Designing Successful Industrialised Construction (IC) Artefacts: Lessons from Nigeria, Kenya and Peru

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Introduction

Industrialised Construction (IC), a high-speed construction methodology, seems an obvious solution to the growing housing crisis in developing cities. Yet, with only a few exceptions, attempts to implement IC in these contexts have repeatedly failed to quickly deliver low-cost adequate[1] homes (e.g., Strassman, 1978; Kedir et al., 2020; Essineyi, 2011; Bah et al., 2018). Exceptions, which I refer to as "outliers", have mostly been overlooked in academic literature, as they are difficult to source, study, and explain. As a result, practitioners and researchers know very little about outliers and the specific design mechanisms underlying their success. Fortunately, I have been able to identify and conduct in-depth research with two outliers, both of which produced unique design artefacts when compared to failures. As a first step toward understanding–and eventually replicating–outlier success, this exploratory study compares design artefacts across outliers and failures through the research question below: (**RQ**) What differentiates outlier IC design artefacts from failures in developing contexts?

Brief Literature Review: Why Design is Crucial for IC in Developing Contexts

Previous academic work has explained failed IC outcomes in developing contexts through narrow macrostructural lenses, which cannot explain the numerous *design*-related failure modes present in the literature. A key example is Strassmann (1978), who critiqued Ghana's Schokbeton project through the lens of macroeconomics, and de-emphasized the effects of its poor ventilation and component design, which ultimately drove the project to failure (UN Report, 1957). Similar to Strassmann, many scholars underplay design as a significant contributor to outcomes, despite evidence that design-related issues substantially affect construction costs and other outcomes (Liu et al., 2025). For example, modern scholars point to macrostructural supply chain issues (Bah et al., 2018; Kedir et al., 2020), insufficient startup capital (Essienyi, 2011), stringent financing requirements (UN Technical Report 1957), unsupportive regulatory frameworks (Kedir et al., 2022), and shortages of skilled labour (Ojoko et al., 2018; Kolo et al., 2014) as the major contributors to IC failure. However, as I demonstrate in the next paragraph, the few in-depth case studies of IC failure available in the literature feature serious design issues.

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[1] Adequate homes are structurally safe, thermally comfortable indoors (habitable), and conforming to local aesthetic and functional requirements (culturally adequate) (UNHCR, 2000). While there are other elements of adequacy, this paper focuses on adequacy elements that are directly affected by architecture and construction practices.

A prominent example of IC failure in developing countries is the Maison Tropicale, an IC prototype that was so aesthetically jarring and expensive due to design-stage material choices and transportation plans that it was discontinued at the pilot stage (Nelson, 2011). Another example is the Jalan Pekeliling Housing Project (JPHP), a Malaysian concrete panel-based project, which had to undergo expensive renovations to correct design issues that made the project uninhabitable (Din et al., 2012). Specifically, the joining mechanism on its concrete components was not designed to prevent moisture and heat creep, making the resulting homes too hot and humid. Sadly, many more IC failures in developing contexts demonstrate similar design issues (e.g., Stanek, 2024; Din et al., 2012).

Methods and Selected Cases

Having established that *design* is an important factor influencing IC success, my research explains what differentiates outlier IC artefacts through the lens of design. My study leverages an important element of the Eisenhardt Method (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Eisenhardt, 2021), which is widely recognised for generating theory from comparative case studies. Following a popular Eisenhardt study design, I am comparing two IC system artefacts that have successfully delivered low-cost adequate homes (System 1 and System 2) to a third one that failed to meet cost and speed criteria (System 3). I selected cases to vary along dimensions of geography, unit of prefabrication, and market context, while sharing the common objective of delivering low- and middle-income urban housing. I use ethnographic methods to study each system, approaching as an observer.

Selected Cases

System 1, first created in 1998 in Nigeria, uses load-bearing interlocking concrete blocks for walls and prefabricated concrete structural beams with lightweight in-fill slates for floors. Since its creation, the system has been used to build 123 units across five projects. During my two-week exploratory study with System 1, I conducted a three-hour in-person interview with the system's primary designer during which I visited a completed project. I also conducted follow-up interviews with his production partner and intern. I cross-validated interview data with archival materials including building plans and construction documentation. I plan to supplement preliminary System 1 data with a 6-week in-depth case study.

System 2, first created in 1996, uses modular monolithic metal formwork to pour concrete walls and floors in-situ. Operating across Chile, Peru, and Brazil, the system builds approximately 2,000 homes annually. During a six-week ethnographic study with System 2, I conducted five hour-long in-person interviews with the system designer, and hour-long interviews with over 40 engineers, architects, managers, and foremen. I also collected archival data including floor plans, and construction documentation.

System 3, first created in 2019 in Kenya, uses cast-in-place reinforced concrete structure in-filled with yellow stone masonry (exterior walls), prefabricated lightweight concrete panels (interior walls), and concrete beam-and-block floors. Since its creation, the System 3 system has been used to complete 137 units in one project. During a ten-week ethnographic study in Kenya, I conducted two hour-long interviews with System 3's primary system designer and 20 interviews with their lead architect, construction manager, and staff. I also visited their office and construction sites and collected archival documentation.

Success Criteria

As described in the *Observed Problem* section, many developing cities require adequate homes that are quick-to-build. I therefore define minimum criteria for IC "success" to align with adequacy, according to Table 1 below:

Table 1: Minimum Criteria for IC "Success", adapted from the construction-related elements of housing adequacy (UNHCR, 2000).

A successful IC system delivers homes that are…	
Low-Cost	≤ Market rate construction
Habitable	Structurally safe
	Protects from elements
	Thermally comfortable
Culturally Relevant	Conforms to local aesthetics
	Conforms to local functional requirements
Quick-to-build	>30% faster than traditional construction

Preliminary Findings

My preliminary cross-case analysis revealed a key design-related factor that distinguishes outliers from less successful systems, which I call Process Level of Development (PLoD). Similar to the term Level of Development (LOD), which is popularly used to describe a BIM artefact's informational and geometric completeness, PLoD describes the procedural and informational completeness of artefacts that detail manufacture and assembly processes. I found that successful projects had artefacts that demonstrated higher PLoDs. In my three case studies, I observed four PLoDs, which I describe below:

1. <u>Level 1 - Planning</u>. A granular, step-level process plan exists for the application of each element, specifying steps, labour and skills, materials, tools, information, etc. At his level, the existence of this plan did not necessitate its documentation. For example, a designer could create and discuss a plan with relevant stakeholders without creating a written document to summarise it.

2. Level 2 - Documentation. The plan is documented and accessible to relevant stakeholders. In the cases studied, Level 2 artefacts included manuals, images, and videos showing assembly sequences in a way that was legible to relevant stakeholders.
3. Level 3 - Understanding. Parties involved in the process have a shared understanding of key process elements, including steps, sequences, tolerances, controls, etc. This was evidenced in my case studies as mandatory quizzes for new hires, based on process documentation from Level 2.
4. Level 4 - Enforcement. Infrastructure exists to ensure the plan is consistently followed. An example of Level 4 was the creation of a spreadsheet used to track each team member's productivity against company benchmarks.

System 1: PLoD 2
S1 featured a granular step-level process plan, which was documented and communicated as a series of animated videos and pictures detailing element-level assembly sequences. I found no evidence of structured mechanisms for verifying worker understanding or enforcing process compliance.

System 2: PLoD 4
S2 had a clear set of detailed assembly manuals and how-to videos, which are characteristic of L2. To achieve L3, the designers institutionalised mandatory quizzes and refreshers based on assembly manuals. Finally, to achieve L4, the designers implemented spreadsheets that could track each worker's productivity against company benchmarks, and leverage performance-linked bonuses.

System 3: PLoD 1
S3 did not have a granular step-level process map. I did not find evidence of process pre-planning beyond a high-level project schedule.

Table 2 summarizes how each case performed on the PLoD spectrum.

Table 2: PLoD comparison across Systems 1, 2, and 3.

PLoD	System 1	System 2	System 3
1. Planning	Featured a step-level process plan for each element.	Featured a step-level process plan for each element.	No step-level plan found
2. Documentation	SketchUp files and animated videos documenting assembly sequences; tapped into embodied knowledge	Featured assembly manuals, how-to videos, all accessible to workers via mobile phones and printouts.	No evidence of accessible process documentation

	from off-shelf materials to fill gaps		
3. Understanding	No evidence of structured activities to verify worker understanding	Mandatory quizzes based on Level 2 documentation	No evidence of structured activities to verify worker understanding
4. Enforcement	No evidence of process enforcement infrastructure	Productivity tracking benchmarked against company standards; performance-linked pay and incentives	No evidence of process enforcement infrastructure

Implications and Future Work

This paper introduces Process Level of Definition (PLoD) as a novel design construct for understanding IC outcomes in developing contexts. My findings suggest that successful systems have carefully pre-planned *process* artefacts, implying that practitioners who see IC's potential but struggle to implement it in developing contexts can leverage a higher PLoD at the design stage. Future work should develop more granular operationalisation of the four PLoD levels across a larger number of cases, and examine how PLoD interacts with product LOD.

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