Modern Methods of Construction and IoT Adoption in New Zealand School Buildings: A Descriptive Multiple-Case Study

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Abstract -

New Zealand's school building programme is deploying modern methods of construction (MMC) and nationwide IoT sensors faster than almost any other public sector, yet this descriptive multi-case analysis of 17 schools shows that this is disconnected from net-zero goals. Government data indicate that 60% of new classrooms now use MMC, but only 18% of audited schools published any details about their modular systems, and none disclosed embodied-carbon targets or energy-performance benchmarks. Similarly, while every school received IoT sensors for temperature, humidity and CO_2 under the Ministry's Te Haratau rollout, no project documents reveal data-privacy protocols, cybersecurity standards or performance dashboards. The descriptive, multi-case analysis demonstrates that MMC and IoT are being adopted to solve capacity, cost and resilience pressures, not to deliver measurable carbon reductions. Mandatory public reporting of construction typology, lifecycle carbon metrics and sensor governance would align New Zealand's most standardised building portfolio with its climate commitments and create a replicable model for other public infrastructure.

Keywords -

Modern Methods of Construction (MMC); Internet of Things (IoT); School buildings; New Zealand; Net-Zero

1 Introduction

New Zealand (NZ) has committed to net-zero greenhouse-gas emissions by 2050, placing the building and construction sector under increasing pressure to deliver both capacity and carbon reductions simultaneously [1]. School buildings are central to this transition: they represent one of the country's largest, most standardised, publicly funded building portfolios, governed centrally by the Ministry of Education (MoE), and are already the focus of policy initiatives to improve performance and resilience [1, 2].

Recent policy pushes have accelerated two major forms of innovation in the school property programme. First, a 2024 government directive instructed the MoE to prioritise MMC, contributing to a rapid increase in modular and prefabricated classrooms: over 60% of new classroom builds used MMC in Q1 2024, up from under 20% in Q4 2023 [2, 3, 4]. Second, the MoE's Te Haratau programme (TeH) is deploying IoT-based Internal Environment Monitoring (IEM) devices across more than 2,500 state schools to capture indoor air-quality and comfort data at scale [5, 6]. Together, these initiatives create an unprecedented opportunity to link construction innovation and smart monitoring with national climate objectives.

However, existing research and reports on zero-carbon buildings in New Zealand highlights institutional, regulatory and knowledge gaps that hinder the translation of high-level climate targets into project-level decisions [7, 8, 9]. Little empirical evidence currently shows how MMC and IoT are combined in completed school projects, how they are framed in publicly available documentation, or whether they are explicitly aligned with net-zero, embodied-carbon or energy-performance targets.

In this context, MMC is understood to include prefabrication, modularisation, volumetric off-site manufacturing and digitally integrated design-to-production workflows [2], while IoT encompasses sensor networks and building-management systems capable of streaming data on energy use, environmental quality, occupancy and equipment performance [10, 11].

This paper addresses these gaps through a descriptive multiple-case study of 17 New Zealand school projects with identifiable MMC typologies and confirmed IoT sensor deployment. The objective is to map how MMC and IoT are documented and justified in these projects, and to assess the extent to which sustainability and carbon-reduction narratives are integrated into their public reporting.

2 Methods and Materials

2.1 Study Design

The study adopts a descriptive multiple-case research design following Yin's approach to case study research [12], focusing on mapping patterns of adoption and framing rather than testing causal relationships. The unit of analysis is the individual school campus (primary, intermediate, secondary and kura kaupapa Māori).

Purposive, multi-stage sampling was used to identify and select cases from the national Directory of Educational Institutions and associated MoE property information [13]. Eligible schools were state or state-integrated institutions that:

- completed significant capital works between 2015 and 2024
- demonstrated some use of MMC
- deployed IoT monitoring systems, and
- showed at least some net-zero or sustainability framing at policy or design level.

Initial screening of MoE and public documentation yielded approximately 35–40 schools with recent capital activity and potential MMC involvement. A more detailed documentary review then confirmed the presence of (1) MMC components, (2) IoT systems and (3) sustainability framing. From these, 17 schools were selected to ensure variation in region, school type and project type (new builds, major redevelopments, roll-growth additions and resilience/recovery works). Schools are anonymised as S1–S17.

2.2 Data Sources and Coding Framework

Data were collected from publicly accessible sources including GETS tender documents, MoE property data, council consent records, architect and contractor case studies, Education Review Office (ERO) reports, media coverage and vendor listings. For each school, a within-case summary was compiled, and key information was extracted into structured coding tables.

A multi-dimensional coding framework operationalised three primary domains:

- **MMC typologies** – manufacturing location (off-site/hybrid/traditional), component scale (volumetric/panelised/structural) and deployment intent (permanent/temporary/adaptive), drawing on MMC literature and UK off-site classifications [2, 14].
- **IoT functions** – confirmation of hardware deployment; intended function (environmental monitoring, building management system, occupancy detection); platform governance (stand-alone vs. integrated, cloud management, open vs. proprietary protocols); and occupant-facing transparency (real-time dashboards vs. opaque backend systems) [6, 10, 11, 15].
- **Carbon reduction claims** – presence and strength of sustainability framing, ranging from explicit building-level net-zero targets to broader programme-level or values-only statements, covering both operational and embodied emissions where stated [7].

Modular classroom blocks were coded as OP-V (off-site, prefabricated, volumetric, permanent) and OP-V-R (off-site, prefabricated, volumetric, relocatable) for analysis. The multi-stage case selection and analysis process is shown in Figure 1.

3 Results

3.1 Audit Group Overview

The audit examined 17 NZ school campuses across eight regions (Auckland, Wellington, Waikato, Bay of Plenty, Hawke's Bay, Christchurch, Palmerston North, Lower Hutt). Group composition: primary schools (8), intermediate (4), secondary (4), kura kaupapa Māori (1). Projects ranged from new builds (3), major redevelopments (7), roll-growth additions (4), and resilience/recovery initiatives (3). For each school, approximately 6–28 distinct documents were available, providing sufficient material to reach theoretical saturation for the descriptive aims of the study.

3.2 MMC Adoption

Only 18% of schools (3 of 17) demonstrated MMC. Despite government policy accelerating MMC adoption to 60% of new classrooms in Q1 2024, only a minority had publicly documented evidence of MMC, reflecting a public-sector documentation gap.

3.2.1 Case 1: TKKM Te Ara Wahanui (S8)

Minister Erica Stanford announced OP-V construction for 8 modular classrooms [16], emphasizing operational efficiency: "By using modular construction, we can deliver classrooms more quickly." Classrooms designed for 20-to-50-year lifespan. Public narrative focused on safety and warmth; no explicit sustainability or carbon-reduction language despite government climate commitments.

3.2.2 Case 2: Addington Primary (S9)

CEBUS relocatable block (OP-V-R, 192 m^2, $235,594) deployed May 2024. Previously relocated; designed for future relocation. Part of post-earthquake rebuild (2015–2020), exceeding Building Code standards. Framed as "stronger, safer" rebuild without net-zero claims.

3.2.3 Case 3: Ōtūmoetai College (S14)

$47M redevelopment addressing weathertightness and capacity [17]. Multiple prefab classrooms on field to be removed [18]. Existing OP-V-R stock; unclear if new modular units will replace structures. Carbon narrative driven by "leaky buildings" rather than sustainability.

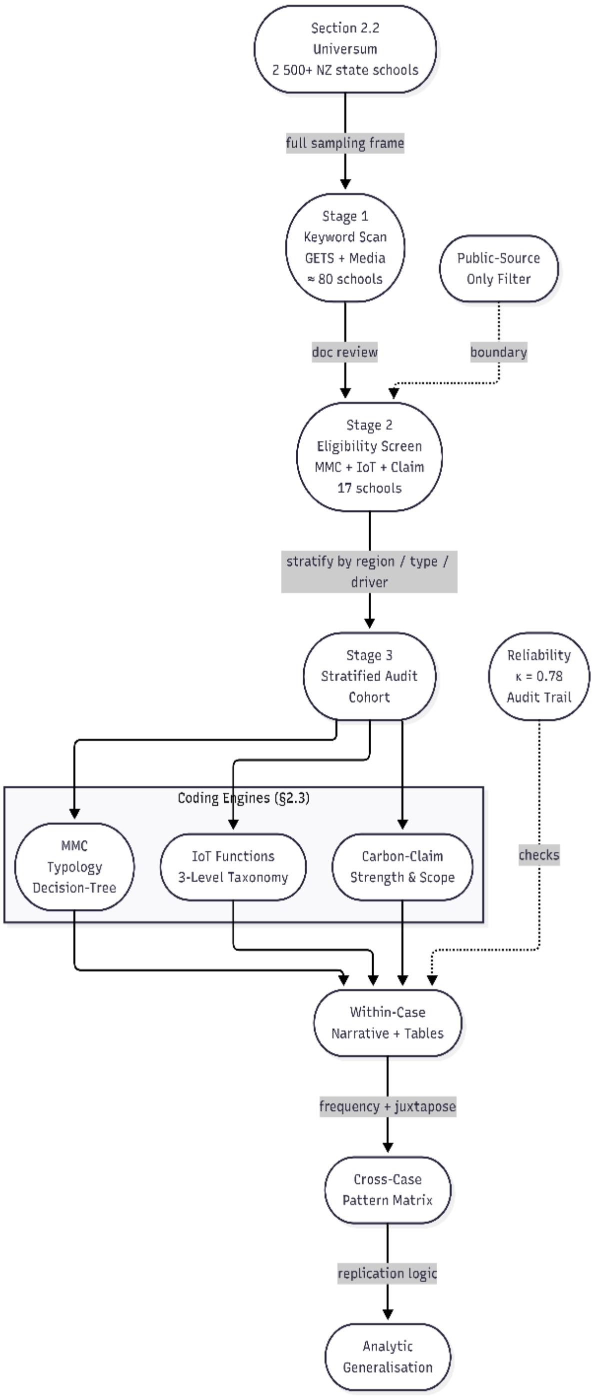

Figure 1. Multi-stage case selection and analytic workflow of MMC and IoT-enabled school buildings.

3.3 IoT and Smart Building Systems

All 17 schools had confirmed IoT infrastructure via MoE TeH programme documentation and IoT provider lists. Zero schools publicly documented BMS, data governance, or performance expectations, creating a transparency gap. Without school-level documentation, system functionality cannot be classified.

The MoE TeH programme plans national rollout to all 2,500 state schools by 2030. Investment: \$12.5–25M (\$5,000–10,000 per installation). All 17 schools are part of a managed, standardised IoT rollout. Heterogeneity in outcomes (energy performance, occupant comfort) is unlikely to reflect system design but rather building typology, envelope performance, and occupancy patterns.

3.4 Carbon Reduction Claims and Sustainability Narratives

Overall, the carbon claim distribution for the 17 schools showed that none used explicit terms like "Net-Zero," "Zero Carbon," or "Carbon Neutral." Only 12% of 17 schools demonstrated any form of implicit sustainability framing through formal environmental certifications or embedded programmes.

Sustainability framing dissociated from procurement. Capacity, cost, and schedule are primary drivers, environmental performance secondary or absent.

3.4.1 Case 4: Waterloo School (S16)

S16 demonstrates institutional commitment to sustainability as a whole-school ethos through Enviroschools Bronze certification active since 2014, with evidence from ERO reports stating that ecological sustainability is highly evident in the school's philosophy and values, although there are no explicit net-zero claims or building-specific carbon targets in its substantial property redevelopments [19].

3.4.2 Case 5: Te Kauwhata Primary School (S17)

Strongest implicit sustainability commitment: Enviroschools Green-Gold certification (2024, highest level). Formal programmes include Community Compost Hub and solar-heated pool for GHG reduction. However, capital activity tenders lack construction method or embodied carbon documentation. Focus on operational metrics (waste, solar) without building-level net-zero strategies.

3.5 Co-Adoption Patterns: MMC, IoT, and Sustainability Alignment

Fusing the three domains reveals three main co-adoption patterns:

- **Full convergence (MMC + IoT + explicit net-zero claim)** – No school in the sample combined documented MMC use, IoT monitoring and explicit building-level carbon-reduction targets.

- **Hardware-only adoption (all 17 schools)** – Every school had IoT infrastructure through TeH, but almost none linked this hardware to measurable energy or carbon-performance expectations, and only a small minority documented MMC. In these cases, MMC and IoT appear as independent responses to capacity and operational pressures rather than components of an integrated net-zero strategy.
- **Split adoption (~82%)** – Most schools combined IoT deployment with traditionally documented or unspecified construction typologies. In other words, smart-monitoring infrastructure is being rolled out regardless of whether buildings use MMC or conventional construction, with little evidence that the two are co-designed for carbon outcomes.

These patterns point to a structural gap: technology adoption is not currently being harnessed to deliver or verify progress towards net-zero commitments at the level of individual school projects.

As shown in Table 1, only 3 schools (18%) had documented MMC components, despite national policy pushing for 60% adoption. All 17 received IoT sensors, yet none reported data usage or governance publicly. Similarly, no schools set explicit carbon targets.

4 Discussion

4.1 The Documentation Paradox: MMC Adoption versus Visibility

The gap between 60% national MMC adoption (Q1 2024, up from 20% in Q4 2023) and only 18% documented MMC use in this cohort signals systematic transparency deficits in public-sector reporting [4]. This discrepancy does not indicate low adoption; rather, it reveals that construction innovation proceeds without public accountability mechanisms.

Documented cases (S8, S9, S14) consistently emphasized operational efficiency, speed, cost, resilience, over embodied carbon reduction, despite NZ's legally binding net-zero by 2050 target. S8's ministerial announcement framed modular construction as delivering "classrooms more quickly" without referencing lifecycle performance. S14's decommissioning of existing prefab classrooms in favour of permanent structures suggests institutional preferences for traditional construction despite MMC availability. This pattern reflects immediate capacity pressures overriding environmental considerations in procurement decisions.

Addressing this gap requires standardized reporting protocols that mandate disclosure of MMC typology, embodied carbon estimates, and operational performance expectations in all publicly funded school projects. Without such mechanisms, policy acceleration proceeds independently of climate accountability.

4.2 Universal IoT Deployment, Opaque Governance: The Te Haratau Programme

The TeH programme's three pillars: condition assessment, fitness for purpose and operational efficiency (energy monitoring), establish a data infrastructure unprecedented in the sector.

Table 1 also shows that 17 schools (100%) confirmed IoT deployment measuring CO_2, temperature, and humidity, yet zero schools publicly documented BMS configurations, data governance protocols, or environmental performance dashboards. This opacity raises critical questions about transparency and occupant agency, particularly in educational settings where children constitute the monitored population. While the MoE centrally manages TeH data via cloud platform, lack of school-level documentation on algorithms or system interoperability prevents independent evaluation of effectiveness.

Aligning TeH with net-zero ambitions would therefore require not only technical rollout but also governance frameworks that specify responsibilities, transparency requirements and mechanisms for linking IoT-derived insights to measurable energy and carbon-performance indicators at school level. The national IoT infrastructure therefore represents a latent platform for net-zero implementation, but only if governance, transparency and integration with BMS are strengthened.

4.3 Decoupled Narratives: Construction Innovation without Sustainability Targets

The most consequential finding is systematic decoupling of MMC and IoT adoption from explicit sustainability performance targets. No schools articulated net-zero, zero-carbon, or carbon-neutral claims. As summarised in Table 1, only 12% (n=2) demonstrated implicit sustainability commitment through formal Enviroschools certification, while 41% (n=7) framed capital projects through resilience and post-disaster recovery rather than climate mitigation.

This decoupling from the Carbon Neutral Government Programme [8] and 2022 Emissions Reduction Plan [9] suggests procurement narratives prioritize operational drivers capacity, cost, speed, resilience over environmental performance. The gap reflects immediate capacity pressures, absence of mandatory embodied carbon caps in Building Code, and persistent institutional knowledge gaps identified in zero-carbon building research [7]. Without enforceable mechanisms linking MMC and IoT adoption to carbon performance targets, technological innovation proceeds independently of climate commitments, under-

Table 1. MMC, IoT, and Carbon Framing Across 17 NZ Schools.

Dimension	Category	Count (n=17)	%	Notes
MMC Documentation	Documented MMC Use	3	18%	All were off-site volumetric; 2 temporary, 1 permanent
	Unknown / No Documentation	14	82%	Indicates a significant public documentation gap
IoT Deployment	Sensors Installed	17	100%	Standard MoE rollout (Temp, CO_2, Humidity)
	Public Data / Dashboards	0	0%	No BMS, transparency, or governance disclosed
Carbon Framing	Explicit Net-Zero Targets	0	0%	No formal carbon or energy benchmarks published
	Implicit Framing (e.g. Enviroschools)	2	12%	Green-Gold and Bronze certifications
	Resilience-Focused Framing	7	41%	Projects linked to earthquakes / recovery
	No Sustainability Framing	8	47%	No carbon / environmental goals evident

mining policy coherence between infrastructure delivery and emissions reduction objectives.

Given their scale, standardisation and central governance, New Zealand schools represent an ideal scene for developing structured net-zero procurement and reporting practices that could subsequently be extended to broader public infrastructure.

5 Conclusion

This case study reveals a paradox in New Zealand's school-building programme: despite accelerated MMC deployment (60% of new classrooms, 2024) and universal IoT rollout, these innovations remain disconnected from net-zero-by-2050 commitments. Across 17 schools, only 18% published construction documentation; none disclosed carbon targets or data-governance protocols. The gap is institutional: procurement rewards speed and cost while Building Code imposes no embodied carbon limits. As New Zealand's most standardized public infrastructure, schools offer strategic opportunity to develop reporting protocols linking construction innovation to measurable emissions reduction, providing a replicable framework for broader public infrastructure decarbonization.

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