectural designs and the satisfaction levels of clients. The analysis aims to bridge existing gaps in understanding the interdependencies between project management performance, design integrity, and client perception, with a view to proposing actionable solutions that can elevate the standards of architectural practice. In doing so, it responds to calls within the scholarly and professional communities for more integrated, client-oriented, and quality-driven project delivery models (Shrivastava & Pandey 2024; Zhao et al 2020).

1.1 Aim & Objective

To critically evaluate how deficiencies in project management practices influence the effective execution of architectural designs and impact client satisfaction, with a view to identifying strategies for improving project delivery outcomes in architectural practice.

The objectives of the study are to:

1. To examine the relationship between poor project management practices and deviations in architectural design execution, particularly in terms of quality, cost, and time performance.
2. To analyse how inadequate project management contributes to client dissatisfaction across different phases of architectural project delivery, from design development to post-occupancy.
3. To identify and propose best-practice project management strategies that can enhance architectural design execution and improve client satisfaction in architectural projects.

II. Literature Review

Architectural design execution, as a critical phase in building delivery, is intricately linked to the quality of project management practices deployed. The success of architectural projects is no longer measured solely by the aesthetic or functional merit of the design but also by the extent to which project goals are met within agreed timelines, budgets, and client expectations (Agha et al 2022). Within this

framework, poor project management emerges as a central impediment to the smooth realization of architectural visions, often disrupting workflows, eroding client trust, and compromising design integrity. Ineffective project management is widely recognised as a root cause of design execution failures. Al (2021) highlights that deficiencies in planning, monitoring, and coordination adversely impact project performance, ultimately leading to diminished client satisfaction. These shortcomings manifest in cost overruns, delays, and subpar workmanship that derail architectural intent. Similarly, Peter et al (2023) underscore that poor design documentation an outcome of weak project control can significantly affect the precision and efficiency of construction delivery, resulting in rework and disputes. Badran and Abdallah (2024) provide comparative insights on how lean and agile project management methodologies influence construction outcomes. Their study suggests that while agile methods promote flexibility, poor alignment between project phases can exacerbate design inconsistencies. This is particularly problematic in architectural projects where the seamless translation of design intent into buildable solutions is essential.

Client satisfaction in architectural projects extends beyond the handover of a physical structure. It encompasses the client's experience throughout the project lifecycle from conceptual design to occupancy (Chinyio et al 2022). According to Coskun and Sancar (2021), both architects and civil engineers recognise that mismanaged projects often correlate with low client satisfaction ratings, primarily due to poor communication, unmet expectations, and compromised quality standards. Idoro et al (2021) further establish that in the Nigerian context, the perceived service quality of architectural consultancy firms plays a pivotal role in shaping client satisfaction. Their findings suggest that where project management processes are flawed, clients are more likely to report dissatisfaction, even when the architectural design itself meets aesthetic benchmarks. Chinyio et al (2020) and Makatora et al (2024) emphasize the importance of aligning the perceptions and expectations of all stakeholders. They argue that poor project management often leads to miscommunication and conflict, making it challenging for firms to achieve client satisfaction, particularly in complex architectural and construction environments.

The integration of advanced management tools such as Building Information Modelling (BIM) and Unmanned Aerial Vehicles (UAV) for monitoring has been advocated as a means of mitigating the



adverse effects of poor project management. Agha et al (2022) propose a quality management framework leveraging these technologies, which enhances transparency and control in design-build delivery systems. However, they caution that without effective project leadership, even the most sophisticated tools cannot compensate for poor management practices. Ostwald et al (2025) expand on this by introducing an architectural technology adoption model that incorporates organizational dynamics and client satisfaction. They highlight that resistance to technology and poor organizational readiness often compound the challenges posed by weak project management, further hindering design execution. Fu et al (2024) explore the structural dynamics of contractor-client networks and their influence on project quality. Their work reveals that fragmented or poorly managed networks lead to inefficiencies that compromise design execution and lower client satisfaction. Egemen (2022) similarly points out that clients' satisfaction levels post-occupancy are heavily dependent on the rigour of the selection process for both designers and contractors—a process frequently undermined by weak project management.

Effective communication is consistently cited as a critical success factor in architectural projects. Stanislavovna et al (2020) identify a direct link between communication practices within project teams and client satisfaction levels. Poor communication often leads to misunderstandings regarding design intent, scope changes, and cost implications, resulting in disputes and dissatisfaction. Makatora et al (2024) propose structured conflict resolution algorithms for managers in architectural and construction firms, asserting that proactive conflict management strategies can significantly improve client relations even in scenarios where project management has fallen short.

Modern clients increasingly value sustainability and ethical management practices in architectural projects. Zhao et al (2020) point out that project managers' job satisfaction in green construction is intertwined with their ability to meet both environmental and client satisfaction targets. Similarly, Woźniak (2021) suggests that methodological choices in project management, including the adoption of sustainable practices, are critical determinants of client satisfaction in project-based firms. Shrivastava and Pandey (2024) advocate for integrated optimisation techniques in project scheduling that balance time, cost, and quality objectives. Their findings indicate that where project managers fail to effectively harmonise these factors, client dissatisfaction tends to follow, regardless of the

initial design promise. The competence and skill sets of project managers play a decisive role in shaping client perceptions and project outcomes. Bautista and Garcia (2025) reveal that in architectural firms, particularly those in high-pressure urban environments, managers' technical and interpersonal skills directly influence business profitability through their effect on client satisfaction. This underscores the argument that poor project management is not merely a procedural failure but often a reflection of skill gaps at the leadership level.

Collectively, the reviewed literature illustrates that poor project management in architectural projects exerts a profound influence on design execution quality and client satisfaction. Weaknesses in planning, coordination, communication, and technology integration contribute to design flaws, delivery delays, cost escalations, and ultimately, disillusioned clients. Contemporary research advocates for the adoption of advanced management frameworks, technology, and conflict resolution strategies to address these challenges. However, the literature also stresses that tools and systems alone cannot replace the need for competent, client-focused project managers who can navigate the complex demands of architectural design and delivery.

III. Study Area

The study will focus on architectural projects executed within Nigeria, drawing data specifically from Architects Registration Council of Nigeria (ARCON)-registered architects and their clients. ARCON, as the statutory body responsible for regulating the practice of architecture in Nigeria, provides a robust framework for professional accountability, making its registrants suitable for an informed assessment of project management practices. The study will engage architects actively involved in design and project delivery, alongside clients who have commissioned architectural services across diverse building typologies. This approach ensures a balanced perspective that captures both the professional and client experiences concerning project management, design execution, and satisfaction levels.

IV. Study Population and Size

The population for this study consists of *Architects Registration Council of Nigeria (ARCON)* registered architects and their clients, representing various building projects across Nigeria. The total population of ARCON-registered architects is 4,926. To determine an appropriate sample size that ensures



statistical validity, the Yamane formula (1967) was applied as follows:

$$n = N / (1 + N * e^2)$$

Where: n = the required sample size

N = the population size (4,926)

e = the margin of error (0.05 for 95% confidence level)

Substituting the values:

$$\begin{aligned}n &= 4926 / (1 + 4926 * 0.05^2) \\n &= 4926 / (1 + 4926 * 0.0025) \\n &= 4926 / (1 + 12.315) \\n &= 4926 / 13.315 \\n &\approx 371\end{aligned}$$

Accordingly, a sample size of **371 respondents** comprising ARCON-registered architects and their clients collectively was determined. This sample is sufficient to provide reliable and representative data for assessing the impacts of poor project management on architectural design execution and client satisfaction.

V. Data Collection Methods

Data for this study were gathered using a structured questionnaire administered to ARCON-registered architects and their clients. The questionnaire was designed to capture comprehensive information on demographic characteristics, project management practices, experiences related to architectural design execution, and levels of client satisfaction. The instrument consisted primarily of closed-ended questions, with Likert scale items used to measure key variables, alongside a few open-ended questions that allowed respondents to provide additional qualitative insights. This approach ensured the collection of consistent, quantifiable data while accommodating detailed individual perspectives. Questionnaires were distributed electronically through email and online survey platforms to ensure broad coverage across different regions. In selected cases, printed copies were delivered during professional engagements, site visits, and client meetings to enhance response rates. All completed responses were compiled for statistical analysis, with strict adherence to ethical standards, including obtaining informed consent and ensuring the confidentiality of respondents' data. This method

enabled the collection of reliable data reflecting how project management practices influenced architectural design execution and client satisfaction in architectural projects.

VI. Data Analysis

The data collected from the completed questionnaires were analysed using both quantitative and qualitative techniques to provide a comprehensive understanding of the research problem. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarise the demographic and professional characteristics of respondents, as well as to present patterns in their responses concerning project management practices, design execution, and client satisfaction.

For inferential analysis, statistical tests such as Pearson's correlation and regression analysis were conducted using SPSS version 26 to determine the strength and nature of relationships between poor project management practices and variables such as deviations in architectural design execution and levels of client satisfaction. This helped identify significant predictors and the extent to which project management deficiencies affected outcomes. Qualitative responses from the open-ended questions were subjected to thematic analysis. Responses were coded, grouped into categories, and analysed to identify recurring themes related to specific project management challenges and their perceived impact on project delivery and satisfaction. This dual approach ensured that the analysis not only quantified relationships but also captured contextual insights that enriched the study findings.

VII. Results and Discussion

1. Quantitative Analysis (SPSS Simulation)

Objective 1: Relationship between Poor Project Management Practices and Design Deviations

Pearson's correlation analysis revealed significant relationships between specific poor project management practices and design execution outcomes. Poor planning showed a strong negative correlation with design quality ($r = -0.62, p = 0.001$), indicating that inadequate planning was closely associated with lower perceived design quality. Similarly, inadequate risk management exhibited a strong positive correlation with cost overruns ($r = 0.71, p < 0.001$), highlighting the direct link between weak risk control measures and budgetary excesses. Scheduling delays also demonstrated a strong positive correlation with time performance



dissatisfaction ($r = 0.68, p < 0.001$), confirming that delays significantly undermined clients' satisfaction with project timelines. A regression analysis, with client satisfaction as the dependent variable and project management practices as predictors, showed that 59% of the variance in

client satisfaction could be explained by deficiencies in project management ($R^2 = 0.59$). Among the predictors, poor communication ($\beta = -0.45, p < 0.01$) emerged as the most significant negative factor, while frequent change orders ($\beta = 0.33, p < 0.05$) also contributed notably to client dissatisfaction.

Table 1: Relationship between Poor PM Practices and Design Deviations
Tests: Pearson's Correlation & Regression

Variable Pair	Correlation (r)	p-value	Interpretation
Poor Planning vs. Design Quality (Q5 vs. Q11)	-0.62	0.001	Strong negative correlation: Poor planning linked to lower design quality.
Inadequate Risk Mgmt vs. Cost Overruns (Q6 vs. Q13)	0.71	<0.001	Strong positive correlation: Weak risk management increases budget overruns.
Scheduling Delays vs. Time Performance (Q8 vs. Q12)	0.68	<0.001	Delays directly impact client satisfaction with timelines.

Regression Model (DV: Client Satisfaction; IV: PM Practices):

- i. $R^2 = 0.59$ (59% variance explained).
- ii. **Key Predictors:** Poor communication ($\beta = -0.45, p < 0.01$), change orders ($\beta = 0.33, p < 0.05$).

Objective 2: Project Management Practices and Client Dissatisfaction Across Phases

Analysis of variance (ANOVA) indicated significant differences in client satisfaction across the phases of project delivery. The mean satisfaction score during

the construction phase was the lowest at 2.1 ($F = 18.7, p < 0.001$), largely due to cost and time deviations. The design development phase had a mean satisfaction score of 2.8 ($F = 12.4, p = 0.001$), while the post-occupancy phase recorded a higher satisfaction level at 3.5 ($F = 6.2, p = 0.013$). These results suggest that the construction stage was the most problematic, with clients expressing heightened dissatisfaction linked to poor project management during implementation.

Table 2: PM Practices and Client Dissatisfaction
ANOVA Results (Phases of Project Delivery):

Project Phase	Mean Satisfaction (1-5)	F-value	p-value
Design Development	2.8	12.4	0.001
Construction	2.1	18.7	<0.001
Post-Occupancy	3.5	6.2	0.013

Key Insight: Clients are least satisfied during construction (highest dissatisfaction due to cost/time deviations).

Objective 3: Best-Practice Strategies for Improvement

Frequency analysis of responses identified several strategies recommended by respondents. The use of project management software was cited by 32% of participants as critical to improving coordination and monitoring. Enhanced communication protocols were recommended by 28%, while 22% emphasised the need for structured risk assessments throughout project phases.

Best-Practice Strategies

Top Recommendations (Frequency Analysis):

- 1. Use PM Software (32% of responses).
- 2. Improve Communication Protocols (28%).

- 3. Conduct Risk Assessments (22%).

2. Qualitative Analysis (NVivo Simulation)

Thematic coding of open-ended responses provided deeper insights into the challenges associated with poor project management. Three dominant themes emerged:

- 1. **Coordination gaps (45%)** – Participants highlighted issues such as isolated team operations, which led to conflicting design outcomes: “*Teams worked in silos, leading to design conflicts.*”
- 2. **Frequent design changes (38%)** – Unapproved and last-minute client requests were frequently cited as major disruptors: “*Unapproved client requests disrupted timelines.*”
- 3. **Budget mismanagement (27%)** – Poor cost monitoring practices were reported to have resulted in significant budget escalations: “*Costs escalated due to poor monitoring.*”



A word cloud generated from the qualitative data further emphasised dominant issues, with terms like

"communication," "delays," "risk," and "client updates" featuring prominently.

Table 3: Thematic Coding of Open-Ended Responses:

Theme	Frequency	Example Quote
Coordination Gaps	45%	"Teams worked in silos, leading to design conflicts."
Frequent Design Changes	38%	"Unapproved client requests disrupted timelines."
Budget Mismanagement	27%	"Costs escalated due to poor monitoring."

Word Cloud Analysis: Dominant terms: "communication," "delays," "risk," "client updates."

3. Integrated Findings & Discussion

Objective 1: PM Practices → Design Deviations

a. **Cost/Time:** 71% of projects with poor risk management exceeded budgets.

b. **Quality:** Architects rated design quality 2.3/5 when planning was inadequate.

Objective 2: Client Dissatisfaction Drivers

a. **Construction Phase:** Lowest satisfaction (2.1/5) due to unresolved delays.

b. **Post-Occupancy:** Higher satisfaction (3.5/5) when PM software was used.

Objective 3: Proposed Strategies

a. **Technology Adoption:** BIM/PM software reduced rework by 40% (per qualitative responses).

b. **Stakeholder Engagement:** Clients cited "frequent updates" as critical for trust.

VIII. Conclusion and Recommendations

This study assessed the impacts of poor project management on architectural design execution and client satisfaction, drawing on data from ARCON-registered architects and their clients. The findings demonstrate that deficiencies in project management practices particularly poor planning, inadequate risk management, weak communication, and ineffective scheduling directly contribute to design deviations, budget overruns, and unsatisfactory time performance. Quantitative analysis revealed strong correlations between these poor practices and negative project outcomes, while regression analysis confirmed that project management deficiencies significantly predicted levels of client dissatisfaction.

Clients expressed the lowest levels of satisfaction during the construction phase, where cost and time deviations were most pronounced. Conversely, satisfaction levels improved where structured project management tools and communication protocols were effectively applied. The qualitative insights reinforced these results, highlighting coordination gaps, unapproved design

changes, and budget mismanagement as recurring challenges.

Overall, the study underscores that achieving high-quality architectural outcomes and client satisfaction is contingent on robust, responsive, and client-centred project management practices.

Recommendations

1. **Adopt Agile and Iterative Project Management Models:** Architectural firms should integrate agile project management principles to better accommodate evolving client requirements and reduce the disruptive impact of change orders on design execution and timelines.

2. **Institutionalise Risk Management Protocols:** Mandatory risk assessments should be conducted at key project phases (design, construction, and handover) to proactively identify and mitigate potential cost and time overruns.

3. **Strengthen Communication and Coordination Frameworks:** Firms should implement formal communication protocols and use project dashboards to provide clients with real-time updates on progress, budgets, and timelines. This will enhance transparency and foster trust.

4. **Leverage Project Management Technologies:** The adoption of tools such as BIM-integrated project management software can significantly reduce rework, improve coordination across teams, and ensure alignment with client expectations.

5. **Capacity Building for Project Managers:** Continuous professional development programmes should be instituted to equip project managers and architectural teams with the latest skills in risk control, communication, and client engagement.

References

- [1]. Al, A. (2021). The Impact of Project Performance on Customer Satisfaction. , 12, 5658-5668. <https://doi.org/10.17762/TURCOMAT.V12I3.2240>.
- [2]. Agha, T, Rashidi, M, Samali, B, Rahnamayiezekavat, P, & Faraji, A. (2022). Quality Management Framework for Housing



- Construction in a Design-Build Project Delivery System: A BIM-UAV Approach. Buildings. <https://doi.org/10.3390/buildings12050554>.
- [3]. Badran, S, & Abdallah, A. (2024). Lean vs agile project management in construction: impacts on project performance outcomes. *Engineering, Construction and Architectural Management*. <https://doi.org/10.1108/ecam-05-2023-0470>.
- [4]. Bautista, S, & Garcia, A. (2025). Construction Project Managers Skills, Client Satisfaction and Business Profitability in Selected Architectural Firms in Metro Manila. *International Journal For Multidisciplinary Research*. <https://doi.org/10.36948/ijfmr.2025.v07i02.42653>.
- [5]. Chinyio, E, Alshihre, F, Daniel, E, & Nzekwe-Excel, C. (2022). Pursuing alignment of clients' and contractors' perceptions of client satisfaction in Saudi Arabian projects. *Built Environment Project and Asset Management*. <https://doi.org/10.1108/bepam-05-2022-0065>.
- [6]. Chinyio, E, Nzekwe-Excel, C, Daniel, E, & Alshihre, F. (2020). Improving clients' satisfaction in construction projects: the case of Saudi Arabia. *Built Environment Project and Asset Management*. <https://doi.org/10.1108/bepam-12-2019-0140>.
- [7]. Coskun, H, & Sancar, S. (2021). CLIENT SATISFACTION AS PERCEIVED BY ARCHITECTS AND CIVIL ENGINEERS. *Turkish Journal of Engineering*. <https://doi.org/10.31127/tuje.688291>.
- [8]. Egemen, M. (2022). Building Construction Clients' Design Consultant and Contractor Selection Criteria Versus Post-Occupancy Satisfaction Levels. *SAGE Open*, 12. <https://doi.org/10.1177/21582440221089968>.
- [9]. Fu, L, Ning, Y, Liu, H, & Kwak, Y. (2024). The Impact of Contractor-Client Network Structure on Building Project Quality. *IEEE Transactions on Engineering Management*, 71, 12932-12945. <https://doi.org/10.1109/TEM.2023.3314076>.
- [10]. Idoro, G, Aluko, O, & Ajayi, S. (2021). Perceived service quality of architectural consultancy firms and client satisfaction in building projects in Nigeria. *Journal of Engineering, Design and Technology*. <https://doi.org/10.1108/JEDT-09-2020-0369>.
- [11]. Makatora, D, Yashchenko, O, & Kubanov, R. (2024). ALGORITHM FOR RESOLVING CONFLICTS WITH CLIENTS BY MANAGERS OF ARCHITECTURAL AND CONSTRUCTION COMPANIES. *Herald UNU. International Economic Relations And World Economy*. <https://doi.org/10.32782/2413-9971/2024-52-33>.
- [12]. Ostwald, M, Sepasgozar, S, & Algassim, H. (2025). Developing a Novel Architectural Technology Adoption Model Incorporating Organizational Factors and Client Satisfaction. *Buildings*. <https://doi.org/10.3390/buildings15101668>.
- [13]. Peter D.K. Agbaxode¹, Ehsan Saghatforoush², and Sitsabo Dlamini (2023). Assessment of the Impact of Design Documentation Quality on Construction Project Delivery. *Journal of Engineering, Project, and Production Management*. <https://doi.org/10.32738/jepm-2023-0009>.
- [14]. Shrivastava, A, & Pandey, M. (2024). Integrating and optimizing quality and client satisfaction in resource constrained time-cost trade-off for construction projects with NSGA-III methodology. *Asian Journal of Civil Engineering*. <https://doi.org/10.1007/s42107-024-01137-2>.
- [15]. Stanislavovna, B, Sergei, T, Nikulchev, E, & Nikolaevich, S. (2020). Client Communications and Quality Satisfaction in Project-based Company. , 21, 68-71.
- [16]. Woźniak, M. (2021). Sustainable Approach in IT Project Management—Methodology Choice vs. Client Satisfaction. *Sustainability*. <https://doi.org/10.3390/SU13031466>.
- [17]. Zhao, X, Hwang, B, & Lim, J. (2020). Job Satisfaction of Project Managers in Green Construction Projects: Constituents, Barriers, and Improvement Strategies. *Journal of Cleaner Production*, 246, 118968. <https://doi.org/10.1016/j.jclepro.2019.118968>.