PRJECT 21: REGULATORY REFORM FOR INDUSTRIALISED CONSTRUCTION

FINAL REPORT

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CONTENTS

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1. EXECUTIVE SUMMARY

The construction industry is evolving toward industrialised building methods, particularly off-site prefabrication, to improve efficiency, reduce costs, and enhance quality. However, regulatory frameworks in Australia have traditionally been structured around conventional on-site construction, creating barriers for modern methods such as modular and prefabricated building systems.

Given the Australian government's commitment to addressing the national housing supply shortfall through off-site construction, regulatory reform is critical. This study examines the challenges associated with current regulations and proposes reforms to improve compliance, streamline approvals, and enhance industry confidence in off-site construction.

This study was conducted in four key stages:

1. **Background Research:** Examining regulatory barriers to off-site construction in Australia and status of off-site construction compliance requirements internationally to identify potential reform strategies.
2. **Regulatory Framework Analysis:** Evaluating Commonwealth and state-level regulatory frameworks (New South Wales, Queensland, Victoria) and their impact on off-site construction.
3. **Case Studies:** Analysing real-world examples, including fire compliance issues, wet area pod production, international best practices (e.g., New Zealand's BuiltReady, the UK's Robust Details, and US ICC standards), and the role of technology in compliance verification.
4. **Workshops:** Conducting three industry workshops with participation from government bodies, regulators, and industry stakeholders to test and refine proposed reforms.

Key regulatory challenges identified in this study are as follows.

- Compliance pathways: Existing compliance pathways, particularly "Deemed-to-Satisfy" (DtS) provisions in the National Construction Code (NCC), do not adequately accommodate off-site construction, leading to reliance on complex and costly performance solutions.
- Lack of Standardisation: Australia lacks a unified classification system for prefabricated components, resulting in inconsistencies across jurisdictions and complicating approval processes.
- Certification Gaps: Existing certification schemes, such as CodeMark and WaterMark, focus on individual products rather than entire modular assemblies, leading to fragmented compliance pathways.
- Jurisdictional Barriers: Regulatory inconsistencies across Australian states create challenges in recognising prefabricated components approved in one state but installed in another.
- Inspection and Compliance Issues: The role of building surveyors and certifiers in off-site compliance lacks clarity. Off-site construction often results in redundant inspections, either requiring multiple approvals for the same components or delaying manufacturing efficiency while awaiting on-site verifications.
- Lack of Futureproofing: The current regulatory framework does not adequately account for emerging technologies and evolving construction practices, potentially stifling innovation in the sector.

To address these issues, the study proposes a series of regulatory reforms aimed at streamlining compliance and fostering innovation in industrialised construction.

- Development of a Unified Classification System: Establish a standardised national framework to classify prefabricated components, ensuring consistency in regulatory interpretation and approval processes.
- Expansion of Certification Schemes: Modify CodeMark and WaterMark to certify entire modular assemblies rather than individual products, drawing inspiration from international best practices such as New Zealand’s BuiltReady scheme.
- Harmonisation of State Regulations: Implement a nationally recognised system for prefabrication approvals, reducing the need for state-by-state re-evaluations of prefabricated components.

- Revised Inspection Protocols: Introduce a risk-based approach to inspections, where certified off-site manufacturers undergo third-party audits, reducing the need for repetitive on-site inspections. Facilitate digital compliance mechanisms, such as real-time monitoring and traceability frameworks, to improve oversight without delaying production.
- Fire Safety and Quality Assurance Enhancements: Implement regulatory provisions specifically addressing fire safety risks associated with modular construction, particularly at interface points where prefabricated and in-situ elements connect.
- Legislative and Policy Adjustments: Amend key regulatory documents, including the National Construction Code (NCC), to explicitly recognise off-site construction as a building method with distinct compliance pathways. This can include integrating off-site-specific DtS provisions.

Australia's current regulatory framework is not well-suited to support the growth of industrialised construction. Without reform, compliance inefficiencies will continue to hinder the adoption of prefabrication and modular building techniques. This study recommends a coordinated national approach to regulatory reform, focusing on streamlined certification, harmonised state regulations, and modernised compliance pathways. These reforms will help unlock the full potential of industrialised construction, supporting cost-effective, high-quality, and efficient building delivery in Australia.

Definitions and acronyms

ABCB	Australian Building Codes Board.
CodeMark	CodeMark Certification Scheme, the voluntary third-party building product certification scheme, administered by the ABCB.
MMC	Modern Methods of Construction. This report adopts the definition introduced by the UK that includes a spectrum of emergent and emerging technologies that transfer construction activities to manufacturing sites (generally off-site).
NCC	National Construction Code
Pre-manufacturing	Means the production of building components that may be manufactured off-site, near-site or in temporary on-site factories. It encompasses both the process of manufacturing, and the materials and process innovation involved in the manufacturing process.
Volumetric modular construction	While the term has a broader application in the literature, this report focuses on non-structural assembly of volumetric pods, including bathrooms, kitchen assemblies, combined bathroom/kitchen assemblies, unitised mechanical electrical equipment assembles. This definition aligns with the 'volumetric pods' subcategory of Category 5 of UK government MMC categorisation framework.

CHAPTER 1 - PROJECT OVERVIEW

Introduction

In buildings, a project design must be approved for regulatory compliance and then during construction, mandatory inspections must be conducted at prescribed stages to ensure the actual work faithfully complies with the approved design.

What is less apparent, is that underlying assumptions about traditional construction potentially disadvantage modern methods of construction including the likes of off-site assemblies; these are typically produced off-site, and this may occur locally, interstate or even at overseas locations.

Any practice that deviates from the received orthodoxy of on-site building tends to fall outside mainstream regulatory practices. At times, this makes traditional compliance and inspection practices difficult or impossible to achieve once assemblies are fabricated off-site.

Further, the limitations of certification and compliance procedures have become increasingly evident to the extent that some off-site assemblies are potentially inspected multiple times or require manufacturing efficiency to be delayed whilst awaiting inspection by an on-site inspector. Such issues effectively erase the potential cost and efficiency benefits of prefabrication.

Still further, jurisdictional issues become apparent where parts that have been manufactured and approved in one state are assembled and need to be approved again in another, thereby reducing competitiveness and market capacity.

At worst, regulatory practices may be causing barriers to industrialised construction processes rather than creating standardised and streamlined pathways for much-needed innovation.

This study therefore focuses on regulatory reform to improve the efficiency and ease of compliance for off-site construction. It aligns with the recent moves within the government to utilise off-site construction to help address the housing supply shortfall. For instance, a national target of constructing 1.2 million new homes over the next five years has been set by the Federal government and potential cost savings have been highlighted by leveraging advanced manufacturing technology, supply chains, and building techniques[1]. Further, federal, state, and territory building ministers directed the Australian Building Codes Board (ABCB) to consult with the industry to recommend regulatory improvements that would stimulate Australia's prefabricated and modular housing industry[1].

As the building industry inevitably accelerates towards an industrialised future, this report undertakes a deep investigation to answer the following questions:

1. How can current regulation be improved to accommodate the whole spectrum of industrialised building practices? For the purposes of this study, industrialised building focuses on off-site construction inclusive of prefabrication, modular, penalisation, and volumetric construction.
2. How can such regulatory reform be ‘future proofed’ for the anticipated changes we foresee resulting from the next chapter of building innovation?

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[1] *Department of Industry, Science and Resources. (2024). Building Ministers’ Meeting: Communiqué March 2024. News. Australian Government. Available at: https://shorturl.at/3lmts. Retrieved June 2024.*

Objectives of this study

The objectives of this study include:

1. Inform future adjustments to current regulations to accommodate industrialised building practices.
2. Certification and Compliance – create standardised and accepted regimes; efficient processes; and accepted evidence trails for compliance.
3. New technology, processes and service delivery – focus on efficient, fast, reliable, simple inspection, simple to organisationally implement.
4. 'Futureproof' the above regulatory reform where possible.

Scope of study

In order to avoid an overly broad study that only serves to deliver diluted conclusions, the scope of this study focuses on specific aspects of industrialised construction that focus on:

- Panelised and volumetric construction (see below for further detail on this)
- Off-site production and subsequent onsite installation processes
- Design compliance with the above
- Process-related issues of the above
- Regulatory compliance frameworks impacting on the above including the National Construction Code (NCC) and state regulatory frameworks (Queensland, New South Wales and Victoria).
- The study does not cover relocatable or temporary structures, as may be used for special events and/or temporarily during building work. Such structures are not classifiable under the NCC and are therefore considered to be outside the scope of this study.

Initial consultation with project stakeholders (and others) indicated that the above areas are particularly relevant in having an ongoing impact.

Also, Mobile homes, or manufactured housing, are widely used in the U.S. for affordable housing and benefit from special mortgage options, though they face restrictions on location due to land use and urban planning regulations. In Australia, mobile housing is less common and is subject to standards different from traditional construction, with fewer urban planning requirements. However, mobile homes are considered to have limited relevance to technical construction compliance and will not be further considered in this study.

This report is organised into several chapters, each addressing key aspects of the study. It begins with an introduction, which outlines the objectives and scope of the research. Chapter 2 details the study design, explaining the steps involved in conducting the research and collecting data. The Background section in Chapter 3 provides a comprehensive overview of emerging issues related to regulatory reform for off-site prefabricated construction in Australia. It also highlights strategic and overarching approaches to off-site construction adopted internationally, drawing on examples from Europe, Canada, the US, the UK, New Zealand, and Singapore. Chapter 4 focuses on terminology, exploring definitions related to different types of off-site prefabricated construction and the categories proposed both nationally and internationally. This is followed by Chapter 5, which examines the Commonwealth government's regulatory framework. Chapter 6 delves deeper into statutory regulations specific to New South Wales (NSW), Victoria (VIC), and Queensland (QLD)—states known for their major construction projects.

Chapter 7 addresses fire safety, a critical area of regulation with significant implications for off-site prefabricated construction. Chapter 8 explores Quality Assurance (QA) and Quality Control (QC) processes, particularly the role of certifiers in maintaining standards. The Case Study chapter (Chapter 9) begins by exploring fire compliance issues identified in specific

Australian projects. It then addresses regulations related to prefabricated plumbing modules for wet area pods, alongside relevant directives from the Commonwealth government and the state of Victoria. The chapter also highlights three internationally practised solutions: New Zealand's BuiltReady Scheme, the UK's Robust Details, and the International Code Council (ICC) standards from the United States. Additionally, it examines the role of technology in defect identification and QA processes, with a focus on the importance of inspecting concealed components. A case study on traceability frameworks in Australia is also included, detailing the requirements for manufacturers to provide verifiable evidence of product use.

Findings from three workshops are presented in Chapters 10, 11, and 12, focusing respectively on NCC compliance for off-site construction, regulatory challenges for wet area pods, and inspection processes. The report then introduces the Feedback Loop in Chapter 13, which outlines targeted stakeholder feedback strategies aimed at disseminating research findings to those best positioned to implement regulatory changes. The report concludes with Chapter 14, which provides recommendations for future regulatory reform in off-site construction, summarising the insights gained from the study and proposing actionable pathways for improvement.

CHAPTER 2 – STUDY DESIGN

This study was conducted according to progressive steps, whereby the themes that became apparent in the earlier steps informed and directed the content and approach of the later steps. Recurring themes were tested at each stage to gradually determine the importance of weighting issues and findings. This study was conducted with ethics approval from the Queensland University of Technology (QUT) Human Research Ethics Committee (Approval Number: LR 2024-8299-18081). The study was conducted through four stages, explained below.

Stage 1- Background

This section specifically examines general problems and arising issues concerning the regulation of off-site construction within Australia and in addition, the general status of regulatory compliance for off-site construction abroad. The objective was to gain an overview of the practical challenges, and the approaches used, compared to traditional construction methods. The intent was to identify and consolidate potential opportunities for reform in Australia.

Stage 2- Regulatory frameworks and implementations

This section provides a description and analysis of both Commonwealth and State-based building legislation and regulation, including how these may apply to off-site construction. The aim of the analysis was to offer a foundational understanding of statutory processes, covering the NCC, building approval procedures, and mandatory or recommended inspection stages during construction. This State-based inquiry focused on the three most active states in both traditional and off-site construction: New South Wales (NSW), Queensland (QLD), and Victoria (VIC). Data was sourced from websites, documentation, and interviews with regulatory bodies, practitioners, and peak industry bodies.

This section identifies and analyses the role of certifiers and surveyors as approvers, checkers, and inspectors of compliance on a project-by-project basis. It also explores alternative certification options such as self-certification and third-party certification, which may better address the specific needs of prefabricated/off-site construction. Additionally, it investigates quality assurance (QA)/quality control (QC) systems to support the reliability and confidence of these alternative certification methods. Data was gathered from peak bodies such as the Australian Institute of Building Surveyors (AIBS), reviews of State-based regulations for certifiers and surveyors, relevant standards, interviews with specialists involved in self/third-party certification, and academic literature.

Stage 3- Case studies

The case studies aimed to provide a more nuanced and practice-based understanding of regulatory issues relating to off-site construction and the solutions practised overseas. They were undertaken in a multifaceted way with details provided below.

1. Case study 1 focused on fire-related compliance issues encountered by practitioners. These cases were sourced from project stakeholders and practitioners attending industry prefabrication conferences, who were asked to share regulatory challenges or obstacles that hindered the adoption of off-site construction. Interviews were then conducted, and relevant web links and documentation were provided. The findings have been presented as snapshot-style vignettes to highlight key and recurring themes in practitioner experiences. Data was collected through semi-structured interviews with professionals who had firsthand knowledge, including project managers, architects, contractors, fire engineers, and acoustic consultants.

2. Case study 2 examined the production and compliance processes of wet area pods, a prominent form of modular construction in Australia. The investigation began with a document analysis of relevant guidelines in Australia and then focused on two large manufacturers based in Victoria and New South Wales, which collectively produced over 8,000 pods annually for markets including apartments, student housing, hospitals, and aged care facilities. Through observations and meetings with manufacturers, clients, and regulators, the study explored production systems, quality assurance (QA) and quality control (QC) mechanisms, regulatory pathways, and compliance challenges.
3. Case study 3 explored potential international solutions for addressing compliance in off-site construction in Australia. Data collection included interviews and analysis of web sources, focusing on international systems such as Built Ready (New Zealand), Robust Detail (United Kingdom), and the International Codes Council (United States). By drawing on global experiences, this section provided insights into potential strategies and practices that could be adapted to the Australian context.
4. Case study 4 on digital technology can be used to assist confidence in compliance concerning off-site construction. Two technologies were investigated including image recognition and product traceability databases; data was obtained via literature, online sources and interviews. The former investigated technologies that can be potentially used to inspect and record compliance at progressive stations on prefabrication production lines for defect identification, pattern identifications and measurable features of objects and related tolerance[2]. The latter focused primarily on a traceability framework aimed at compliance data for individual building products as undertaken by National Building Products Coalition. Among other things, the framework aims to strengthen NCC evidence of suitability requirements.

Stage 4- Workshops to explore, test and refine regulatory reform options in Australia

This phase included three workshops: two in-person workshops, held in Sydney and Melbourne in collaboration with the Australian Building Codes Board (ABCB), and one online workshop conducted in partnership with the Victorian Building Authority (VBA). Prior to the workshops, several preparatory meetings were conducted to establish key issues, approaches, and strategies for the workshops in collaboration with this research project's partners, including the ABCB and VBA. These discussions were invaluable for the research team, enabling them to identify and engage the most relevant participants from industry, government bodies, and academia.

Data collection during all workshops was conducted through direct observation, expert presentations, and participant discussions. The workshops were recorded and converted to transcript for analysis purposes. Detailed notes were taken during Q&A sessions to capture further insights into the concerns and proposals of participants. The research team reviewed the notes and transcripts following each workshop and coded the discussions to identify recurring themes. Challenges were grouped into categories, and solutions were aligned with each challenge to provide a comprehensive understanding of the regulatory barriers and potential pathways for enhancing compliance in off-site construction. Further details for each workshop are provided below:

1. The Sydney workshop was developed based on themes identified in earlier stages of the project. It focused on improving compliance pathways within NCC, specifically targeting the need for faster, simpler, and less risky processes related to off-site construction. The half-day event attracted 54 participants, with 42 attending in person and 12 joining online (Figure 1). Working with the ABCB enabled an agreed strategy, agenda, presentation approach, and data-sharing strategy. This partnership was valuable in securing key participants from peak industry bodies, Commonwealth organisations, and state regulatory

[2] Note: these instances were from applications in other industries as no significant instances in construction could be found despite inquiring with multiple sources overseas including large construction assembly robotics manufacturers such as Randek (Sweden).

authorities, with many attendees travelling from interstate. The participants included representatives from industry associations, off-site manufacturers, contractors, and both state and federal regulatory bodies. This diverse group fostered robust discussions on the regulatory challenges and opportunities for off-site construction, considering a wide range of perspectives.

2. The online workshop, held after Workshop #1, was a two-hour session conducted in collaboration with the Victorian Building Authority (VBA). It focused on plumbing-related challenges associated with wet area pods, such as bathroom pods. The agenda was developed in partnership with the VBA, and this collaboration proved valuable in securing relevant participants from the plumbing industry. The workshop had 7 participants, including representatives from professional associations, unions, and technical experts (Figure 2).
3. The Melbourne workshop built on themes and findings from earlier stages of the project, as well as insights from the Sydney and the online workshop. It focused on changing from traditional onsite inspection of compliance to off-site certification models. The half-day event gathered 51 industry experts, regulators, and stakeholders, with 40 attending in person and 13 joining online (Figure 3). Held in collaboration with one of the major off-site construction manufacturers and the ABCB, the agenda was agreed upon by all parties prior to the event.
4. The participants included representatives from peak industry associations, off-site manufacturers, contractors, as well as state and federal bodies with (direct/indirect) interest in regulatory issues. The workshop began with facilitators outlining the objectives of compliance checking including comparative pros and cons between traditional onsite and off-site approaches. Compliance frameworks were identified as well as alignment with State regulatory requirements. This was followed by a short survey to gather participants' insights on key challenges affecting the implementation of off-site construction. The event host, an off-site construction manufacturer, presented compliance pathways for the wet area pods they produce, while Standards Australia provided updates on off-site construction in Australia. After each presentation, participants engaged in discussions and Q&A sessions. A practical component included a tour of the host's factory and a live demonstration of their construction processes. International solutions, such as BuiltReady (NZ) and International Codes and Standards (US), were presented and explored, with representative speakers discussing these certification schemes. The research team collected data through observations and recordings of presentations and discussions, identifying recurring themes and aligning them with solutions to address regulatory barriers in off-site construction.
5. The results from each of the applied stages are elaborated in the following sections. These results provide a comprehensive understanding of insights gained throughout the process.

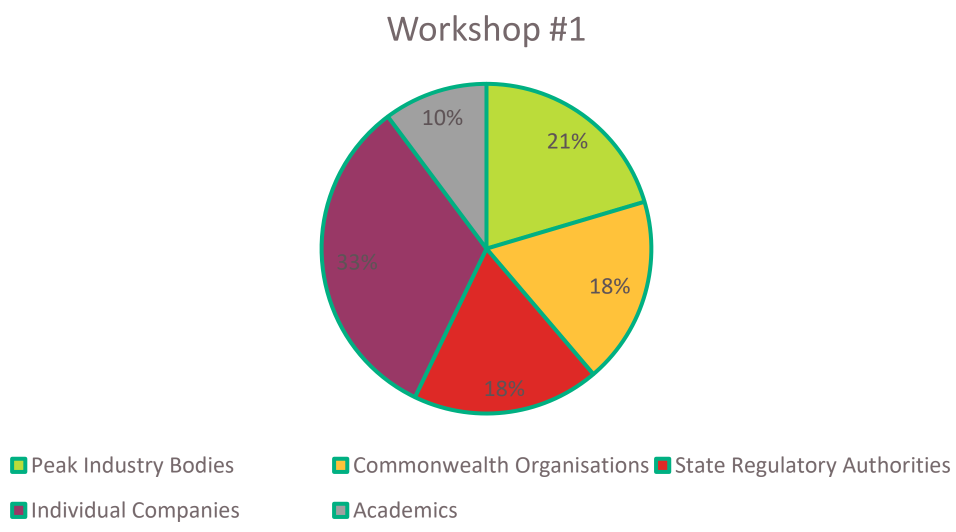

Figure 1 Workshop #1 participants

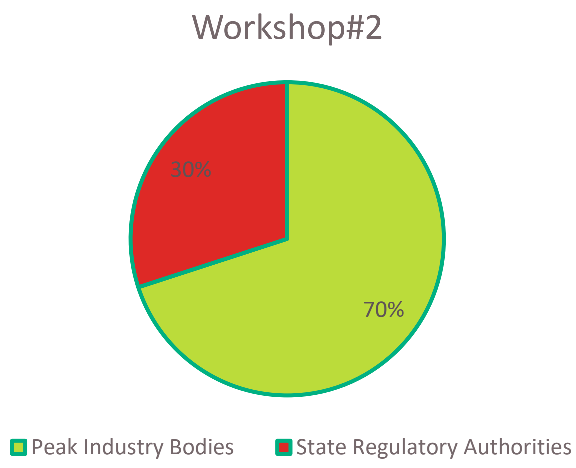

Figure 2 Workshop #2 participants

Figure 3 Workshop #3 participants

CHAPTER 3 - BACKGROUND

This section presents a broad overview of arising issues regarding regulatory reform for off-site construction, both within Australia and internationally. This background section specifically examines practice-based problems and solutions concerning the impact of regulations and compliance on off-site construction. The objective is to gain insights into the practical challenges in achieving compliance through off-site construction, compared to traditional construction methods. The review encompasses international sources, with a focus on how compliance processes are addressed in various regions, including the Europe, Canada, US, the UK, New Zealand and Singapore. In some instances, examples from parallel industries were considered to illustrate how regulatory changes are managed in different sectors.

Additionally, the background analysis explores statutory compliance in industrialised construction across various countries. This provides a comparative framework, allowing for benchmarking and the identification of methods that could potentially benefit the Australian context.

Background Within Australia

Until recently, relatively little has been published on off-site construction and its regulation within Australia. In undertaking this study, key prompts have come from previous studies that have identified regulatory barriers that impede the progress of off-site construction in Australia. Of note, the Housing Industry Association (HIA) and Swinburn University published a detailed report entitled Regulatory barriers associated with prefabricated and modular construction (2022)[3]. It involved broad coverage of the construction supply chain as can be seen in Figure 4.

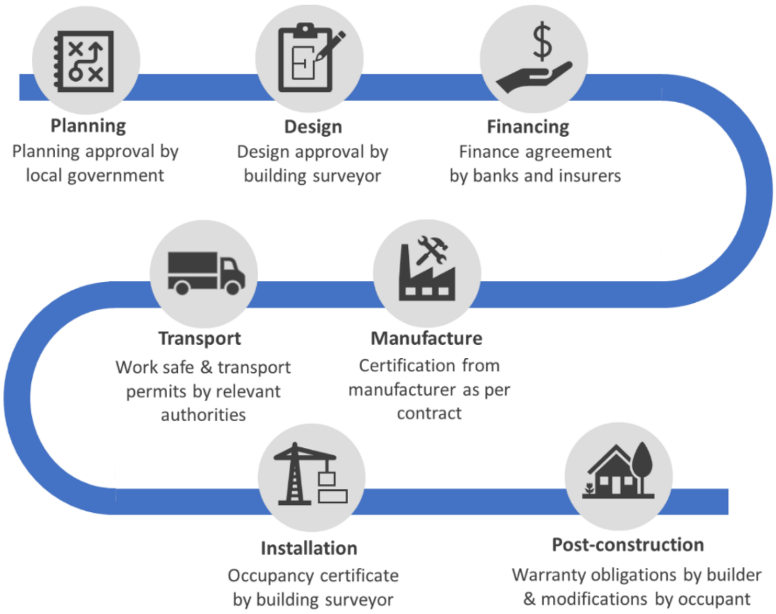

Figure 4 Off-site construction supply chain

[3] *Housing Industry Association Ltd. (2024). Prefab and modular construction. Accessed at: https://hia.com.au/our-industry/prefab-and-modular-construction. Retrieved on June 2024.*

The study covered international and local practices using interviews, meetings, and survey-based data collection methods. The main findings and recommendations were:

- A lack of formal recognition for off-site and modular construction as acceptable construction practice in both planning and building regulations.
- A lack of standard definitions for off-site construction which causes ambiguity, uncertainty and inconsistencies that hinder regulatory approval and as a consequence, reduce market uptake. The report recommends standardised terminology and identification of ways to provide prescriptive and performance requirements in the NCC to support approval.
- The role of inspectors for off-site work is unclear. Guidance is needed to demonstrate compliance at various stages.
- The quality of off-site construction products needs to be assured since on-site inspection cannot necessarily verify work undertaken off-site.
- Certification of off-site work could be a means to increase the confidence of all practitioners.
- Barriers exist in the design rules, approvals processes and financing arrangements, particularly for housing.
- The product certification system needs improvement to cope with testing and approving innovative prefab products. A manufacturer certification scheme is suggested.
- Supply chain responsibilities are unclear as prefab components transition from off-site fabricated products to on-site building work.

The report's section on design guidelines and standards provides guidance on arising issues for off-site construction such as transportation loads, component rigidity during lifting and transport, precision and tolerance requirements, and connection and integration requirements. These guidelines apply to various construction materials, building classes, and both 2D and 3D assemblies.

Among other contributions within Australia, a technical design guide exists, titled the Handbook for the Design of Modular Structures. It is instructive regarding a broad palette of primarily engineering design issues that potentially support solutions for a mix of regulatory and best practice issues[4] . It is mainly commentary of what ‘should’ be done, more so than a normative standard of what ‘must’ be done. The main topics covered by the handbook include:

- Structural Design: inclusive of manufacture, storage, transport and module assembly.
- Building services, Performance and Amenity: inclusive of discontinuities between modules, fire engineering, acoustic performance and thermal regulation.
- Architecture: inclusive of varying degrees of prefabrication.
- Facades and Materials: inclusive of integration of facades with modular components; material manufacturing, tolerances, quality and certification.
- Durability: longevity of the structures.
- Safety: inclusive of benefits of off-site conditions.
- Transportation, Erection, and Temporary Works.
- Disassembly, Reuse & Recyclability, Relocatable Modular Structures.
- Design for Manufacture & Assembly, Digital Engineering and Lean Manufacturing[4].

The Handbook is largely targeted at an engineering level of inquiry and to some extent this may make it less accessible to other parts of the supply chain where less is involved in detailed engineering issues.

[4] *Modular Construction Codes Board. (2017). Modular Construction Code Board Handbook: A Guide to Offsite Construction. Monash University. Accessed at: https://builtoffsite.com.au/emag/issue-04/modular-construction-code-board-handbook. Retrieved in June 2024.*

In terms of compliance, the Handbook provides guidance around design certification, performance criteria, testing-based design, and manufacturing testing where robust verification is emphasised (p47). It also identifies targeted areas for physical inspection such as interfaces between in situ and modular assemblies; spaces between modules; locations hidden from sight/accessibility; fire resistance at joints; cavities, and service penetrations between modules.

Another aspect calls for production processes to adhere to formal certification processes using themes from AS/NZS ISO 9001 Quality Management Systems as a means of creating confidence in the reliability of compliance (i.e. for work undertaken off-site work and therefore not inspected using traditional onsite means). Without evidence of conformance there can be no confidence that production requirements have been assessed or attained.

Background Internationally

Regulatory requirements and reform for off-site construction vary significantly around the world and so this section primarily focuses on strategic or overarching approaches used in different countries. This includes both enabling examples as well as problematic situations. The approach here has been selective, with a focus on advanced economies and those with strong uptake of off-site construction.

Canada

Arguably the best snapshot of current regulatory compliance practice in Canada clusters around four Standards applicable to factory-constructed homes, prefab, and modular construction as follows:

- CSA A277- Procedure for certification of prefabricated buildings, modules and panels i.e. the primary administrative standard for off-site construction compliance and utilisation of QA.
- CSA Z240 MH- Series-16 (R2021): Manufactured Homes i.e. this standard enables simplified compliance for single-storey, single-family, detached houses.
- CSA Z240.10.1- Site preparation, foundation, and installation of buildings i.e. encompasses technical specifications, quality control measures, markings, and installation instructions.
- CSA Z250- Process for Delivery of Volumetric Modular Buildings. i.e. design, quality control, approvals, logistics, transportation, storage, lifting, placement, installation and handover[5].

In terms of off-site compliance certification processes, the standard of most direct relevance to regulatory reform here in Australia is CSA A277. It is an administrative standard (non-technical) and outlines procedures for certifying compliance of factory-constructed buildings or components with the technical requirements of the locally applicable building code and regulations. It follows quality assurance requirements that align with general quality assurance standards as per CAN/CSA-ISO 9001 and as used in manufacturing[5].

In line with CSA A277, the approval process involves several stakeholders, commencing with the Standards Council of Canada, followed by certification bodies, then factories, and concluding with local inspectors. The Standards Council of Canada accredits certification bodies, while these bodies approve and audit factory product quality and inspect products. Factories document adherence to codes, standards, and regulations applicable at the installation site, and they apply certification marks such as labels and specification sheets. Ultimately, local inspectors verify compliance at the site, and the certification marks serve as assurance that the factory work aligns with the required standards. Even so, not all jurisdictions mandate CSA A277 certification. In addition, prefab and modular buildings must

[5] *Housing Industry Association Ltd. (2024). Prefab and modular construction. Accessed at: https://hia.com.au/our-industry/prefab-and-modular-construction. Retrieved on June 2024.*

also comply with provincial and territory building code requirements and provide separate certificates confirming adherence to sustainability and energy efficiency criteria[6].

United Kingdom

In 2019, an overview of off-site regulatory issues was published by the British Standards Institute, entitled 'The role of Standards in offsite construction'[7]. At the time, it indicated that most current standards were developed for traditional on-site construction and did not address the unique requirements for off-site construction. Many existing off-site construction related standards were outdated and there was also a general lack of quality control, poor collaboration, and interface issues. Recommendations from the paper included reviewing and revising current standards, developing new standards to address gaps covering design processes, accuracy, tolerances, connections, promoting terminology consistency and knowledge sharing, guidance on common connections.

Following up on the white paper, a new standard for Modern Methods of Construction (MMC) is currently under development by BSI (commissioned by the UK Government's Department for Levelling Up Housing and Communities), which will set out recommended technical standards for building homes using a range of MMC categories. It will also define quality assurance and compliance processes for the sector[8].

Along a separate line of inquiry, companies such as UK-based Waugh Thistleton, have focused on developing a New Model Building to facilitate simplified compliance. This includes standard details at key junctions that are fully compliant with UK building regulations, to facilitate production of technical designs in off-site mass timber construction. It approximates a 'pattern' approach to construction compliance, without being overly prescriptive about how relevant details should be applied to individual projects[9].

According to Gharbia et al. (2023), third party certification is consistently used in the UK for off-site construction. In this context, organisations such as the British Board of Agreement act as an independent certification body in the Construction and Civil Engineering Industries who undertake product approval and certification, undertake audit and inspection of production facilities, accredit management systems such as ISO 9000 and also administer installer schemes for onsite works[10]. Off-site and modular solutions are a targeted part of their operations. Another organisation of relevance is the Building Offsite Property Assurance Scheme (BOPAS), who provide independent third-party accreditation of MMC providers. The aim is to provide confidence among clients, contractors and those involved in financing and insuring construction projects, regarding the quality of MMC from accredited organisations[11]. BOPAS assesses individual systems and components that can form part of a traditional build or an MMC-based structure.

New Zealand

Lin et al. (2022), focused on identifying gaps in current quality assurance processes for off-site components in New Zealand. The main gaps include a lack of standardisation especially for offshore products, unclear qualifications for third-party inspectors, and poor design

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[6] Housing Industry Association Ltd. (2024). Prefab and modular construction. Accessed at: https://hia.com.au/our-industry/prefab-and-modular-construction. Retrieved on June 2024.
7 The British Standards Institution. (2019). The role of Standards in offsite construction.
8 https://www.housing.qld.gov.au/
9 https://waughthistleton.com/
10 Gharbia, M., Chang-Richards, A., Xu, X., Höök, M., Stehn, L., Jähne, R. & Feng, Y. (2023). Building code compliance for off-site construction. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction. Vol. 15. 2nd edn. 04522056. Retrieved on June 2024.
11 https://www.bopas.org/

coordination[12]. They propose a framework for early stakeholder engagement, an emphasis on reputable third-party quality assurance entities, and manufacturer accreditation. However, to a large extent, these features are already being currently dealt with via the rapidly evolving BuiltReady scheme in New Zealand. BuiltReady is a scheme that goes beyond the premise of literature review. As a result, this foundational scheme, providing a regulatory basis for third party certification of off-site construction, is dealt with in detail as a case study, later in this report.

United States

A recent report, *Off-site Construction Housing Research Roadmap,* indicates that the United States is not particularly advanced in its uptake and regulation of off-site construction[13]. It calls for an increased need for guidelines and standards to reduce risk, which will in turn increase uptake. Such an appraisal is not surprising given that the United States appears to have a highly fragmented regulatory system, which tends to lack national consistency and instead, varies under the auspices of individual states and within these, individual variations at the local government level[14],[15]. A Codes' briefing report states that, "without clear code compliance pathways for off-site construction inspections and approvals, off-site projects can face lengthy delays, limiting the realisation of off-site construction's advantages"[16]. This becomes particularly problematic where the states' manufacturing and installation regulatory systems have different rules and this may be further complicated where, for instance, local government employees must mandatorily inspect the onsite building work, but the same people may not have legal entitlement to inspect work fabricated outside their local jurisdiction[17]. Yet another issue concerns differences in state highway regulations about allowable transport sizes (Obando, 2022)[18].

Some states have developed their own legislation and as one example, South Carolina has implemented the Modular Buildings Construction Act (MBCA)[19]. It defines modular buildings as structures built in factories and transported to sites for installation. It requires manufacturers to be certified by an approved third-party agency ensuring compliance with codes. It outlines requirements for permits, inspections, installation, and certification.

In general, most other off-site regulations may fall under International Building Code (IBC) requirements, but this is a voluntary standard, selectively called up by individual states and/or individual local governments according to perceived need[20]. It includes provision for compliance inspections to be undertaken at the modular facility by third-party inspectors on behalf of the jurisdiction, as well as on-site after installation. The inspection requirements

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12 Lin, R. et al. (2022). Developing a quality assurance framework for off-site manufactured building components: A case study of the New Zealand housing sector. IOP Conference Series Earth and Environmental Science. World Building Congress 2022. https://www.researchgate.net/publication/366119812_Development_of_a_framework_for_quality_assuran_of_off-site_manufactured_building_components_A_case_study_of_the_New_Zealand_housing_sector. Retrieved in June 2024.

13 Smith, R. et al. (2023). Offsite Construction for Housing: Research Roadmap. Office of Policy Development and Research. U.S. Department of Housing and Urban Development. https://shorturl.at/p8PDy. Retrieved on June 2024.

14 Colker, R. et al. (2022). Codes Working Group: Brief. New Off-Site Construction Standards. Advanced Building Construction Collaborative. Accessed at: https://shorturl.at/Kv85G.pdf. Retrieved on June 2024

15 Bour, S. & Koger, M. (2021). Do Different Building Codes Apply When Using Modular Units on a Project? AIA Contract Documents. Accessed at: https://shorturl.at/ULWbo. Retrieved in June 2024

16 Colker, R. (2023). Reaping the benefits of offsite construction, with ICC's Ryan Colker. Building Design + Construction. Accessed at: https://www.bdcnetwork.com/video/reaping-benefits-offsite-construction-iccs. Retrieved on June 2024

17 Cooper, D. (2024). Off-site Construction Impact: Building Safety+Quality Control with Ryan Colker ICC. Youtube. Accessed at: https://www.youtube.com/watch?v=fA5W4fCCGnE. Retrieved on June 2024.

18 Obando, Sebastian. (2022). Builders, MBI press for modular standards. Builders, MBI press for modular standards | Construction Dive

19 https://www.scstatehouse.gov/code/t23c043.php

20 Woodworks. (2024). Modular Construction. Panelized Construction. Accessed on: https://shorturl.at/uYBaT. Retrieved on June 2024 depend on the type of modular component and vary between off-site fabrication and on-site installation[21].

Singapore

Compliance is primarily dealt with via Singapore's Building Control Act (BC Act)[22]. It requires that all building works should be carried out under the supervision of an appropriate Qualified Person for Supervision (QPS).

The QPS appointed to supervise the carrying out of building works is required to take all reasonable steps and exercise due diligence in supervising and inspecting such building works to ensure compliance with the Act, building regulations, relevant plans approved by the Commissioner of Building Control (CBC), and any terms and conditions imposed by the CBC. The QPS must also ensure that all off-site structural elements comply with the technical specifications, design and material codes (as for traditional construction) as prescribed in the building regulations. This means that the QPS is required to supervise the fabrication of structural prefabricated elements carried out at the off-site factory. The QPS could also choose to appoint their site supervisors (SS) to assist in the supervision, similar to onsite construction. Of note, the QPS is either appointed by the developer or the builder as per sections 8 and 11 respectively of the BC Act[22]. The duties of the QP are mentioned in Section 9 of BC Act[22]. The QPS is required to submit the Certification of Supervision for the building works including the abovementioned off-site works once the building works have been completed. On this basis, self-certification is the main basis for dealing with compliance during construction[23].

Conclusion

Themes from this chapter revolve around the need for clear and simple compliance pathways for off-site construction inspections and approvals. Lack of these features causes lengthy delays and subsequently limits the realisation of off-site construction's advantages. Speed of approval is important and so the process must be designed to minimise confusion or risk of delays. In this context, standards reduce risk by creating reliable and repeatable process for standard construction. In Canada, it is apparent that certain standards have been developed to address the above via standards for targeted building types such as Manufactured homes. In the US, national fragmentation creates interjurisdictional problems to compliance where limited standards and agreed practices exist. This appears to be particularly problematic where economies associated with large-scale production are thwarted because interstate markets become inaccessible due to different compliance requirements.

It is also clear that administrative standards are important for creating compliance certification processes for off-site construction and this is yet to be developed in Australia. Even so, specific versions of certification (e.g., first party certification, third party certification) varies from one country to the next and so a central theme exists.

Within Australia, the background work undertaken by HIA/Swinburn provides a useful framework for the current study. Key points include: the lack of formal recognition for off-site and modular construction as acceptable construction practice; the lack of standard definitions for off-site construction; the unclear role of inspectors for off-site work; and compliance certification of off-site construction. The Handbook for the Design of Modular Structures makes a number of similar points and in addition, the identification of physical interfaces between in situ and off-site assemblies is important, as these represent risk locations not usually dealt with in ways that are deemed to satisfy compliance requirements. Finally, use of QA/QC

21 Woodworks. (2024). Modular Construction. Panelized Construction. Accessed on: https://shorturl.at/vzitw. Retrieved on June 2024

22 Building and construction Authority. (2024). Building Control Acthttps://shorturl.at/PRBno. Retrieved in October 2024

23 https://sso.agc.gov.sg/Act/BCA1989

programs to underpin the reliability of off-site production are recurring themes both in the Australian and International literature; they act as an important framework for compliance certification.

CHAPTER 4 - CLASSIFICATION OF OFF-SITE ASSEMBLIES

A consistent issue concerning regulatory reform is the lack of clarity and consistency concerning terminology for different types of off-site construction. This causes difficulties in creating a consistent structure around compliance and related inspection issues. Creating common terminology is therefore important and can also potentially encourage more efficient dialogue, simplified specification and more targeted compliance requirements.

Obviously, a key issue is the separation between mobile and fixed homes/buildings as they tend to be dealt with under separate legislation and regulatory requirements. The focus of this study is purely on fixed construction, as dealt with under construction regulations.

In trying to improve terminology in this area, simple, self-descriptive and practical terms that fit within a defined hierarchy, and are easily recognisable along the supply chain (architects, engineers, contractors, subcontractors, product suppliers, administrators, regulators, clients, inspectors, certifiers), are favoured. In terms of the envelope and structure of the building, terminologies such as 2D for panelised assemblies and 3D for volumetric, meet these criteria. Further, terms that incorporate 'Closed' and 'Open' construction help indicate the extent of construction that will be hidden during prefabrication processes and hence the ability/inability to inspect onsite. Still further, terminologies that help identify key interfaces with separate assemblies and/or in situ construction can assist in directing when and where inspection would be most useful.

Modern Methods of Construction, Off-site Construction and Modular Construction are all general names for industrialised approaches to construction. Arguably, the variant that requires most immediate attention concerns off-site assemblies. This is because parts of the off-site work become hidden from view during production and cannot be inspected onsite.

Greater definition and categorisation for such assemblies would be useful so that alternative arrangements (such as third-party certification) can be put in place for related assemblies.

The general benefits of such a classification framework are multi-faceted and in overarching terms, serve to 'regularise'[24] off-site construction. This ostensibly means creating familiarity and confidence across the industry, regulators, and stakeholders such as inspectors, lenders, warranty providers, building insurers, and valuers[25]. The same framework also provides a structured approach to data gathering that can further assist compliance pathways where certain types of assembly become increasingly standardised. Ginigaddara et al. (2022), add that benefits are also created in product specification, process improvement, minimised operational risk, efficient procurement process, multi-skilling for optimal process integration, skill prediction and targeted levels of automation[26].

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24 https://www.gov.uk/government/publications/modern-methods-of-construction-working-group-developing-a-definition-framework#:~:text=The%20MMC%20Definition%20Framework%20also,Strategy%20Challenge%20Fund%20Construction%20Sector
25 https://www.gov.uk/government/publications/modern-methods-of-construction-working-group-developing-a-definition-framework#:~:text=The%20MMC%20Definition%20Framework%20also,Strategy%20Challenge%20Fund%20Construction%20Sector
26 Ginigaddara, B., Perera, S., Feng, Y., & Rahnamayiezekavat, P. (2021). Development of an offsite construction typology: A Delphi study. Buildings, 12(1), 20.

UK Categorisation System

The UK Government (via work done by Cast Consultants) has perhaps the best known categorisation framework, internationally. The framework was formulated for the UK Government's housing ministry as a means of supporting data collection on types of MMC being employed and the capacity in the market[27]. It was also meant, by combining primary structural material classification with pre-manufactured philosophy, to enable a large national dataset relating to risks and underwriting for warranty providers and insurers, which in turn could guide market adoption and confidence[28].

It categorises the physical manifestation of the manufacturing and construction process and is linked to the ability to increase 'Pre-Manufactured Value' (PMV) as a percentage of overall project value.

According to Cast Consultants CEO (Mark Farmer), the framework has been widely picked up in the UK to drive the language of MMC, especially in housing but less so in wider infrastructure programmes and non-residential buildings[29]. It has been used by Homes England to clarify MMC funding policy on our UK affordable homes programme[30] and by the UK's major warranty provider, NHBC, to guide their MMC assurance work[31]. It is recognised by BOPAS as part of their off-site assurance work[32]. However, as yet, it is not recognised in any of the UK Building Regulation documents.

The framework consists of seven primary categories, each having a number of subparts (refer to Figure 5)[33].

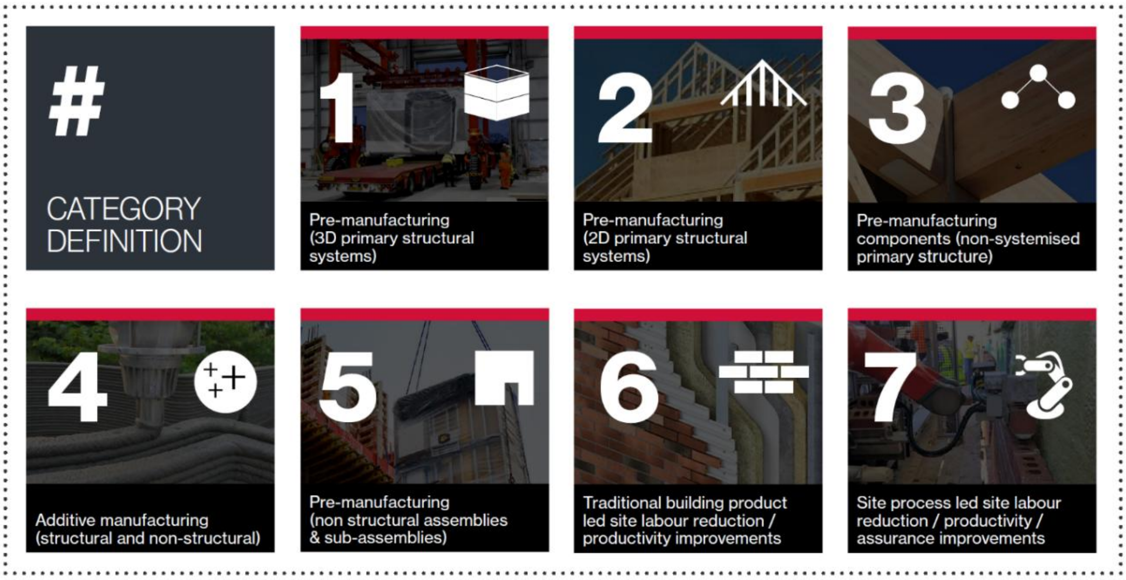

Figure 5 Modern Methods of Construction Categories[33]

[27] https://www.gov.uk/government/publications/modern-methods-of-construction-working-group-developing-a-definition-framework
28 Based on email correspondence with Mark farmer of Cast Consultants.
29 Based on email correspondence with Mark farmer, cast Consultants.
30 https://www.gov.uk/guidance/capital-funding-guide/8-procurement-and-scheme-issues
31 https://www.nhbc.co.uk/builders/products-and-services/techzone/accepts/accepted-systems
32 https://www.bopas.org/who-how-we-accredit/bopas-accreditation-database/#:~:text=Category%201%3A%20Pre%2Dmanufacturing%20(,(structural%20and%20non%2Dstructural
33 Cast Consultancy. (2019). Modern Methods of Construction: introducing the MMC definition framework. MHCLG Joint Industry Working Group. Available at: https://www.cast-consultancy.com/wp-content/uploads/2019/03/MMC-I-Pad-base_GOVUK-FINAL_SECURE.pdf. Retrieved on June 2024.

Of note, each classification contains sub-divisions indicating escalating degrees of prefabrication and consolidation within a given class. Each classification can be employed either as a complete system or blended with traditional onsite construction methods.

- Category 1: 3D primary structural systems with subcategories that define:
  - Structural chassis only,
  - Structural chassis plus internal fitout,
  - Structural chassis, internal fitout and external cladding/roofing complete,
  - Structural chassis and internal fitout with potted room assemblies,
- Category 2: 2D primary structural systems inclusive of floor/wall/roof structures. Variants range from 'open' to 'closed' assemblies with subcategories that define:
  - Basic framing and including walls, floors, stairs and roof
  - enhanced consolidation-installation, internal linings et cetera
  - further enhanced consolidation-installation, linings, external cladding, roofing, doors, windows
- Category 3: Components for non-systematised primary structures with subcategories that define:
  - driven/screw piling
  - prefabricated pole caps/ring beams
  - columns/shear walls/beams
  - floor slabs
  - integrated columns, beams of floor slabs
  - staircases
  - preassembled roof structure-trusses/vandals
- Category 4: additive manufacturing (structural and non-structural) utilising 3D printing.
- Category 5: non-structural assemblies and subassemblies with subcategories including:
  - volumetric pods (whole bathrooms, kitchen assemblies, combined bathroom/kitchen assemblies, unitised mechanical electrical equipment assemblies
  - panelised/linear assemblies (façades, roof assemblies unitised mechanical and electrical call distribution assemblies, mechanical electrical infrastructure assemblies inclusive of multiple types, floor cassettes, partition cassettes, door sets)
- Category 6: traditional building product-led labour and productivity improvements. Subcategories include:
  - large format walling products (internal and external)
  - large format roofing finishes
  - pre-sized and cut to measure traditional materials
  - easy site installation in various manifestations
- Category 7: site process-led labour reduction/productivity/assurance improvements. Subcategories include:
  - Encapsulation/enclosure for weatherproofing and environmental control
  - standardised or sacrificial temporary works e.g. tunnel forms
  - BIM and digitally enabled workflow
  - site worker augmentation visual e.g. AI
  - site worker augmentation physical e.g. exoskeletons
  - site worker planning tools e.g. GPS
  - site process robotics and drones
  - autonomous plant and equipment and drones
  - digital site verification tools e.g. lidar scanners, photogrammetry, site worker video[34].

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[34] *Cast Consultancy. (2019). Modern Methods of Construction: introducing the MMC definition framework. MHCLG Joint Industry Working Group. Available at: https://www.cast-consultancy.com/wp-content/uploads/2019/03/MMC-I-Pad-base_GOVUK-FINAL_SECURE.pdf. Retrieved on June 2024.*

Whilst the above categories do a good job of capturing the breadth of modern methods of construction, the main categories that are of key relevance to this study and the above emphasis on prefabrication, include categories 1,2,3 & 5. These reflect the main methods of panelised and volumetric construction currently active in the Australian construction market.

Other Categorisation Schemes

Apart from the above offering, other categorisation schemes also exist. These are mainly from the academic literature and appear yet to have been applied in practice.

Ginigaddara et al. (2021), created a typology based on a multi-stage developmental process including attention to international literature, case studies and an expert forum. It is shown diagrammatically in Figure 6[35].

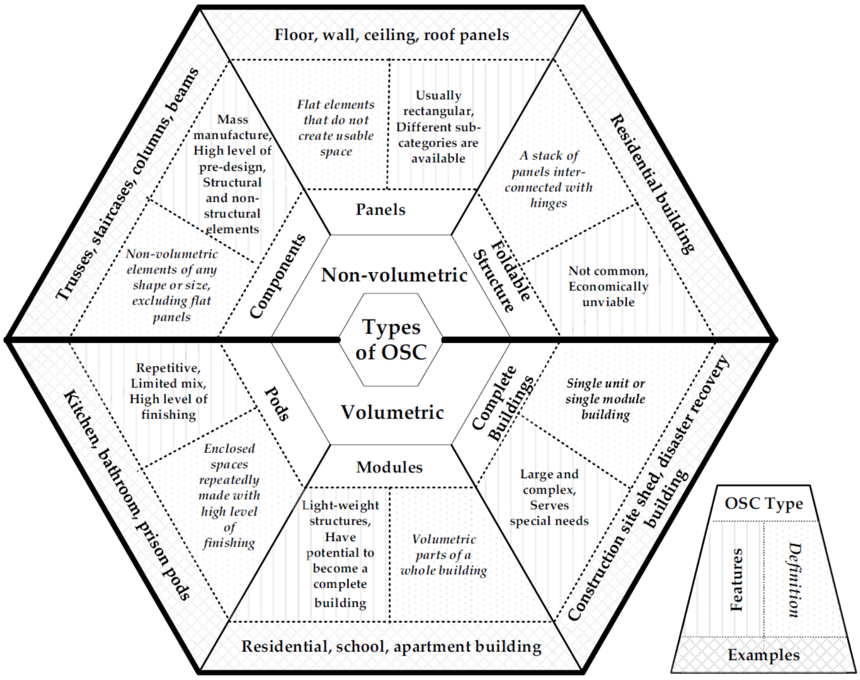

Figure 6 OSC classification[36]

Ayinla et al. (2019), developed an Off-Site Construction (OSC) classification based on product type and incorporating product location, geometric configuration, material, procurement processes, assembly processes, and production processes[36].

In contrast, Vlbaek's approach (2011) involves a multi-tier map, which depicts six levels of off-site value adding (from raw materials to entirely prefabricated buildings); beneath each type, the map incorporates targeted levels of preparation, standardisation and service levels[37].

Still further, PrefabAUS, being the peak body for prefabrication in Australia, created a hybrid categorisation that included a number of the above sources, and was developed for the purpose of supply chain mapping, which is shown in Figure 7.

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[35] Ginigaddara, B., Perera, S., Feng, Y., & Rahnamayiezekavat, P. (2021). Development of an offsite construction typology: A Delphi study. Buildings, 12(1), 20.

[36] Ayinla, K.O.; Cheung, F.; Tawil, A.-R. Demystifying the concept of offsite manufacturing method. Constr. Innov. 2019, 20, 223–246.

[37] Vibæk, K. (2011). System structures in architecture (Doctoral dissertation, PhD thesis, School of Architecture, Design and Conservation, The Royal Danish Academy of Fine Arts).

Cat 6 Processed materials	Cat 5 Linear elements	Cat 4 2D frames (non-value added)	Cat 3 2D value added	Cat 2 3D skeleton (non-value added)	Cat 1 3D value added
The likes of cement, concrete, structural timber, plywood, boards reinforcing bars, masonry/concrete bricks, PVC pipes, wires, fire pipes and fittings Membranes and coatings Adhesives, epoxies, sealants Insulation materials	**The likes** of concrete beams, columns Steel beams, columns, braces Timber (Glulam, CLT, LVL) beams, columns Light gauge steel members	**The likes** of concrete walls and slab panels Timber frames, timber walls, SIPs LGS wall frames, floor trusses	**Category 4** elements with the addition of one or more of the following: Insulation, gypsum boards, electrical wiring, ducting and piping, doors, windows, façade etc.	**The likes** of modular units/pods/box skeletons made of concrete, timber or steel/LGS	**Category 2** elements with the addition of one or more of the following: Insulation, gypsum boards, electrical wiring, ducting and piping, doors, windows, façade etc.

Figure 7 Six-scale category classification system for off-site products in construction

Conclusion

In considering these different options, it is pertinent to mention that past studies[36] recognise that typologies such as those presented above, tend to be aimed at a particular purpose and may not be robust enough to cover all aspects of interest. Arguably the one best suited to the regulatory reform agenda of this research, is the one that best defines prefabricated products. For instance, the NCC is vested in the compliance of products as is evident in the likes of the CodeMark and WaterMark schemes.

Given the above, the PrefabAUS and the UK Government models appear to have the most useful and holistic application for regulatory reform in Australia – mainly categories 1,2,3 & 5, but others could be included if aiming for higher degrees of future proofing. Further, the sub-categories in this framework offer an extra level of detail that is more likely to be useable for specific and streamlined compliance pathways (i.e. well targeted prefabricated products and standard design patterns). Notwithstanding this, the primary categories in the PrefabAUS model have the benefit of reflecting prefabricated products prevalent in the Australian supply chain and in this context, are more targeted to the local context than the UK's MMC framework[38]. It is concluded that the two be selectively merged and adapted with Australian regulatory compliance in mind (subject to consultation with relevant key regulatory bodies). As mentioned previously, such a categorisation framework would serve to regularise prefabricated products – especially for those involved in the compliance chain.

[38] *Of note, the UK framework deals with aspects of MMC that currently have limited impact in Australia (mainly categories 4, 6 and 7) but for the purposes of futureproofing, these should be considered for inclusion in the future and according to need)*

CHAPTER 5 – IMPACTS OF COMMONWEALTH GOVERNMENT REGULATORY FRAMEWORKS

Commonwealth Government Regulatory Frameworks impacting Off-site Construction

At a Commonwealth Government level, the Australian Building Codes Board stands out as the national standards writing body responsible for: the National Construction Code; WaterMark and CodeMark Certification Schemes. It is also responsible for regulatory reform in the Australian construction industry. To establish a frame of reference relevant to regulatory compliance, selected aspects are discussed below.

The National Construction Code

The National Construction Code (NCC) represents the main regulatory framework for complying with construction across Australia. Whilst it is developed and administered by the Australian Building Codes Board, its uptake and application are empowered under State government legislation - each state and territory calls up the NCC as part of their overall regulatory framework for environmental planning and construction[39].

Encompassing a comprehensive set of technical specifications and performance requirements, the NCC outlines provisions for the design and construction of buildings and structures. It provides the minimum necessary construction and plumbing standards dealt with across three volumes: Volume One includes provisions for multi-residential, commercial, and public buildings; Volume Two covers housing provisions for detached and semi-detached buildings; Volume Three outlines plumbing and drainage provisions across all construction types.

The technical focus of the NCC is to create fitness for purpose standards that apply to the performance of the finished building (i.e., during occupation use) with prevention of risk to:

- Safety, including structural safety and safety from fire
- Health
- Amenity
- Accessibility
- Sustainability[39].

Given the focus on the performance of the finished building, the NCC is relatively neutral about the specific processes used to create a building. It therefore does not differentiate between on-site or off-site construction processes, which in theory should not impact the performance expectations of the finished building. It does however provide different compliance pathways (discussed further below). ‘Deemed to Satisfy’ pathways (discussed further below) provide the fastest and simplest option but at the current point in time, do not necessarily deal with the array of specific construction detailing issues encountered by off-site construction. Rather, ‘Deemed to Satisfy’ solutions tend to reflect traditional onsite construction[39].

Compliance Pathways

[39] *Australian Building Codes Board (2022). National Construction Code Series. National Construction Code. Canberra, Australia, Retrieved May 2024.*

Compliance with the NCC's performance requirements is satisfied via two main pathways or using a hybrid approach combining the two (Figure 8):

- 'Deemed-to-Satisfy' solutions (DtS) typically rely on Australian Standards and other referenced documents that are formally called up in the NCC. These documents prescriptively describe how products and construction should take place in order to comply with the NCC's performance requirements. DtS solutions tend to reflect well known and traditional construction methods[40]. They therefore represent the most common compliance pathway and allow fast and simple approval.
- Performance solutions apply situations not covered by DtS solutions and these often include problematic scenarios as well as new or novel forms of construction. Under these scenarios, there is an onus on the applicant (usually on a given construction project) to provide 'evidence of compliance' in meeting performance requirements[40].

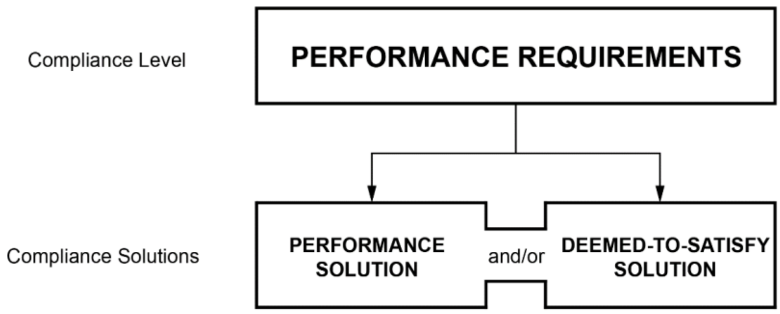

Figure 8 Compliance in the National Construction Code[40]

Importantly, off-site assemblies are essentially complex products that piece together different types of construction (e.g., for a closed wall panel this could include wall frames, waterproof membranes, vapour barriers, insulation, cladding, linings etc). Subsequently, a solution may commonly involve a 'patchwork quilt' of DtS solutions as the simplest and fastest compliance pathway. However, where gaps occur through a lack of available DtS solutions to cover the entire assembly, supplementation to fill the gaps becomes necessary via performance solutions. Hence, hybrid solutions occur via a ratio of DtS to performance solutions e.g., 90% DtS:10% Performance.

Performance solutions also involve much greater process including the following necessary steps: Preparation of a performance-based design brief in consultation with relevant stakeholders; analysis as detailed in the performance-based design brief; evaluation of the results and; a final report that includes scope of applicability in meeting performance requirements and limitations[41].

Compliance fundamentals

Product compliance requirements are evident in a dedicated handbook published by the NSW government (on behalf of commonwealth and state/territory representation) on 'A Guide to Australian Building Product Conformity'. It details how to avoid usage of non-conforming and non-compliant products. The former are products that make false claims or do not meet standards for their intended use. The latter is where products or materials are used in a way that does not comply with the National Construction Code (NCC), relevant laws, or Australian Standards[42].

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[40] Australian Building Codes Board. (2018). Protocol for the Development of National Construction Code Reference Documents. Canberra, Australia.
[41] Australian Building Codes Board (2022). National Construction Code Series. National Construction Code. Volume 1. Canberra, Australia, Retrieved May 2024.

Compliance and conformance of building products are regulated by the planning and building authorities within each jurisdiction in Australia. State and territory laws also govern specific occupations in the construction sector, including builders and specialised trades such as plumbing and electrical work. Additionally, professionals like architects, designers, engineers, and fire safety practitioners must be licensed or registered to ensure they meet the required standards for compliance in their respective roles[42].

Assessing conformance and compliance typically involves testing, inspection, certification, or declarations. Testing evaluates product samples, while inspection reviews design, production, or installation. Certification is provided by authorised bodies based on product evaluation, and declarations are formal statements from manufacturers or suppliers. Each method results in a certificate or formal statement detailing the standards applied and the outcomes.

Assessment Methods and Evidence of Suitability

In order to prove the validity of a compliance solution (including both DtS and Performance Solutions) four Assessment Methods are available in the NCC and can be mixed together, as required[42]:

1. Evidence of suitability – this comes in various sub-forms
2. Comparison deemed to satisfy solutions - at least equivalent to the relevant DtS Provision(s). (Note: only relevant to performance solutions.)
3. Verification methods - test or calculation modelling that typically involves quantifiable benchmarks or predetermined acceptance criteria. (Note: only relevant to performance solutions.)
4. Expert judgment - if physical criteria cannot be tested or modelled through calculation, the opinion of an expert may be considered[43].

Among the above, evidence of suitability is particularly important as a systematic means of proving fitness for the purpose (for compliance purposes) of construction products[43]. A handbook published by the ABCB assists NCC users in understanding and applying the evidence of suitability provisions of the NCC (A5.1, A5.2 and A5.3 of each volume of the NCC). The evidence must support a claim that a material, product, form of construction or design meets a Performance Requirement or a ‘Deemed-to-Satisfy’ Provision[44].

If a performance solution is chosen, any assessment method mentioned above can be used to demonstrate compliance, provided it shows that the solution meets the NCC performance requirements, with methods varying based on complexity. For a ‘deemed-to-satisfy’ solution, only evidence of suitability and expert judgment methods are permitted[44]. The evidence of suitability framework is shown in Figure 9.

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[42] *Australian Building Codes Board. (2022). National Construction Code Series. Understanding the NCC. Canberra, Australia. Retrieved September 2024.*
[43] *NCC Vol 1, Part A2. Retrieved September 2024.*

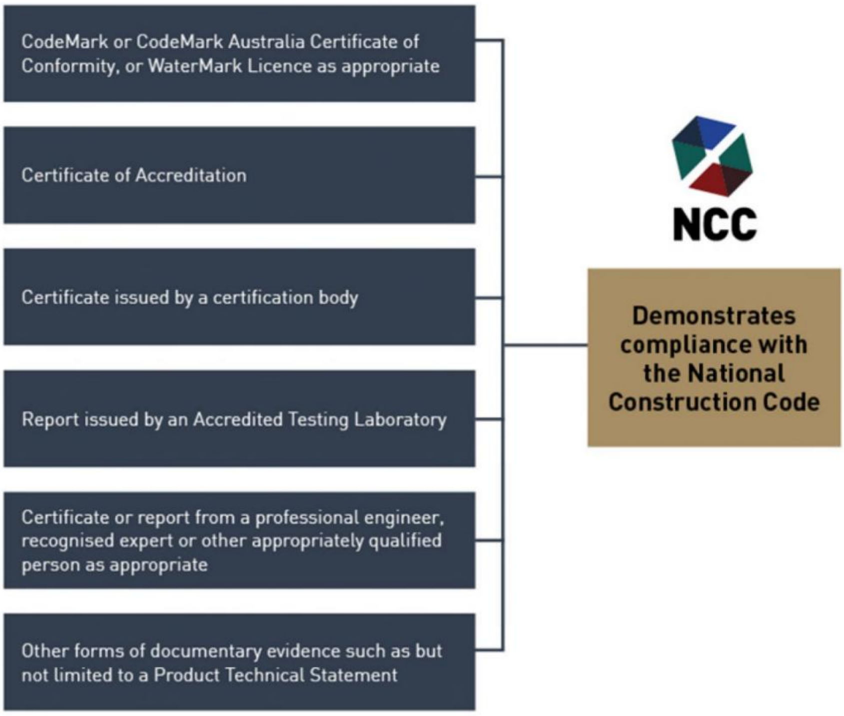

Figure 9 NCC Evidence of Suitability Framework

It is notable that the framework options 'reflect a hierarchy of rigour'[44] whereby options at the top of the list offer stronger forms of evidence compared to the bottom of the list.

For instance, at the top are CodeMark and WaterMark, which provide mandatory legislative acceptance by building authorities (anywhere in Australia) and time saving consent and inspection processes. In the case of CodeMark, it is 'best suited to innovative, higher-risk products where the manufacturer or supplier may find it difficult to satisfy the requirements of the NCC'[45].

At the bottom are Product Technical Statements. This is an area that has received significant attention in recent times by virtue of Recommendation 21 of the Building Confidence Report to improve regulatory compliance and safety in the building and construction sector (discussed later in this report)[46]. The ABCB instigated the National Building Product Assurance Framework to address this recommendation, which covers the following five key elements:

1. Strengthened NCC evidence of suitability requirements (including minimum information needed for verifying product suitability based on risk levels).
2. Information obligations for manufacturers and suppliers.
3. Product traceability and identification.
4. Improved surveillance, research, and information sharing.
5. Strengthened compliance and enforcement[46].

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[44] *Australian Building Codes Board, (2021). Evidence of Suitability Handbook. Retrieved September 2024.*
[45] *Australian Building Codes Board. (n.d.). About CodeMark. Available at: https://www.abcb.gov.au/about-CodeMark#:~:text=CodeMark%20is%20designed%20to%20provide,National%20Construction%20Code%20(NCC). Retrieved May 2024.*
[46] *Australian Building Codes Board, (2021). Building Product Safety National Building Product Assurance Framework - BCR recommendation 21.*

Of note, progress concerning traceability is reported under a separate case study in this report - it details evolving development in this area. Once implemented, traceability potentially provides a simplified means for checking product compliance on a day-to-day basis by all involved in the construction supply chain (including a national, industry-wide traceability framework, related standards and consistent product labelling).

Schemes Administered by the ABCB

As alluded to above, the ABCB administer two notable schemes that support targeted pathways of compliance in the NCC and also provide direct and unequivocal evidence of suitability.

1. CodeMark: is a voluntary third-party building product certification scheme that aims to support the use of new or innovative building products by providing a nationally accepted process for demonstrating compliance with the NCC[47]. It is attained after going through extensive third-party assessment and allows issuance of a Certificate of Conformity to prove compliance with the NCC[48]. Of note, CodeMark may include installation as part of the assessment process, and this is arguably the only part of the NCC that extends beyond traditional product certifications which tend to stop at how the product is manufactured in the factory.
2. WaterMark: is a mandatory scheme for plumbing and drainage products of a certain type. Certification ensures products are fit for purpose and appropriately authorised for use in plumbing and drainage installations.

Regarding WaterMark, a key point of interest from a prefabrication perspective is that a holistic technical specification (WMTS-050:2018 Prefabricated modules) has been developed for prefabricated wet area pods. The specification covers the entire off-site plumbing installation within (typically) a pre-finished, 3D, prefabricated bathroom. In doing so, the technical specification tends to treat such pods as (complex) products. It primarily groups what are normally individually WaterMarked components into an overarching WaterMarked assembly[49].

WMTS-050 outlines product certification criteria 'to provide independent assurance of the claim by the manufacturer that products comply with this Technical Specification'[49]. Further, the certification scheme serves to indicate that the products consistently conform to the requirements of this Technical Specification'[49]. A sampling and testing plan is provided in the specification and is to be used by the WaterMark Conformity Assessment Body.

WMTS-050 clearly aims to streamline and simplify the approval of pod assemblies. In doing so, this may have counterbalancing ramifications for state-based regulation concerning changes to traditional onsite inspection regimes and where statutory consumer warranties are linked to plumbing licenses that assume site-based work practices.

Notwithstanding this, it seems that based on the example above, schemes such as CodeMark and WaterMark (or future variants thereof) have the potential to provide a streamlined and de-risked compliance pathway for complex prefabricated products.

However, a review conducted by Deloitte on the current status of CodeMark in New Zealand outlined substantial criticism for several issues that undermine its effectiveness and accessibility[50]. The report outlined the concerns regarding the lack of clarity around the roles and responsibilities within the scheme, which has led to inconsistencies and reduced

[47] *Australian Building Codes Board CodeMark Certification Scheme | CodeMark (abcb.gov.au). Retrieved September 2024.*
[48] *Australian Building Codes Board. (n.d.). About Codemark. Available at: https://www.abcb.gov.au/about-codemark#:~:text=CodeMark%20is%20designed%20to%20provide,National%20Construction%20Code%20(NCC). Retrieved May 2024.*
[49] *Australian Building Codes Board. (2018). WMTS-050:2018 Prefabricated modules, p11.*
[50] *Ministry of Business, Innovation and Employment. (2019). Building (Product Certification) Amendment Regulations.*

confidence in the certification's reliability. Despite efforts to improve transparency and quality control, these unresolved issues have resulted in a fragmented system that fails to fully realise its potential to promote product quality and safety across the industry. As such, calls for a revised and more accessible certification approach continue to gain traction among industry professionals[50].

The Building Confidence Report – an Agenda for Regulatory Reform across Australia

In 2019 the Building Confidence Report (BCR) was initiated by the Builder Minister's Forum, encompassing Commonwealth as well as state and territory governments across Australia[51]. It aimed to improve the effectiveness of compliance and enforcement systems in the building and construction industry including policy, regulatory structures, and compliance issues nationwide. The report also raised the need for greater harmonisation in compliance and enforcement systems (p.14). Of note, this represents a pressing issue for off-stie construction because the achievement of economies of scale is typically reliant on large market demand, which is only achievable by combining inter-state markets; cross-border regulatory compatibility becomes critical in providing this scale without causing unwanted cost impacts through incompatibility.

Twenty-four recommendations were made in the report, as summarised in Table 1. These are still in the process of being implemented. Regarding this, the ABCB developed a nationally agreed model responding to 22 report recommendations to assist with implementation. Implementation is still in various stages of progress at respective Commonwealth, State and Territory levels[52].

The recommendations from the report, the ABCB responses and potential connections to the off-site construction agenda of this report are provided in Table 1.

[51] *Shergold, P. and B. Weir, Building Confidence: Improving the effectiveness of compliance and enforcement systems for the building and construction industry across Australia. 2018.*
[52] *Based on meeting with Bronwyn Weir*

Table 1 Summary of Recommendations, ABCB responses and relevance to off-site construction - Building Confidence Report

	BCR Recommendations	NO	ABCB Responses	Content	Relevance to this project
Practitioner Registration and experience	Nationwide registrations and requirements for building practitioners i.e., builders, project managers, building surveyors, building inspectors, architects, engineers, designers/drafts people, plumbers, fire safety practitioners.	1	National Registration of building practitioners	Nationally consistent scheme	Scheme should include off-site construction manufacturers as either a distinct category or as an endorsed sub-category of the mentioned categories (refer to changes in NSW that advocate for treating off-site contractors as part of onsite contractor licensing arrangements).
	Consistent registration requirements	2	NCC CPD micromodules	Qualifications and years of experience. Professional indemnity and/or warranty insurance. Financial viability requirements. Evidence of practitioner integrity.	As above
	Continuing professional development on the NCC	3	Introducing mandatory CPD on the NCC into new and existing CPD schemes.	Provides specialist training prepared by ABCB for practitioners to help achieve and maintain NCC knowledge and registration.	As above
	Evidence of experience for building surveyor registration	4	Career path and registration for surveyors details the methods for documenting experience.	Typical career pathways for building surveyors. Details the methods for documenting experience for candidates. Information for supervisors to establish expectations.	As above
Regulatory oversight	Building regulator collaboration	5	Model for regulatory oversight and collaboration (state government bodies, local governments, and private building surveyors) to avoid fragmentation, duplication and unclear lines of responsibility.	Instruction on: Membership Chairperson Advice Meeting schedule and procedures Reporting	This should be inclusive of off-site construction including the existence of self-certification or third party certification in proving compliance on specific projects.

	Building regulator powers	6	Provides guidance on priorities and processes for regulators to assess and enforce compliance with building standards and laws.	Each jurisdiction can grant a suite of powers for monitoring and enforcing compliance with building regulations. The model guide outlines minimum powers e.g. auditing, rectification, enforcement.	As above
	Auditing and compliance	7	Provides guidance on priorities and processes for regulators to assess and enforce compliance with building standards and laws for Class 2–9 buildings.	Public strategy for audits responsible to the state/territory regulator in each jurisdiction - audits of documentation standard, performance solutions, building surveyor conduct, and builder management of variations and product substitution. Provides guidance for statutory powers to support auditing strategies.	As above
Integrated Fire Safety	Code of conduct for fire safety engineers	8	Sets out minimum expectations of fire safety engineers.	Requirement for developers, architects, builders, engineers, and surveyors to engage with fire authorities – aligned with nationally consistent code (International Fire Engineering Guidelines).	Code of conduct for fire safety engineers in off-site construction (however there is a gap in NCC).
	Early engagement with fire authorities including performance solutions.	8	Engagement of fire authorities in the design process.	Sets out criteria and processes for building designers to consult fire authorities during the design process. For fire authority advice during the approval process.	Early engagement of fire authorities in the off-site construction design process.
	Fire Safety System	19	Guidance on the installation, testing, certification, and maintenance of fire safety systems.	Mandatory inspections, certifications of testing and commissioning.	The responses are relevant to this project.
Building surveyor integrity	Building surveyor integrity and their role in enforcement	9, 11	Sets out the core obligations of a building surveyor when acting as an approval authority and acting in the public interest.	Surveyor skills, roles and responsibilities.	There should potentially be an endorsement category for surveyors handling off-site construction primarily for their role in understanding their role and requirements on such projects.
	Code of conduct for building surveyors	10	Supplements existing codes of conduct to clarify what is expected (minimum expectation) of building surveyors when acting as an approval authority.	The Code contains obligations and explanatory information.	-

Better design, construction, and certification processes	Design acceptance	13, 14, 15, 16	Sets out processes to improve the standard and compliance of project documentation, including variations during the construction process.	Specific responses include requiring all design practitioners to provide a declaration of design compliance, creating a Project Product Register, and ensuring Performance Solutions are prepared and documented in accordance with the National Construction Code (NCC).	Develop a method to establish structure and, to some extent, standardise the context for performance solutions re off-site construction to minimise time, cost, bureaucracy, risk, and confusion.
	Independent third-party review	17	Sets out criteria and processes for the independent review of complex and high-risk buildings or parts of buildings.	Independent Third Party Review (ITPR) ensures appropriate processes, assumptions and decisions are made to improve compliance with the building design. Responses include making the statutory building surveyor responsible for the ITPR process, considering risk in ITPR, and specific attention to structural and fire safety designs.	ITPR for the performance solution in off-site construction. How and when should they be used.
	Building product safety	21	Provides a Product Assurance Framework to improve compliance through a package of measures aimed at addressing building product safety across the supply chain.	Five key elements include: Strengthened NCC evidence of suitability requirements. Information obligations for manufacturers and suppliers Product traceability and identification Improved surveillance, research and information sharing Strengthened compliance and enforcement	Implement a national, industry-wide traceability framework for assemblies in off-site to in situ processes, across supply chain. Requires clarification of ‘Building Products’, ‘Processes’, and ‘Building works’.
	Mandatory inspections	18	It gives guidance on when a building surveyor acting as an approval authority should inspect work under construction and initiate enforcement action.	Mandatory inspection	Clarifying the relevance and/or replacement of statutory mandatory inspection where off-site construction is being used. What replaces such inspection to ensure compliance (e.g., self-certification, third-party certification, auditing, virtual inspections.

Information Sharing	Building Manual	20	It provides building owners, managers and regulators with minimum information required for the safe and proper maintenance and use of buildings, so they can continue to perform as intended.	Information sharing with owner and government after the project completion.	Provision of built design documentation including off-site assemblies and how they are joined to each other and to in situ elements.
	Building Confidence Glossary	22	Compiles and explains key terms from the Implementation Team Outputs to help understand and use them.	Harmonising terminologies	Providing the consistent terminology for the off-site construction.
	Data sharing MOU	12	Undertaking between state and territory governments to enhance data collection and sharing to improve regulatory oversight.	Data collection and sharing	Should be inclusive of common digital data structures used in off-site construction to simplify this process.
	Standards Australia's construction dictionary	22	Provides a central repository of definitions from the NCC and Australian Standards and improves understanding by defining and explaining key building terminology.	Recommendation to supply a national dictionary of terminology for jurisdictions, industry and consumers.	For future proofing and completeness, the dictionary should utilise a version of the UK categorisation system used for modern methods of construction, as detailed earlier in this report

Conclusions

The Australian building industry operates under a regulatory framework that is governed by both federal and state-based regulations, creating certain gaps in consistency and application. The National Construction Code (NCC), developed by the Australian Building Codes Board (ABCB), provides the overarching national standards for construction, but its adoption, administration and enforcement are state based.

While the NCC sets minimum performance standards, it is neutral regarding specific construction processes, whether on-site or off-site. At first glance, this suggests that the NCC should have no direct role in the regulation of prefabrication as it is a process, more so than a finished end product (a building), but that is not the conclusion drawn here. More subtle areas of impact exist. For instance, it is apparent that DtS pathways provide the fastest, lowest cost, lowest risk, and simplest option as a compliance pathway, but at the current point in time, such solutions are under-represented for the specific needs of off-site assemblies. Instead, a ‘patchwork quilt’ of DtS solutions is potentially applied to a complex off-site assembly with a high likelihood of additional performance solutions being necessary where gaps exist in the ‘quilt’. Such solutions immediately make compliance harder, more costly and slower for off-site assemblies and so this is an area that needs to be addressed in future work.

Compliance is fragmented and inconsistently applied across jurisdictions and at the certifier/approver level. The schemes administered by the ABCB, such as CodeMark and WaterMark, aim to streamline compliance pathways. The WMTS050 specification provides an example of how this can be applied to complex prefabricated products.

Even so, gaps remain in state

-level inspection, licensing, and trade certification, particularly concerning the regulation of off-site assemblies and how prefabrication (at times) confronts traditional onsite work assumptions. This is discussed later, in chapter 6 on state regulatory frameworks. Notwithstanding this, states often have varying levels of regulation, which can undermine the potential benefits of off-site construction. Addressing these gaps through coordinated federal and state efforts is essential to ensure a streamlined, efficient regulatory framework that maximises the advantages of off-site construction techniques.

Schemes such as CodeMark provide simple, quick and low-risk approval mechanisms but at this point, in time the targeted scope of implementation is not particularly oriented towards the needs of off-site assembly producers. They provide a degree of semi-standardised products that still vary from project to project and are therefore often undertaken by SME scale businesses, more so than mass production manufacturers; consequently, applying compliance benefits of CodeMark to off-site assemblies would require a yet-to-be-developed, modified approach.

Much of the previous discussion about commonwealth regulation focuses on the compliance of ‘products’, more so than the compliance of the eventual installation of those products onsite (i.e. which is dealt with State/Territory legislation). The main point here is that off-site assemblies can be seen as (complex) ‘products’, which is significant insofar as this potentially shifts the main compliance issues to the ABCB (i.e. to approve such complex products under the NCC) and conversely, reduces compliance inspection during off-site production, of the states. In such a transition, certification of the off-site product would become increasingly important. Such a position likely sits in a ‘grey’ area between Commonwealth and State interpretation of statutory jurisdiction but would potentially improve compliance pathways in terms of speed, consistency, cost, efficiency and simplicity.

The BCR report creates an agenda for ongoing regulatory reform for building construction. Its recommendations have been interpreted by this report for the specific context of off-stie construction and presented in Table 1. Key areas for consideration include:

- The National Registration Framework could explicitly include off-site construction workers as either a distinct category or as an endorsed sub-category within the existing category framework. Benchmarks in the framework could delineate the expected competence and licensing requirements for prefabrication work including their role in checking/certifying compliance in off-site production systems.

- Establish a code of conduct and level of competence for fire safety engineers in off-site construction and ensure early engagement of fire authorities in the design process of off-site construction.
- Surveyor skills, roles and responsibilities could be more clearly defined for off-site construction.
- Efforts should be made to give off-site construction certification a formal status in State Building regulations where they are to be used as an alternative to mandatory on-site inspection regimes (now made redundant by virtue of work being undertaken off-site).
- Performance solutions regarding off-site construction could be identified and gradually converted to DtS Solutions to minimise time, cost, administration, risk, and confusion.
- The criteria and processes for Independent Third Party Review especially for the performance solutions in off-site construction should be set out.
- A national, industry-wide traceability framework for assemblies in off-site to in situ processes, across supply chains, would be particularly useful for off-site assemblies. This is underway, as discussed later in this report.
- Clarification of process as distinct from product regulation e.g., building products, installation processes, and holistic building works need to more clearly delineate off-site works from traditional on-site works.
- Establish a method for treating off-site compliance where this changes on-site inspection schedules.
- Establishing consistent terminologies – as discussed in the ‘Classification of off-site assemblies’ chapter of this report.

The next section will provide a detailed exploration of the statutory regulations focusing on major construction projects in Australia, especially New South Wales, Queensland, and Victoria.

CHAPTER 6 – IMPACTS OF STATE REGULATORY FRAMEWORKS

State regulatory frameworks impacting off-site construction

As detailed in the previous chapter, states and territories work in a coordinated way with the ABCB in administering the likes of the NCC. In this context, the NCC is called up by, but subordinate to, State Planning Legislation. Subsequently, the NCC is one aspect of compliance requirements but there are many other compliance issues called up by state legislation and at the local government level as well.

By mapping state-based statutory processes, there is the ability to identify areas where things like approvals, mandatory inspection practices, certification processes, trade registration and trade licensing schemes impact off-site construction. Also, since Performance Solutions potentially occur on a project-to-project basis they typically go through a State/Territory controlled process that potentially impacts off-site construction because it is more prone to require this type of compliance pathway – as is especially the case for fire safety matters[53]. The objective of this section is therefore to obtain a better understanding of the practical challenges in achieving compliance using off-site construction compared to traditional construction methods, under state-based regulation.

In this framework, legislation provides an overall legal framework whilst beneath this, regulation provides a more precise set of rules to achieve the legislated objectives.

As stated previously, the NCC defines minimum standards applied to how a product performs in a finished building but has very little involvement in the physical construction/production processes used in reaching that finished state. However, a state government delves more into these processes, primarily through mandatory on-site inspections. These inspections check compliance during the construction process or through other checking mechanisms of the on-site process to make sure they reflect the approved construction design. Understanding of state legislation and regulation in the three eastern seaboard states of Australia (Queensland, New South Wales, Victoria) are explored further below.

New South Wales statutory framework

Prior to any building works in New South Wales, development consent must be obtained. The summary of the approval process is indicated in Figure 10. A Development Consent application is a formal request for approval to carry out a development. The development consent can be either a Complying Development Consent (CDC) or a Development Application (DA) approval. A CDC is issued by a private accredited certifier or local council, while a DA can only be issued by a council. CDC is a fast-track approval process for straightforward residential, commercial, and industrial developments[54].

[53] *This is different to DtS solutions which are (typically) automatically approved under State Legislation as referenced documents in the NCC.*

[54] *https://selectstructure.com.au/*

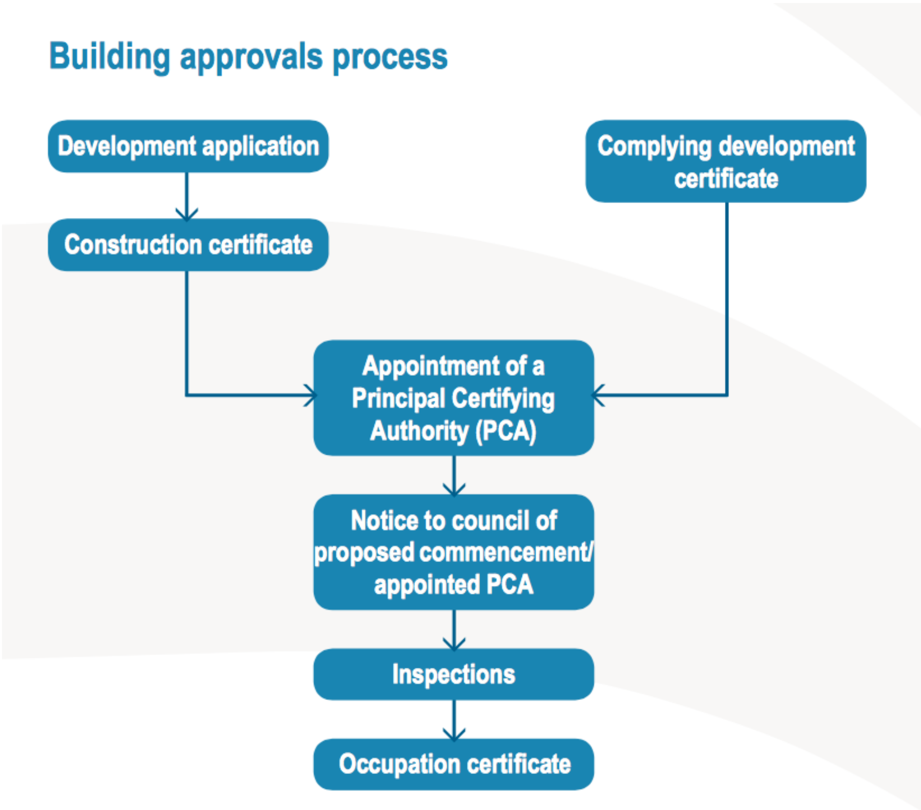

Figure 10 Building approval process in NSW. Select Structure. (2022). *Building approval process in NSW*[54]

The New South Wales environmental planning and assessment act 1979[55] is the main legislation that deals with building construction in NSW. Some key aspects of interest include Part 1 (Preliminary issues), which provides base definitions for buildings, development and exempt development (i.e. not requiring development consent or subsequent inspection). Part 6 addresses certification of the building design and construction and the functions of certifiers for building work (e.g. issuing construction certificates, carrying out inspections of building work, issuing occupation certificates, issuing compliance certificates, issuing complying development certificates). Related issues are also dealt with in the Building and Development Certifiers Regulation 2020[56]. In broad terms, the main functions arising from Part 6 include:

- Determining applications for complying development, construction certificates and occupation certificates.
- Inspection of building work at specific stages to determine consistency with approved plans, and compliance with legislative requirements and conditions of consent.
- Taking action to address non-compliant work and, if needed, report it to the appropriate authority, such as the local council.

The accompanying regulation to the legislation deals with practical implementation and greater detail pertaining to the above. As of 2021, there are two separate documents:

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[55] *Environmental Planning and Assessment Act 1979 No 203 - NSW Legislation*
[56] *New South Wales Government. (2023). Building and Development Certifiers Regulation. NSW Legislation. Available at:* *https://legislation.nsw.gov.au/view/html/inforce/current/sl-2020-0078. Retrieved June 2024.*

- Environmental Planning and Assessment Regulation 2021, which primarily deals with Planning and Development provisions[57].
- Environmental Planning and Assessment (Development Certification and Fire Safety) Regulation 2021[58].

The former has limited interest to this research except where the document calls up the NCC as the minimum mandatory standard for building construction[59] and where it effectively enables a consent authority (such as local government) to impose its own compliance requirements (as ancillary conditions). This effectively enables the consent authority to require compliance requirements over and above NCC standards[60]. Even so, the latter regulation is of more interest because it focuses on provisions for fire safety, building regulation, certification, and requirements for building inspection.

Inspection of building work

Inspection of building work is covered under Division 8 of the regulation[61] and represents a key area of interest to this research because it defines 'Critical stage inspections' [62]. The question is, do these site-based inspections create problems, risks or lack of relevance for off-site constructions and/or the way they are installed on-site.

Critical inspections are to be carried out by the principal certifier or another certifier, as agreed with the principal certifier. For instance, the latter could include a structural engineer but only if they are a registered certifier. The timing of critical inspections is detailed below for specific classes of buildings.

Class 1 or 10 building must be inspected on the following occasions:

- after excavation for, and before the placement of, a footing,
- before pouring an in situ reinforced concrete building element,
- before covering the framework for a floor, wall, roof or other building element,
- before covering waterproofing in a wet area,
- before covering stormwater drainage connections,
- after the building work is completed and before an occupation certificate is issued for the building (the ***final critical stage inspection***).

The building work for a class 2, 3 or 4 building must be inspected on the following occasions:

- after excavation for, and before the placement of, the first footing,
- before covering fire protection at service penetrations to building elements that are required to resist internal fire or smoke spread,
- before covering the junction of an internal fire-resisting construction bounding a sole-occupancy unit and another building element that is required to resist internal fire spread,
- before covering waterproofing in a wet area, for at least 10% of rooms with a wet area in the building,

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[57] *New South Wales Government. (2024). Environmental Planning and Assessment Regulation 2021. Available at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0759. Retrieved June 2024.*

[58] *New South Wales Government. (2024). Environmental Planning and Assessment (Development Certification and Fire Safety) Regulation 2021. Available at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689 Retrieved June 2024.*

[59] *New South Wales Government. (2024). Environmental Planning and Assessment Regulation 2021. Division 2, Subdivision 1, Section 69. Available at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689 Retrieved June 2024.*

[60] *New South Wales Government. (2024). Environmental Planning and Assessment Regulation 2021. Division 2, subdivision 1, Section 77. Available at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689 Retrieved June 2024.*

[61] New South Wales Government. (2024). *Environmental Planning and Assessment (Development Certification and Fire Safety) Regulation 2021.* Division 8 – Clause 61. Accessed at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689. Retrieved on May 2024.

[62] New South Wales Government. (2024). *Environmental Planning and Assessment (Development Certification and Fire Safety) Regulation 2021.* Division 8 – Clause 61. Accessed at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689. Retrieved on May 2024.

- before covering stormwater drainage connections,
- after the building work is completed and before an occupation certificate is issued for the building (the ***final critical stage inspection***).

The building work for a class 5, 6, 7, 8 or 9 building must be inspected on the following occasions:

- after excavation for, and before placement of, the first footing,
- for a class 9a or 9c building—before covering fire protection at service penetrations to building elements that are required to resist internal fire or smoke spread,
- before covering stormwater drainage connections,
- after the building work is completed and before an occupation certificate is issued for the building (the ***final critical stage inspection)***.

Other clauses in the regulation further qualify and create conditions concerning the above. For instance, fire protection at service penetrations on class 2-9 buildings, requires inspection for each type of protection method, for each type of service, and on each storey of the building[63].

Further, on Class 2-4 buildings, at least 30% of sole-occupancy units on each storey of the building, must be inspected where covering the junction of an internal fire-resisting construction bounding a sole-occupancy unit and another building element under subsection[64].

However, interestingly, all of the above do not appear to apply; when a building/dwelling is built off-site in sections and transported to the site for assembly'**[65].** It would seem that this would only apply to the parts constructed off-site and not their installation on-site.

Whilst this clause seems to create considerable freedom for off-site construction to occur, it also seems to create a degree of uncertainty because of the lack of definition about what happens off-site in terms of checking or creating confidence in compliance. For instance, some form of compliance checking should reasonably be expected to replace the on-site inspection that now becomes redundant by virtue of the work now being done off-site. For instance, there is no mention of inspection, certification or quality assurance processes that serve to create confidence that the off-site product has met compliance criteria.

What can therefore be said about the above, is arguably the need for further regulatory context about what happens regarding confidence of compliance for off-site construction. Also, that the on-site installation of off-site assemblies should be targeted as an area of inspection as such locations present a risk of non-compliance at interfaces between off-site assemblies and in situ construction.

Arguably a further issue that is separate to the above, concerns the potential need for inspection prompted by other parts of the regulation and not under Division 8 of the regulation. For instance, under Part 5, Division 3 of the regulation, the fire commissioner may be involved in issuing a final fire safety report, in that the building work complies with approved performance solutions (to class 2-9 buildings)[66]. Even though this does not explicitly state the need for inspection, it potentially occurs

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[63] New South Wales Government. (2024). Environmental Planning and Assessment (Development Certification and Fire Safety) Regulation 2021. Division 8 – Clause 61, clause 8. Accessed at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689. Retrieved on June 2024.

[64] New South Wales Government. (2024). Environmental Planning and Assessment (Development Certification and Fire Safety) Regulation 2021. Division 8 – Clause 61, clause 9. Accessed at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689. Retrieved on June 2024.

[65] New South Wales Government. (2024). Environmental Planning and Assessment (Development Certification and Fire Safety) Regulation 2021. Division 8 – Clause 61, clause 10. Accessed at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689. Retrieved on June 2024.

[66] New South Wales Government. (2024). Environmental Planning and Assessment (Development Certification and Fire Safety) Regulation 2021. Part 5, Division 3, Section 50. Accessed at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689. Retrieved on June 2024.

as part of checking the compliance on-site. Again, this requires clarification, especially in the context of off-site construction[67].

To an unknown extent, a number of the issues raised above may be dealt with in the proposed regulation of off-site construction in NSW, which has yet to be tabled at the time of writing this report. A number of position papers published by the NSW government pertaining to the proposed regulation are detailed later in this chapter.

Compliance Declarations under The Design and Practitioners Act

The Design and Practitioners Act was introduced in 2021[68] and responds to aspects of the previously discussed BCR report; it is currently limited to Class 2, Class 3 and 9c buildings. It requires key designers to submit a design compliance declaration that lets a building practitioner know that the design complies with regulatory requirements[69]. Key points as relevant to Class 2 buildings include:

1. Designers must be registered with the NSW Government and in doing so, must meet a prescribed level of professional experience and competency. They must also adhere to a Code of Practice, maintain relevant insurance, undertake ongoing CPD and retain design records for a prescribed period of time.
2. Targeted Designers include critical areas such as architects and a variety of engineering disciplines (e.g. structural, electrical, mechanical, fire, drainage, civil, geotechnical).
3. A compliance design declaration (for construction design) must be registered on the NSW Planning Portal and commit to Building Code of Australia (NCC) compliance; an integrated overall building design; compliance of performance solutions; specialist advice received; and compliance with other guidelines
4. Principal designers exist on larger projects. They make a principal design declaration and serve the role of coordinating, checking, verifying and submitting the designs of other registered practitioners[70].

Fire safety and performance Solution in NSW

Fire safety regulation is topical for this research because off-site construction often tends to attract the need for performance solutions around fire safety. Relevant issues pertaining to performance solutions include:

- A certifier must not issue a construction certificate for building work that involves a performance solution unless a ‘performance solution report’ that satisfies Clause A2G2(4) of the BCA/NCC and fire safety requirements has been submitted (for certain classes of building)[71].
- A ‘performance-based design brief’ must be developed and submitted after consultation with the Fire Commissioner[72].
- The certifier must forward plans and specifications to Fire and Rescue NSW where among other things, the Fire Commissioner must notify the certifier whether they will prepare an initial fire safety report which may recommend conditions to be imposed on the building[73] .

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[67] *New South Wales Government. (2020). Certifier responsibilities. Accessed at: https://www.fairtrading.nsw.gov.au/trades-and-businesses/business-essentials/building-certifiers/certifier-responsibilities. Retrieved on June 2024.*
[68] *New South Wales Government. (2024). Design and Building Practitioners Regulation 2021. Accessed at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0152#statusinformation. Retrieved on June 2024.*
[69] *New South Wales Government. (2024). Design and Building Practitioners Regulation 2021. Accessed at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0152#statusinformation. Retrieved on June 2024.*
[70] *https://player.vimeo.com/video/551770017*
[71] *New South Wales Government. (2024). Environmental Planning and Assessment Regulation 2021. Division 2, Section 18. Available at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689 Retrieved June 2024.*
[72] *New South Wales Government. (2024). Environmental Planning and Assessment Regulation 2021. Division 3, Section 26. Available at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689 Retrieved June 2024.*
[73] *New South Wales Government. (2024). Environmental Planning and Assessment Regulation 2021. Division 2, Section 27. Retrieved on May 2024.*

- A certifier must undertake a formal process of consideration of the initial fire safety report, before issuing a construction certificate[74].
- Caveats and timeframes are specified for the above processes.

These points are raised, not to debate their appropriateness, but purely to highlight that performance solutions take considerably more time, effort, and risk, relative to those deemed to satisfy solutions.

In situations where off-site assemblies are more prone to performance solutions than traditional forms of construction, the main concern is simply that the key reason to use off-site construction is to save time in the overall process, but if the probability of time-consuming approval of fire safety performance solutions is high, then this may undermine the very reason for choosing off-site construction in the first place. On this basis, it can be concluded that an increased palette of DtS would, for the most part, offer a faster and less risky pathway of compliance for off-site construction.

Newly Proposed Comprehensive Regulation of Off-site Construction

Over the last 3 years, the NSW Government has released a series of three publications[75],[76],[77] aimed at developing regulatory reform for off-site construction. Each progressive publication has sought public feedback and ongoing refinement of the proposed regulatory reforms, in preparation for inclusion in a broader building reform package (the Building Bill) yet to be presented to the NSW parliament (at the time of writing). The Bill aims to create a single frame of reference for building work, inclusive of off-site construction.

The stated intent of the proposed reforms focuses on providing adequate oversight, improved construction quality, and better protection for homeowners concerning off-site construction. A key issue initiating the reforms was that the NSW Home Building Act did not effectively protect consumers as prefabricated forms of construction primarily fell under ‘Building Products’ more so than holistic ‘Building works’. Of note, there were no requirements for prefabrication manufacturers to hold a licence to do holistic building work. In addition, such work may not be covered fully under the home building compensation scheme, statutory warranties, and NSW Fair Trading’s rectification powers[78]. The main prefabrication issues to be covered include:

- regulating off-sited building work by redefining it as building work,
- licensing of practitioners to ensure that work is undertaken by competent, qualified and experienced people,
- appropriate certification for off-site building work through a chain of responsibility that operates from design through to installation, and
- implementing key consumer protections for prefabricated home building work.

The paper identifies three types of prefabrication (linear components, 2D panels and 3D modular assemblies) but chooses to only focus regulation on 3D modular on the basis that the other categories are regulated under other schemes such as the Building Product (Safety) Act 2017. These boundaries of the proposed prefabrication regulation are shown in Figure 11.

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[74] *New South Wales Government. (2024). Environmental Planning and Assessment (Development Certification and Fire Safety) Regulation 2021. Division 2, Section 28. Accessed at: https://legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0689. Retrieved on May 2024.*
[75] *Consultation paper - Regulating prefabricated building work. (2022)*
[76] *Position Paper - Building Bill 2024; regulation of Prefabricated Building Work (November 2023)*
[77] *Building Commision 2024 Position Paper, Regulation of Prefabricated Building (August 2024)*
[78] *NSW Department of Customer Service. (2023). Position Paper – Regulation of Prefabricated Building Work.*

Figure 11 Proposed definition of off-site building work[76]

In identifying issues that could be addressed by the proposed reforms, the paper mentions the lack of standards for off-site construction. Of note and by default, this situation tends to support earlier conclusions in this report that lack of DtS standards reduces access to preferred compliance pathways and in doing so, limits optimisation of off-site construction[78]. Whilst they do not intend to develop such standards, they acknowledge that such documents play a complementary role in the proposed reforms and will work with other government agencies accordingly.

The paper identifies that inconsistencies exist between certain forms of off-site construction and planning legislation. For instance, the Environmental Planning and Assessment Act 1979 (EP&A Act) presently stipulates that the term 'building' excludes manufactured homes, movable dwellings, or any related structure as defined by the Local Government Act 1993 (LG Act)[79]. Such exclusions mean that: complying development pathways, construction certificates, inspections during construction, and occupation certificates do not apply to manufactured housing[80].

This transfers approval responsibilities to the Building Act and Local Environment Plans (LEP) and presents the potential for varying approval pathways for different local government areas (LGA). Even so, once approved, there is currently no regulatory framework to support compliant and defect-free prefabricated construction[80].

In terms of design responsibilities, the paper identifies that there are currently limited requirements for a designer, engineer or architect to provide detailed design for off-site construction and that this should change to be more consistent with the Design and Building Practitioners Act (2017)[80].

Certification of off-site construction is also discussed in terms of three options including certification with on-site inspection, self-certification and third-party certification. The second position paper recommends the use of third-party certification along the lines of the model developed in New Zealand (the BuiltReady scheme), but the final position paper is non-committal on how certification will take place or be monitored.

The proposed legislative framework aims to create clear accountabilities for key practitioners to ensure compliance with the NCC and there is an auditable record of the inputs and processes involved. It proposes that this will be done by:

1. Capturing off-site building work within the definition of building work.
2. Establishing a bespoke consent process.
3. Introducing standardised licensing for those designing and constructing prefabricated buildings.
4. Creating a fit-for-purpose certification process for off-site building work.
5. Ensuring there is a chain of responsibility from design through to installation[80].

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[79] *NSW Department of Customer Service. (2023). Position Paper – Regulation of Prefabricated Building Work.*
[80] *Building Commision 2024 Position Paper, Regulation of Prefabricated Building (August 2024)*

The above will not include moveable dwellings. As mentioned, it will only focus on 3D volumetric buildings with the expectation that other off-site building products can be visually inspected on-site using traditional means[80] .

A process is proposed for development consent to construct, install or erect a prefabricated building that is consistent with existing traditional onsite requirements:

1. Determine the relevant consent pathway related to the proposed use of the building.
2. Prepare designs detailing the nature of the building work - standardised designs aim to provide expedited consideration.
3. Prepare any further supporting documentation required by the consent authority.
4. Consent authority determines the application, with a certifier subsequently responsible for authorising the construction documentation including complying development, construction certificates, and compliance with NCC.

The Building Bill reforms propose extending licensing requirements to key building designers and engineers, which includes off-site building work. It also proposes an overarching building licence for the manufacture of building work carried out off-site to align with on-site building licensing requirements. All off-site building work companies would be required to hold a licence, as well as have an individual practitioner who is authorised to hold a building licence as their nominee. This new licensing requirement will complement existing licensing requirements for specialist work such as work undertaken by electricians. Plumbers and mechanical services[81] .

While the manufacturer and specialist trade practitioners would need to be licensed, other trades would not need to be licenced and this aims to appreciate the higher level of control in manufacturing, relative to traditional onsite work.

Parts of the position paper that could have favourable outcomes include:

- consistent application of rules to off-site building work across planning, building and local government legislation
- If there are specialised rules for off-site building work statutory warranties, it is important to consider whether whole buildings and components of buildings should be treated separately in relation to relocations.
- off-site building work should be covered by the Home Building Compensation Scheme and should be treated consistently with onsite construction

Licensing Requirements for Specialist Trades in NSW

Plumbing licenses

In New South Wales, a Notice of Work (NoW) is required that outlines the plumbing and drainage work to be carried out, and the person responsible. The Certificate of Compliance (CoC) confirms the plumbing work completed complies with the Act, Regulation, Plumbing Code of Australia and the Deemed-to-Satisfy requirements of AS/NZS 3500, and identifies the plumber or drainer as the responsible person for that work[82]. A licensed plumber and/or drainer must complete a CoC at the completion stage of their work. The completed NoW and CoC must be submitted to the person arranging the work, and to either Fair Trading (prior to arranging a final inspection) or the local plumbing regulator. However, for emergency work, minor works and bathroom renovations, a NoW is not required[82].

The plumbing inspection process is executed by either NSW Fair Trading in water and sewerage operation regions of Sydney and the Hunter region, whereas inspections in all other areas of NSW are managed by the relevant local council. If work completed does not comply with the Plumbing

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81 Building Commision 2024 Position Paper, Regulation of Prefabricated Building (August 2024)
[82] NSW Government. (2024). Plumbing inspection documents. Plumbers and Drainers. https://www.fairtrading.nsw.gov.au/trades-and-businesses/construction-and-trade-essentials/plumbers-and-drainers/plumbing-inspection-documents

Code of Australia (PCA) and the ‘Deemed-to-Satisfy’ requirements of AS/NZS 3500, a ‘caution’ notice will be issued for rectification on the spot, or a formal notice of direction to comply will be written for resolution within a specified timeframe by the Fair Trading or local regulator inspector. A follow-up audit will then be conducted for the inspector to review. If the plumber or drainer fails to follow the directions to comply notice, a Penalty Infringement Notice can be filed as the record of the offence. Payment of this Penalty Infringement Notice (PIN) does not exclude the responsible person from fixing the work, and further legal action can be taken if the work is not rectified[82].

License types in NSW include a contractor license, qualified supervisor certificate, endorsed contractor license and tradesperson certificate. A contractor license is issued to individuals, companies and partnerships, and allows them to contract and advertise for the type of work only as described on their license card. A qualified supervisor certificate allows individuals to advertise and deliver work as described on their certificate, however, does not permit contracted work. Individuals who apply for a contractor license and also have the qualifications and experience needed to be a qualified supervisor can obtain an endorsed contractor license, which is considered equivalent to a qualified supervisor certificate[83]. A tradesperson certificate is issued to individuals who have the necessary qualifications and allows one to work with minimal supervision, however, this work must be overseen and signed off by someone who holds a contractor license or qualified supervisor certificate. A provisional tradesperson certificate can also be issued for three years without renewal if the required offshore technical qualifications can be provided[8382].

If a defect is found in the work completed and certified by a licensed plumber within two years (or within the timeframe specified by the Regulator) from the date of the final inspection, and the Regulator for Plumbing and Drainage certifies in writing that the defect is due to faulty workmanship or defective materials, the licensed plumber must rectify the work at their own expense. This rectification must be completed within the timeframe directed by the Regulator[83].

Electrical licenses

In NSW, electricians are required to submit a Certificate of Compliance for electrical work (CCEW) under the Gas and Electricity (Consumer Safety) Act 2017 and Regulation 2018, within seven days of completing any safety and compliance test on an electrical installation. Licensed electricians must provide a copy of the CCEW to Fair Trading, the customer and the distributor with their unique serial number[85]. The electrical license, being either contractor license, qualified supervisor certificate, endorsed contractor license or tradesperson certificate, is required for any electrical wiring work in New South Wales, regardless of the cost of the work, and if the site is residential, commercial or industrial, and applies to electrical wiring and electrical installation work[84].

There are different types of licences available in NSW depending on whether the applicant wants to contract for another party, supervise work, do the work, or a combination of these roles.

Upon failure to deliver electrical installation work in accordance with the technical standards as described in the Gas and Electricity (Consumer Safety) Regulation 2018, substantial penalties of up to $550,000 apply. Spot fines of up to $1000 apply for each occasion when a licensee does not supply a Compliance Certificate to a customer[85].

Mechanical licenses

For mechanical work under the category of air-conditioning and refrigeration work, a license is required of the tradesperson conducting work, showing evidence of being either an individual

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[83] *NSW Government. (2024). Plumbing inspection documents. Plumbers and Drainers. https://www.fairtrading.nsw.gov.au/trades-and-businesses/construction-and-trade-essentials/plumbers-and-drainers/plumbing-inspection-documents*

[84] *NSW Government. (2024). Licensing & qualifications. Electrical licenses. https://www.fairtrading.nsw.gov.au/trades-and-businesses/licensing-and-qualifications/electrical-licences Accessed on November 2024.*

[85] *NSW Government. (2024). Electrical compliance requirements. Electricians. https://www.fairtrading.nsw.gov.au/trades-and-businesses/construction-and-trade-essentials/electricians/electrical-compliance-requirements*

contractor, qualified supervisor or tradesperson. Types of work in mechanical services include air conditioning, refrigeration, associated electrical wiring and medical gas (requiring a separate license for medical gas fitting or medical gas technician work)[86]. Work completed is required to comply with AS 1668.2-2002, under the use of ventilation and air-conditioning in the building. When handling refrigerants, a Commonwealth Government refrigerant handling license is also required through the Australian Refrigeration Council (ARC), on behalf of the Department of Sustainability, Environment, Water, Population and Communities, and the Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995[87].

It is an offence to do air conditioning and refrigeration work without a license or certificate and can result in a fine of $22,000 for an individual or $110,000 as a company. Repeated non-compliant behaviour under ARC regulations across Australia may lead to license suspension, with penalties of up to $1,100 for individuals and $5,500 for corporate entities. The ARC conducts regular audits on behalf of the Department of Sustainability, Environment, Water, Population and Communities. Minor breaches of the Refrigerant Trading Authorisation (RTA) must be rectified within a set timeframe, and repeated failure to comply can jeopardise license renewal[87].

Queensland Building Statutory Framework

The Queensland Building and Construction Commission (QBCC), established by the QBCC Act of 1991, oversees Queensland's building industry [88]. Queensland's building system is mainly governed by the Building Act 1975 and Building Regulation 2021, which establish rules for the management and execution of construction projects, without specifically distinguishing between off-site and on-site construction methods. In particular, the Building Act 1975 aims to regulate building development approvals, building work, building classification and building certifiers[89].

The QBCC also specifies licencing requirements which broadly cover hydraulic services design, drainage, plumbing, gas fitting, termite management, fire protection, building inspections, building design for various classifications, and mechanical services[88]. The Plumbing and Drainage Act 2018 and Regulation 2019 in Queensland cover licensing for plumbing and drainage, outline the role of the Services Trades Council, and detail local government responsibilities[88]. However, these documents do not specifically regulate modular construction components such as bathroom pods, leading to the WaterMark certification becoming the key standard throughout Australia.

A search of the Queensland Building and Construction Commission Regulation 2018 using the terms ‘off-site construction’, ’prefab’, and ‘modular’ only identified prefabricated swimming pools. This highlights a regulatory gap in the integration of off-site construction with on-site construction practices.

The plumbing work undertaken in Queensland requires a QBCC licensed plumber or drainer to undertake the work. For electrical compliance, electrical contractors and their workers must issue a ‘certificate of testing and safety’ for equipment work and a ‘certificate of testing and compliance’ for installation work to their customers, as mandated by the Electrical Safety Regulation[90].

Development and Building Approval Process in QLD

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[86] NSW Government. (2024). Licensing & qualifications. Air conditioning and refrigeration licenses. https://www.fairtrading.nsw.gov.au/trades-and-businesses/licensing-and-qualifications/air-conditioning-and-refrigeration-licences#insurance Accessed on November 2024.

[87] Skills Certified. (2024). Air-Conditioning and Refrigeration License New South Wales. https://www.skillscertified.com.au/air-conditioning-refrigeration-licence-nsw/ Accessed on October 2024.

[88] Queensland Building and Construction Commission (QBCC). 2021. The regulatory framework. Accessed on: https://www.qbcc.qld.gov.au/about-us/what-we-do/regulatory-framework. Retrieved March 2024.

[89] Queensland Government. (1975). Building Act. Retrieved March 2024.

[90] Queensland Government. (2020). Electrical safety laws. Work Safe. Accessed on: https://www.worksafe.qld.gov.au/. Retrieved March 2024.

Development Approval (DA) is required before commencing work on Building Developments (BDs) in Queensland[91]. Since there is no specific definition to exclude modular components from the building work in QLD, it is assumed that the modular components are encompassed within these categories and undergo a similar approval process In Queensland; the Building Approval (BA) process involves the assessment of development applications by either local government or private certifiers before commencing construction on any class of building. The approval, aligning with the Building Act 1975, must comply with the National Construction Code (NCC), Queensland Development Code (QDC), and other relevant standards (Figure 12).

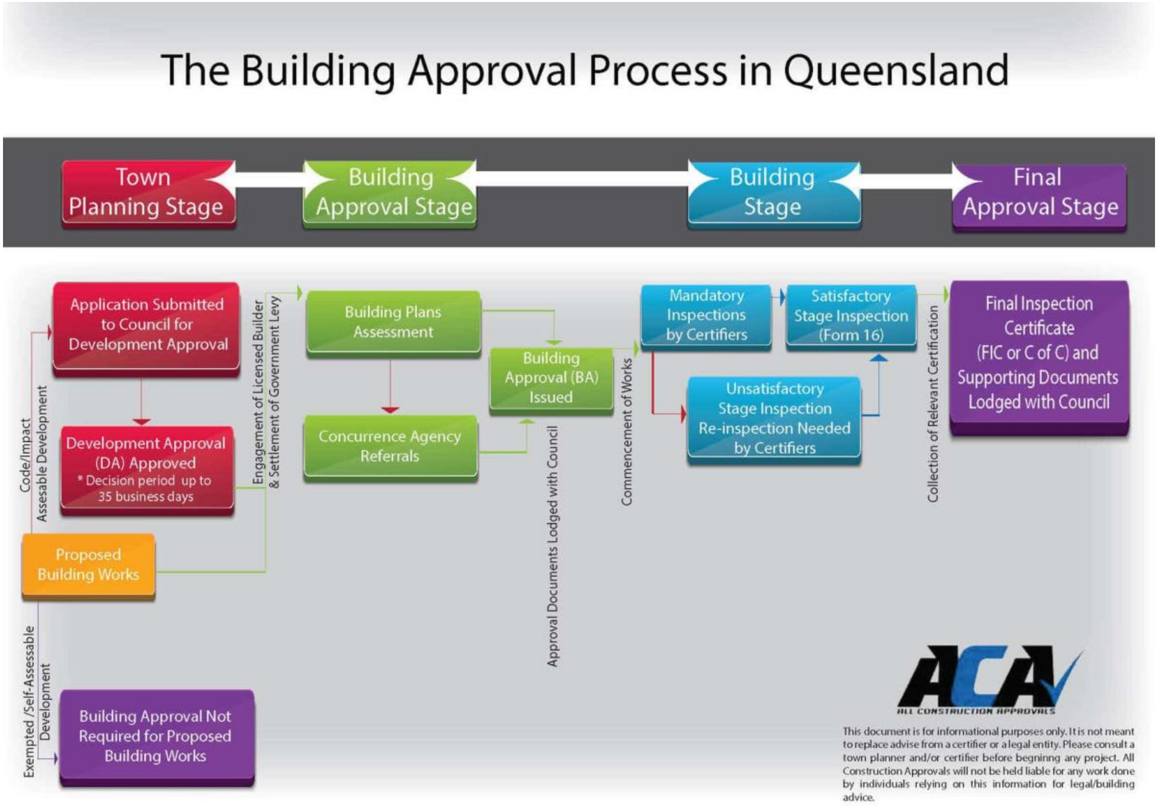

Figure 12 The building approval process in Queensland [92]

QLD's building inspection regime

Certifiers play a key role in inspecting and ensuring compliance throughout construction, culminating in the issuance of a Certificate of Occupancy; here, private certifiers have a specific endorsement with and without development approval endorsement. They can also rely on a competent person, for instance, to utilise an engineer's signoff inspection report and Form 12 In Queensland. The Form 12 Aspect Inspection Certificate (Appointed Competent Person) is a crucial document related to building development approvals. Form 12 is used to certify that a specific aspect of building work has been completed and complies with the building development approval. It serves as evidence that an appointed competent person has inspected the work and is satisfied with its compliance[93].

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[91] *Queensland Building and Construction Commission (QBCC). 2021. The regulatory framework. Accessed on: https://www.qbcc.qld.gov.au/about-us/what-we-do/regulatory-framework. Retrieved March 2024.*
[92] *https://acapprovals.com.au/building-approval-process-qld-all-construction-approvals/*
[93] *Business Queensland. (2022). Building approvals and inspections. Accessed on: https://www.business.qld.gov.au/industries/building-property-development/building-construction/approvals-inspections. Retrieved March 2024.*

It is stated in Building Regulation 2021, that to meet the statutory obligation to carry out inspections in accordance with best industry practice, inspections of any of the aspects should be physically undertaken on the construction site [94].

The Building Regulation (2021) requires inspections for simpler structures such as houses and sheds (class 1a and 10 buildings), but not for the more complex class 2 to 9 buildings, which are dealt with using a risk matrix approach (Guidelines for inspection of class 2 to 9 buildings, 2023). The two separate categories are discussed in more detail and separately below.

Class 1a and 10 Buildings

Under the Building Regulation (2021), Class 1a buildings require mandatory and staged inspections as detailed below:

- after excavation of foundation material and before the concrete for the footings, or slab, for the building are poured;
- if the building is to have footings—after the placement of formwork and reinforcement for the footings but before the concrete for the footings is poured;
- if the building is to have a slab—after the placement of formwork and reinforcement for the slab but before the concrete for the slab is poured;
- to the extent the bracing for the frame of the building consists of cladding or lining—after the cladding or lining is fixed to the frame;
- to the extent the bracing for the frame of the building does not consist of cladding or lining—before the cladding or lining is fixed to the frame;
- if reinforced masonry construction is used for the frame of the building—before the wall cavities are filled; at the completion of all aspects of the work[94].

The final inspection covers aspects such as: siteworks and drainage, termite management systems, damp and weatherproofing, fire safety, health and amenity, safe movement and access, construction of wet areas, glazing, sub-floor ventilation, energy efficiency, water saving[94.] At this stage, inspections focus solely on visible areas. For example, the terms 'siteworks' and 'drainage' do not refer to underground drainage systems but rather to the stormwater drainage on the ground surface, such as ensuring the ground slopes away from the house for a 1meter perimeter around the house, etc.

The only mandatory stage of inspection for class 10 buildings and structures (other than swimming pools) is the final stage of inspection. However, a building approval may list additional stages that require inspection[94].

When an inspection is required, as per notice, the inspector must ensure that the work completed at that stage adheres to the building development approval. There is provision for the inspector to rely on certificates from others (e.g. a QBCC licensee certificate) thereby not requiring a direct inspection under certain conditions. However, reliance on such certificates for the final stage's aspects is not permitted[95].

Class 2 to 9 Buildings

With regard to class 2 to 9 buildings, being more complex propositions, the Queensland government developed inspection guidelines to assist building certifiers in fulfilling their responsibilities under the Building Act 1975 and Building Regulation 2021[96] .These guidelines adopt a risk-based strategy and

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[94] *Queensland Government. (2021). Building Regulation. Retrieved March 2024.*
[95] *Queensland Government. (2021). Building Regulation. Retrieved March 2024.*
[96]*Business Queensland. (2022). Building approvals and inspections. Accessed on: https://www.business.qld.gov.au/industries/building-property-development/building-construction/approvals-inspections. Retrieved March 2024.*

aim to provide practical and effective methods for meeting statutory duties and obligations[97]. The guideline introduces a risk matrix with three categories: low, medium, and high, to determine building inspection schedules based on five broad risk factors including, the building classification, height/floor area, adopted performance solution, experience of the design and building team, climatic conditions (Table 2). The risk assessment helps certifiers determine the necessary types and frequencies of inspections. Development proposals may introduce unique risk factors not covered by the existing matrix. In such cases, the matrix should be applied in context with these unique factors to determine a logical risk level for each proposal. This flexible approach allows for tailored adjustments, ensuring appropriate oversight for each project's specific risks[97].

According to this guide, Guidelines for Inspection of Class 2 to 9 Buildings (2023), the first step involves determining the NCC building classification, which includes calculations of floor area and volume. This is followed by determining the building's height and the number of storeys. Assessing any relevant performance solutions for compliance with NCC performance provisions is critical. This is followed by the risk level in accordance with a risk matrix for the two remaining risk factors: experience of the design and building team, and climatic conditions. An inspection schedule is then produced, based on the risk level assessment, and includes elements identified to be inspected. This schedule is incorporated into the conditions of the development decision notice, including a provision that triggers the reassessment of the need for additional plans and construction details should there be changes. Communication with the builder and relevant practitioners is essential to verify the inspection schedule requirements. Inspections are carried out according to the schedule, including audits of the building work and any additional certifying functions requested by the owner to ensure compliance with the Building Development Approval (BDA). Upon the satisfactory completion of the building work, a certificate of occupancy is issued in accordance with the Building Act, marking the final step of the process (Figure 13).

[97] *Queensland Government. (2023). Guidelines for inspection of class 2 to 9 buildings. Retrieved March 2024.*

Table 2 Risk Matrix for building class 2 to 9

Risk factor	Risk level		
	Low risk	Medium risk	High risk
Building classification	Building is a class 2, 3, 4 (part of a building), 5, 6, 7 or 8 and has a rise in storeys of less than three storeys.	Building is class 2, 3, 4 (part of a building), 5, 6, 7 or 8 and has a rise in storeys of more than three storeys.	Building is class 9 or of any class determined to be of importance level 3 or 4 in accordance with the BCA.
Height/floor area	Not greater than three storeys above the ground. Fire compartments do not exceed the provisions of BCA Table C2.2.	More than three storeys above ground but no more than 25 metres in height.	Contains fire compartments exceeding the provisions of BCA Table C2.2. More than 25 metres in height.
Performance solutions	No performance solution – proposal meets deemed-to-satisfy provisions of BCA.	Incorporates performance solution not involving fire safety systems.	Incorporates performance solution involving fire safety systems.
Experience of the design and building team	Practitioners designing and constructing the building have been involved with more than three buildings of the same classification.	Practitioners designing and constructing the building have been involved with, and completed, fewer than three buildings of the same classification.	Practitioners designing and constructing the building have no previous experience relating to the proposed classification or building type.
Climatic conditions	Area is not impacted upon by known risks e.g. flood, bushfire, earthquake, cyclone, landslip.	Area has known risks e.g. flood, bushfire, earthquake, landslip, contaminated land. Building is not a class 9.	Area has known risks e.g. flood, bushfire, earthquake, landslip, contaminated land. Building is a class 9.

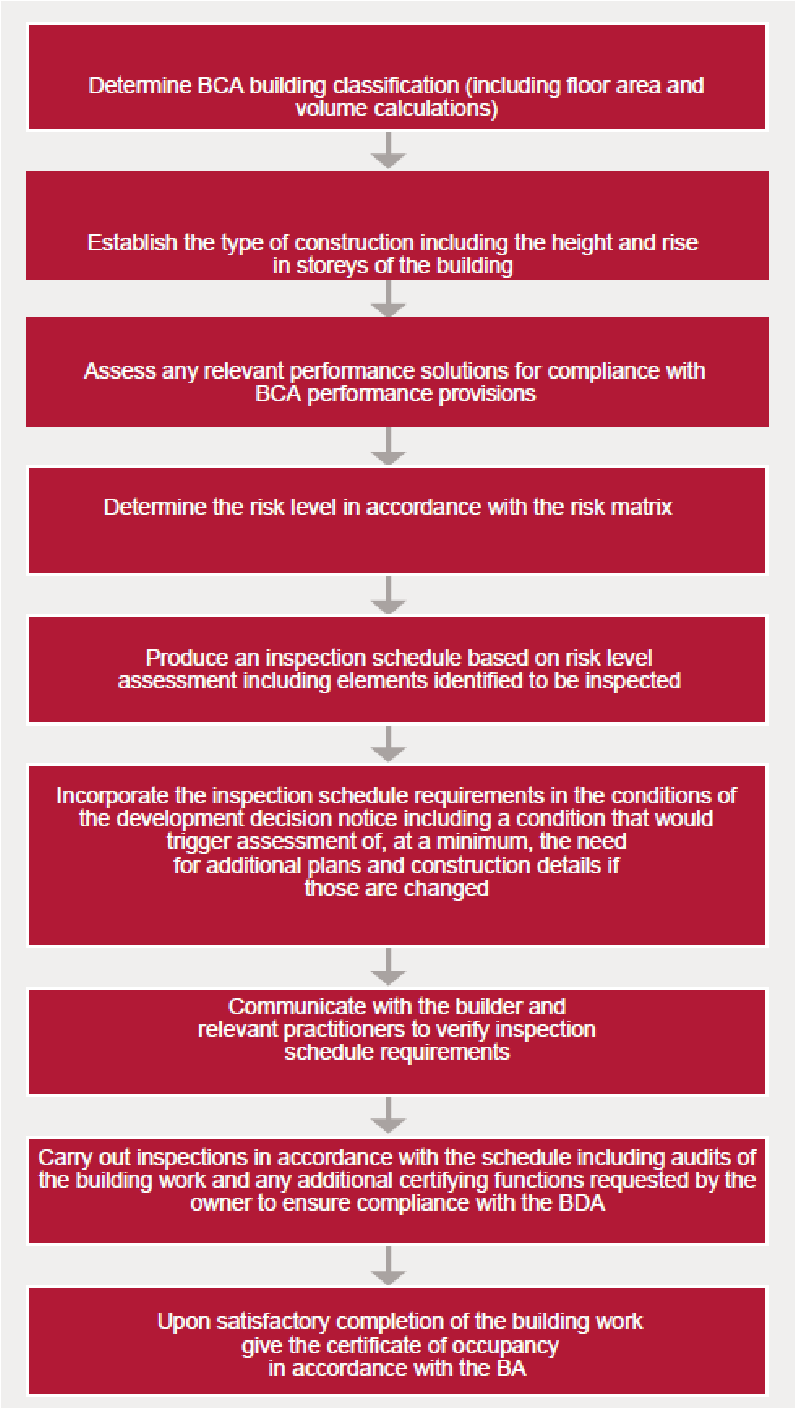

Figure 13 Class 2 to 9 assessment flowchart based on the risk matrix

For low-risk buildings, the Guidelines for Inspection of lass 2 to 9 Buildings, suggests establishing an inspection schedule that accounts for the complexity of fire safety installations, the building's number of storeys, and the construction program. For instance, in a three-storey class 2 building with multiple fire safety installations, it may be wise to inspect these systems as each level is completed, such as before wall and ceiling finishes are applied. Auditing walls, ceilings, and service penetrations for fire resistance and acoustic construction early on is beneficial. Inspections of fire detection and alarms might occur later, aligning with system testing and commissioning stages, depending on the system's complexity. For the high-risk buildings, fire safety systems in buildings such as hospitals, and aged care facilities, involve complex requirements often incorporating performance solutions. Inspections should account for the complexity of these requirements, with schedules allowing access to elements before they're obscured by progressive construction. Regular site visits are crucial for inspecting service penetrations and ensuring compliance at all construction stages. Visual inspections, carried out by the building certifier or a competent person on their behalf, are the most effective way of confirming that the details of the documentation are reflected in the actual on-site construction[98].

It is also apparent in the risk matrix that performance solutions attract medium to high risk. It is therefore relevant to point out that under the Building Act 1975, when a performance solution is utilised for a building, documents must be submitted that clearly outline the specific performance requirements that the building intends to meet and demonstrate how the building work aligns with these requirements. Additionally, the documentation must detail how the performance solution diverges from the standard 'Deemed-to-Satisfy' (DtS) provisions of the NCC or the acceptable solutions outlined in the Queensland Development Code (QDC). Queensland's unique environmental challenges include cyclones, bushfires, floods, and even earthquakes. These factors necessitate specific provisions within the Queensland Development Code (QDC), which can override the National Construction Code (NCC) when conflicts arise, ensuring that the building standards are robust enough to address local risks. Acceptable solutions are specific building solutions established by the Queensland Development Code (QDC) that deviate from the 'Deemed-to-Satisfy' Provisions outlined in the Building Code of Australia (BCA). These solutions are deemed acceptable for meeting particular performance requirements set by the BCA, offering alternative approaches to compliance with construction standards. The documentation must also include the results of inspections or tests and any other documents or information that were used in the preparation of the application, ensuring a comprehensive approach to validating the performance solution's efficacy and compliance. This efficiency of this process appears even more crucial for off-site construction because such projects are more likely to evoke the need for performance solutions over DtS. The main concern with the risk-matrix approach is the potential for variability driven by subjectivity in interpreting the appropriate inspection regime on a given project. Moreso, the simple lack of mention concerning off-site construction is only likely to add to this subjectivity as inspectors are unlikely to know what to do or how to deal with the different risk variables for off-site construction[98].

Fire safety systems and performance solutions in QLD

In Queensland, performance solutions involving fire safety systems, are also preferable to Queensland Fire and Emergency Services (QFES)[99]. The QFES referral process for performance solutions ensures fire safety compliance through several key stages[99] .Initially, the fire engineer, alongside the design team and building certifier, identifies areas within the development requiring fire-engineered performance solutions. Subsequently, the fire engineer prepares a comprehensive Performance-Based Design Brief (PBDB) outlining the proposed fire strategy for the building[99]. This PBDB is then submitted to QFES for a thorough review and referral advice, with evaluation against the requirements outlined in the NCC clause A2.2. Throughout this process, consultation with relevant stakeholders, including QFES, is paramount. Applications for QFES Building Approval Officer (BAO) involvement are facilitated via QFES e-lodgement, ensuring the endorsement of stakeholder engagement processes outlined in the Australian Fire Engineering Guidelines[99]. Importantly, experienced QFES BAOs, equipped with operational firefighting expertise and specialised knowledge of the built environment, participate actively as relevant stakeholders. Finally, during the construction, testing, commissioning, and final inspection phases, the responsible fire engineer oversees the implementation of performance solution requirements on-site, certifying that

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[98] *Queensland Government. (2023). Guidelines for inspection of class 2 to 9 buildings. Retrieved March 2024.*
[99] *Queensland Fire and Emergency Services (QFES). 2023. Performance solutions referral process. Accessed on: https://www.qfes.qld.gov.au/compliance-and-planning/referral-agency-advice/referral-agency-advice-guidelines/guide-performance-solutions/referral-process. Retrieved April 2024.*

the building adheres to the specified performance solution and other associated fire safety aspects[100].

Licensing requirements for specialist trades in QLD

Plumbing licenses

In Queensland, plumbing and drainage work is certified through inspections conducted by local government or a public sector representative. The local government is responsible for inspecting the work under the Plumbing and Drainage Regulation 2019. For plumbing and drainage permit work, the process typically requires an inspection before the work is covered, or within 5 days of reaching a specific stage. The inspection certificate, issued by the local government, confirms that the work complies with code requirements and is fit for use[101].

In certain cases, local governments may accept alternatives to inspections, such as declarations or reports (e.g., Form 3 for covered work or Form 5 for testing/commissioning) which can be done by a licensed plumber. In remote areas, a remote area compliance notice can be submitted in place of an inspection. If the inspection is successful, a final inspection certificate (Form 19) is issued, certifying that the plumbing or drainage work is compliant and ready for use. The work cannot be used until this certificate is issued, and penalties apply for non-compliance[102].

Mechanical licenses

In Queensland, licensing requirements for mechanical services work are regulated by QBCC, where licenses are required for contractual work, supervision or personal execution of the work, regardless of the value of the work. Variances in licensing types include occupational and limited or unlimited design licenses for air conditioning and refrigeration works[103]. Particularly for regulating the compliance of installation, repair and maintenance of air-handling and water systems, mechanical licensees are required to adhere to the AS/NZS 3666. Work undertaken without a license is considered an offence, with escalating maximum penalties of up to 350 penalty units or up to one year's imprisonment for the unlawful execution of mechanical services work (section 42CA of the QBCC Act) and engagement of an unauthorised person for mechanical services work by a licensed contractor (section 42DA of the QBCC Act)[104].

Electrical Licenses

In Queensland, electricians are permitted to self-certify their work if they meet the competency requirements outlined in the Building Regulation (BR) and Building Act (BA). Before a building certifier can accept an electrician's self-certification, they must verify that the electrician is licensed under the Electrical Safety Act 2002 (ESA) and assess their experience, qualifications, and skills, particularly for complex installations like fire alarms and emergency lighting systems. Once the certifier is satisfied that the electrician possesses the necessary expertise, they document this decision, including all assessment details and justification for deeming the electrician a 'competent person'. With this verification, the electrician can self-certify their work, ensuring it aligns with health,

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[100] Queensland Fire and Emergency Services (QFES). 2023. Performance solutions referral process. Accessed on: https://www.qfes.qld.gov.au/compliance-and-planning/referral-agency-advice/referral-agency-advice-guidelines/guide-performance-solutions/referral-process. Retrieved April 2024.

[101] Business Queensland. (2022). Inspection certificates for plumbing and drainage. https://www.business.qld.gov.au/industries/building-property-development/building-construction/plumbing-drainage/inspection-certificates. Retrieved in October 2024.

[102] Business Queensland. (2022). Inspection certificates for plumbing and drainage. https://www.business.qld.gov.au/industries/building-property-development/building-construction/plumbing-drainage/inspection-certificates. Retrieved in October 2024.

[103] QBCC. (2021). Mechanical Services Licenses. https://www.qbcc.qld.gov.au/licences/apply-licence/available-licences/mechanical-services Retrieved in November 2024.

[104] QBCC. (2020). Mechanical Services Licensing Regulatory Guide. Retrieved from: https://www.qbcc.qld.gov.au/sites/default/files/2021-10/reg-guide-mechanical-services.pdf Retrieved in October 2024.

safety, and quality standards. Despite this, the ultimate responsibility for compliance with the BA rests with the building certifier, even when they rely on an electrician's certification[105].

Electrical contractors, and workers completing work on behalf of an electrical contractor in Queensland, must either provide a Certificate of Testing and Safety or Certificate of Testing and Compliance for customers, depending on the type of work done, which includes details of the licensee, customer, work completed and a statement certifying the electrical equipment or installation is electrically safe. The classes of electrical work licenses include electrical mechanic, electrical linesperson, electrical fitter, electrical jointer, restricted electrical work, and electrical work training permit[106]. For electrical installation, the statement must certify that it adheres to the Electrical Safety Regulation 2013, Electrical Safety Code of Practice 2020, Electrical Safety Code of practice 2021, Electrical Safety Act 2002 (Qld) and is in accordance with the requirements of necessary wiring rules and other applicable standards[107].

This means that under the Queensland Home Warranty Scheme, licensed contractors are responsible for collecting an insurance premium from the customer and paying it to the Queensland Building and Construction Commission (QBCC). These premium covers specific types of residential work. Essentially, contractors act as intermediaries, ensuring that consumers are enrolled in the warranty scheme for protection against defective work or unfinished projects[108].

Victorian Building Statutory Framework

Building Inspection Process in Victoria

In Victoria building work on a property may require a planning permit, a building permit, or both. Planning permits are required to develop or use land in a particular way, such as for a new home, extension, renovation, or an additional dwelling on the land. The local council is responsible for issuing a planning permit before obtaining a building permit. The applicants are encouraged to employ a town planner to determine whether a planning permit is necessary or not. Planning permit applications submitted to the council may need to include the proposed design, planning report, shadow diagrams, etc[109].

A building permit is a written approval by a private or municipal building surveyor that certifies that a proposed building complies with the relevant building regulations. It allows the building work to be undertaken according to the approved plans, specifications, and other relevant documentation.

Before applying for a building permit, a registered building surveyor should be appointed. In fact, a building permit should be applied through a building surveyor.

To apply for a permit the following documents must be provided:

[105] Queensland Government, Department of Housing and Public Works. (2017). Certificates from electricians relating to building work.
https://www.hpw.qld.gov.au/__data/assets/pdf_file/0024/5289/certificatesfromelectriciansrelatingtobuildingworkguideline.pdf.
[106]Electrical Safety Office. (2023). Electrical licensing eligibility guide. Queensland Government.
https://www.worksafe.qld.gov.au/__data/assets/pdf_file/0008/20042/es-licensing-eligibility-policy.pdf Retireved in November 2024.
[107] Queensland Government. (2017). Electrical contractor safety duties. Business Queensland. Retireved from:
https://www.business.qld.gov.au/industries/building-property-development/building-construction/electrical-contracting/safety-duties
[108] Queensland Building and Construction Commission. (2021). Queensland home warranty scheme.
[109] Victorian Building Authority. (n.d). Planning and building permits. Retrieved October 2024.

- drawings, specifications and allotment plans along with the completed application form and other prescribed information.
- payment of building permit levy fee.

A building permit can only be issued once the relevant planning permit (if required) is obtained, and the building levy is paid, resulting in a building permit number. The building surveyor must also receive consent from other authorities, such as the local council or water authority, if necessary. Permits can be issued for the entire project or specific stages and may include conditions. Mandatory inspections will be outlined, and additional inspections can be required at the surveyor's discretion. If the work impacts neighbouring properties, protective measures may be mandated. If a permit is denied, the applicant can amend the application or appeal the decision to the Building Appeals Board[109].

A Building Permit, issued by a Building Surveyor, will state what class of building has been approved for construction. Also, only a building surveyor can issue the final certificate for that building upon the completion of the works listed on the Building Permit[110].

Building Inspection Regime

For the construction of a new building or alterations to an existing building, the prescribed stages are:

- before placing a footing
- before pouring an in-situ reinforced concrete member that is specified in the relevant building permit by the Relevant Building Surveyor (RBS)
- completion of framework
- inspection of fire and smoke resisting building elements as required under regulation 172
- final, on completion of all building work[111].

Regulation 172 requires additional mandatory inspections in each storey of a Class 2, 3 or Class 4 part of a building for:

- any building element that is of lightweight construction required to resist the spread of fire in at least one sole occupancy unit
- one of each stair shaft, lift shaft or service shaft of a lightweight construction that is required to resist the spread of fire
- the components and junctions of the building elements listed above.

Regulation 172(2) also requires a mandatory inspection for one of each type of fire protection method for each type of service penetration that is required to resist the spread of fire or smoke on each storey of Class 2, 3, 4, 9a or 9c building[112].

For new construction or alterations, the Relevant Building Surveyor (RBS) can skip mandatory notification stages in Regulation 167 if they do not apply to the work as defined in Regulation 170[112]. Otherwise, all prescribed stages must be specified in the building permit and must be inspected.

The RBS can either perform the inspection themselves or appoint a person specified under section 35B of the Act to do it on their behalf. The RBS cannot delegate inspections to another person unless that person is either:

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[110] *Victorian Ombudsman. (2023). Investigation into a Building Permit Complaint. Parliament of Victoria. Accessed at: https://www.ombudsman.vic.gov.au/our-impact/investigation-reports/investigation-into-a-building-permit-complaint/ Retrieved on October 2024*

[111] *Victorian Building Authority. (2021). Building Practice Note MI-01: Mandatory notification stages and inspection of building work. Retrieved on October 2024*

[112] *Victorian Legislation. (2018). Building Regulations 2018. Retrieved on March 2024.*

- a registered building surveyor or inspector with the appropriate authorisation to perform the inspection, or
- a designated person permitted to conduct a specific type of inspection under regulation[111].

The Building Surveyor (BS) must ensure that all inspections at mandatory notification stages are carried out in person (section 34)[113]. The BS must not rely solely on photographs, drones, videos, declarations, or reports from individuals who are not registered building surveyors, inspectors, or authorised persons under section 35B of Act 39 to conduct mandatory inspections.

If the non-compliance issues are addressed through the rectification process, the RBS should document the inspection, indicating that the mandatory inspection stage has been approved and the building work is compliant. This documentation is essential to confirm that the issues have been resolved. If the builder does not comply with a written directive to rectify, the RBS should record that the mandatory inspection stage has not been approved, providing details of the non-compliant work. The RBS may then decide to issue a building notice or order under Part 8 of the Act[114].

In Victoria, certificates of final inspection are covered in Part 4, Division 3 of the Building Act (p. 89) which requires the relevant (appointed) building surveyor to issue a certificate of final completion following the final mandatory inspection of building work. Certificates of final inspection are provided when an occupancy certificate is not required, and the building work is deemed to be complete and in compliance with all the requirements of building inspections listed under Part 4 of the Act, although the issuing of this certificate is not considered 'evidence' that the building or building work complies with the Act[115]. The issuing of a certificate of final inspection also does not prevent the building surveyor from re-attending the site to serve a building order or building notice (p. 151) although, like Occupancy Permits, building action may only be bought within 10-12 years from the date of issue of this certificate.

Certificates of Occupancy, which are now called Occupancy Permits but are still often referred to as occupancy certificates (NCC), are included here as they are similar to certificates of Final Inspection and are they are often considered together (Building Regulations Part 13, p. 174). Occupancy Permits are covered in Part 5 of the Victorian Building Act Parts 8 Division 3 (Occupancy Permits) and Part 13, Division 2 (Application for Occupancy Permit) of the Vic Building Regulations. Occupancy Permits are issued by the building surveyor who must identify in the building permit whether occupancy certificates are required and whether they are required for parts of the building or the whole of the building work[116].

The main difference between the issuing of an Occupancy Permit and the Certificate of Final Inspection is that occupancy certificates can be refused if the building surveyor deems the building or any part of the building to be 'uninhabitable' or if plumbing work carried out in conjunction with the building work on the building or part of the building in respect of which the permit has not been granted (or cannot produce) a certificate of compliance (Building Act Div 4 – Compliance Certificates Section 221ZH p404). In addition, Occupancy Permits can be amended or even cancelled by the issuing building surveyor if this action is considered necessary in the public interest (p101)[116]. Grounds for the cancellation of an occupancy certificate include determinations of part of the building as being 'no longer suitable for occupation'. Occupancy Permits are required to be registered with the local Council and may be associated with essential safety measures (Building Regulations Section 196 Compliance with AS1851-2012)[116].

Fire safety and performance Solution in Victoria

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[113] *Victorian Legislation (2021). Building Act 1993. Retrieved on March 2024.*
[114] *Victorian Legislation (2021). Building Act 1993. Retrieved on March 2024.*
[115] *Victorian Building Authority. (2021). Building Practice Note MI-01: Mandatory notification stages and inspection of building work. Retrieved on October 2024*
[116] *Victorian Building Act. (1993). Retrieved October 2024.*

An example of building work that the relevant building surveyor (RBS) may require additional inspections of is fire-rated construction. To determine whether a performance solution complies with the performance requirements as noted in Part A2 of the NCC, RBS must produce a copy of both the performance-based design brief (PBDB) and the final report of their assessment[117]. This final report would include all performance requirements and the Deemed-to-Satisfy Provisions as applicable through A2G2(3) and A2G4(3), identify all assessment methods used, details of steps, confirmation that the Performance Requirement has been met, and the details of any conditions or limitations regarding the Performance Solution[118]. For a fire-related performance solution, regulation 121 of the Victorian Regulations 40 states that the surveyor must:

- hold a Graduate Certificate in Performance-Based Building & Fire Codes from Victoria University or equivalent
- rely on a report of the chief officer under regulation 129 that states the chief officer is satisfied by the fire safety achieved by the performance solution[119].
- rely on a certificate under section 238 of the Act by a fire safety engineer or registered building surveyor who did not design the building work
- rely on a determination of the Building Appeals Board under section 160A of the Act
- rely on a certificate of accreditation issued by the Building Regulations Advisory Committee
- rely on a Certificate of Conformity issued by a person or body authorised by the ABCB.

It should also be noted that under section 192B (1) of the Act, certain high-risk external wall cladding products are prohibited from use by any person carrying out building work in Victoria in connection with a Class 2 to 9 building of Type A or B construction. These prohibited external wall cladding products consist mostly of aluminium composite panels with a core of less than 93% inert mineral filler, and expanded polystyrene products used in external insulation and rendered wall[120].

The evaluation process for fire-related performance solutions involves developing a Performance-Based Design Brief (PBDB), which defines the specific fire safety performance requirements and acceptance criteria that the proposed solution must meet. These criteria typically include ensuring structural integrity during a fire, providing safe evacuation routes, controlling the spread of fire and smoke, and minimising risks to occupants and emergency responders. The PBDB guides the analysis and forms the basis for assessing whether the solution meets the intended safety objectives. The performance solution is then evaluated using approved assessment methods, such as fire engineering analysis, simulation models, or expert judgment. Quantitative measures like fire resistance levels (FRLs) and evacuation times, along with qualitative assessments, form the acceptance benchmarks. Independent certification from qualified professionals, such as fire safety engineers, is often required to validate that the solution meets these standards[120].

The RBS plays a crucial role in confirming compliance by reviewing the PBDB, assessment methods, and final documentation. In some instances, the report and consent of the Chief Officer from Fire Safety Victoria must be obtained, particularly if the solution deviates from standard 'Deemed-to-Satisfy' (DtS) provisions. Any conditions, limitations, or site-specific factors that could impact the effectiveness of the solution must also be thoroughly documented and addressed[120].

Licensing requirements for specialist trades in Victoria

Plumbing licenses

The regulatory framework in Victoria relies on a self-certification system for plumbing compliance through the lodgement of compliance certificates. The self-certification system places responsibility for compliance on the licensed plumbing practitioner who certifies the plumbing work and has mandatory insurance cover for that work (where this is required). Upon completion of most plumbing

[117] *Victorian Building Authority. (2023). General GE-07 | Fire related performance solutions. Retrieved October 2024.*
[118] *Victorian Legislation. (2018). Building Regulations 2018. Retrieved on March 2024.*
[119] *Victorian Legislation. (2018). Building Regulations 2018. Retrieved on March 2024.*
[120] *Victorian Building Authority. (2023). General GE-07 | Fire related performance solutions. Retrieved October 2024.*

work, the licensed plumber must issue a compliance certificate certifying the work's compliance with the relevant plumbing standards, codes and other regulatory requirements. All certificates must be lodged with the Victorian Building Authority (VBA) and are used to inform audits occurring under its Plumbing Audit Program.

Only licensed plumbers are authorised to issue compliance certificates—registered plumbers do not have this authority. According to VBA, a registered plumber holds the base qualification required to perform plumbing work but has limitations. They can carry out plumbing tasks but are not permitted to supervise other plumbers, including apprentices, nor can they sign compliance certificates[121]. A licensed plumber, on the other hand, is more experienced and knowledgeable than a registered plumber. To obtain a licence, a plumber must first be registered, complete additional units of competency, and meet practical experience and insurance requirements. A licensed plumber is authorised to supervise apprentices and registered plumbers, perform design work, and sign compliance certificates. Their licence is valid for one year. A licensed plumber must self-certify works valued at $750 or more and submit a compliance certificate to the VBA within five days if the work involves any of the a) below-ground sanitary drains, b) gas appliances, gas piping, or c) cooling towers[122].

VBA action against non-compliance by plumbers falls under 'Compliance and Enforcement Policy Framework'. According to this framework, licensed plumbers must follow core obligations like inspecting drains, issuing compliance certificates, and providing insurance information. If they issue a compliance certificate for a non-compliant work, they can receive an infringement notice. For repeat offences, more serious actions like discipline or prosecution may follow. First-time offences might result in just a caution or warning, depending on the situation[123]. The VBA advises licensed plumbers to either promptly rectify any non-compliant plumbing work they performed or supervised to avoid an insurance claim or provide their insurance details to the client if they are unable or unwilling to fix the issue within the six-year insurance period[124].It is required that all licensed plumbers must be covered by insurance when executing work that requires a compliance certificate. The limit for public liability is $5,000,000 for any one claim, and $50,000 relating to domestic plumbing work, and $100,000 relating to non-domestic plumbing work[125].

Electrical licenses

In Victoria, a Certificate of Electrical Safety is issued by an electrician to record the details of their electrical work. This is a legal document required by the Electrical Safety Act 1998 and the Electrical Safety (General) Regulations 2019 and must be issued upon completion of electrical installation work as proof of certification. Compliance of electrical work is required by the Electrical Safety Act, Electrical Safety (General) Regulations, Electrical Safety (Registration and Licensing) Regulations, AS/NZS 3000: Wiring Rules, relevant Standards (including referenced sections of the BCA), and Victorian Electricity Distributors Services and Installation Rules. Electrical work is completed by Registered Electrical Contractors and Licensed Electrical Workers such as electricians or Restricted Electrical License holders, who are responsible for purchasing and completing the Certificate of Electrical Safety and providing a copy to their customer[126]. Registered Electrical Contractors can

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[121] *Victorian Building Authority. (n.d). Plumbing registration and licensing. https://www.vba.vic.gov.au/registration-and-licensing/plumbing-registration-and-licensing. Retrieved October 2024.*

[122] *Victorian Building Authority. (2024). Plumbing compliance certificates. https://www.vba.vic.gov.au/consumers/home-renovation-essentials/plumbing-compliance-certificates. Retrieved October 2024.*

[123] *Victorian Building Authority. (2024). Compliance & Enforcement Policy Framework.*

[124] *Non-compliant plumbing work and plumbing insurance. (2024). VBA. https://www.vba.vic.gov.au/news/news/2024/non-compliant-plumbing-work-and-plumbing-insurance. Retrieved on October 2024.*

[125] *Victoria Building Authority. (2024). Insurance for building and plumbing work. https://www.vba.vic.gov.au/consumers/home-renovation-essentials/insurance-building-plumbing-work Retrieved November 2024.*

[126] *Energy Safe Victoria. (2024). Certificates of Electrical Safety. https://www.energysafe.vic.gov.au/certificates-electrical-safety/about-certificates-electrical-safety Accessed on October 2024.*

identify as individuals, partnerships or companies, and are required to hold a current public liability insurance, with a minimum cover of $5,000,000[127].

Auditing of the electrical installation work described in the Certificate of Electrical Safety can occur prearranged or upon request, and where the electrical installation is discovered to be not compliant with the minimum requirements of the relevant section of the Act or Regulations, details concerning item, location and description will be recorded in the Certificate of Inspection. An inspection must be completed within eight business days after the completion of work. An installation work deemed unsafe by the Electrical Inspector is first isolated from the supply for safety and must be rectified within the specified time. Failure to do so may result in suspension of license, issued infringement notices or further prosecutions[128].

Mechanical licenses

Licensed practitioners are required to issue compliance certificates and maintain appropriate insurance coverage[129]. Refrigerated Air-Conditioning work is described by the Plumbing Regulations 2018, under Part 4 as the construction and maintenance processes for air-conditioning equipment associated with the heating and cooling of a building, a split system heat pump water heater, and any design work associated with them. An understanding and application of the compliance requirements of Refrigerated Air-Conditioning work include AS/NZS ISO 817:2016, AS/NZS 5149.1,2,3,4:2016, HB 276-2004, Building Act 1993, Victoria Plumbing Regulations 2018, NCC, and the Australia and New Zealand refrigerant handling code of practice. In addition, to qualify as a licensee, the VBA describes the units of competency necessary for meeting knowledge and experience requirements[130]. Licensees in Victoria are also required to hold a refrigerant handling license and either an electrician's license (A grade) or engage a Registered Electrical Contractor registered by Energy Safe Victoria. Upon completion of the work, a Certificate of Electrical Safety (Electrical Safety Victoria) and a Plumbing Compliance Certificate (Victoria Building Authority) are to be issued to customers[131]. As a mechanical services licensee in Victoria, public liability insurance is highly recommended for consumer protection, and to secure engagement as a subcontractor.

Conclusion on State Regulatory Framework

The review of regulatory frameworks in NSW, Queensland, and Victoria highlights that each state has established comprehensive inspection and certification systems, which are primarily focused on traditional on-site construction methods. The statutory regulations however show a lack of clarity when it comes to off-site construction.

The NSW Government has released several publications over the past three years aimed at developing a comprehensive regulatory framework for off-site construction, culminating in the proposed Building Bill set to be introduced in 2024. However, there are specific areas of concern with the proposed regulatory changes in NSW as follows:

1. The proposed regulatory change is purely focused on Volumetric (3D) construction and everything else is lumped under the alternative category of 'products' (which are not dealt with by the proposed regulation). However, a

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[127] Energy Safe Victoria. (2024). Certificates of Electrical Safety. https://www.energysafe.vic.gov.au/certificates-electrical-safety/about-certificates-electrical-safety Accessed on October 2024.
Energy Safe Victoria. (2024). Registered Electrical Contractors (REC).
[128] Energy Safe Victoria. (2024). Licensed Electrical Inspectors. https://www.energysafe.vic.gov.au/licensing/your-responsibilities/licensed-electrical-inspectors Accessed on October 2024.
[129] Victoria Building Authority. (n.d). Mechanical Services. https://www.vba.vic.gov.au/registration-and-licensing/plumbing-registration-and-licensing/mechanical-services.Retrieved on October 2024.
[130] Victoria Building Authority. (2024). Refrigerated Air-conditioning. Plumbing registration and licensing. https://www.vba.vic.gov.au/registration-and-licensing/plumbing-registration-and-licensing/refrigerated-air-conditioning Accessed on October 2024.
[131] Energy Safe Victoria. (2022). Air-conditioning systems – Fact Sheet. https://www.energysafe.vic.gov.au/sites/default/files/2022-12/Fact-sheet-Air-conditioning-systems-VBA.pdf Retrieved in October 2024

significant proportion of advanced 2D prefab panel and service assemblies are missed by both categories because they are not 3D volumetrics but do also involve hidden construction that occurs off-site and therefore cannot be easily inspected by a certifier onsite (which the paper mentions as being expected of 'Products'). This is commercially disappointing as these 2D panels and service assemblies could potentially be cost effectively produced off-site. Examples include

- All closed or semi-closed panels.
- Prefabricated wall frames that are lined or with off-site construction sheathing and an external vapour barrier (easily added off-site and weatherproofs the onsite building more quickly so that ongoing work can continue internally and externally at the same time).
- Windows and glass facades with electronically operated louvres/blind systems included.
- Roof cassettes that already have roof sheeting added off-site (holding down fixings become hidden).
- Service walls aimed at simplifying kitchen/bathroom/laundry installations.
- Most mechanical and electrical distribution assemblies.
- Prefabricated fire shafts in multi-storey buildings.
- Floor cassettes where they are closed on the underside and/or contain service runs.

2. The NSW legislation has always contained mandatory inspection points for traditional on-site inspection. However, it does not provide an alternative course of action where these inspections become redundant because some/all construction is prefabricated off-site. Increased confusion and risk will likely prevail in meeting statutory inspection requirements (for both builder and project certifier). Wording change is needed to clearly say what to do when using off-site assemblies.
3. Further to the above point, the position paper states that the 'certifier prescribe critical stage certification' (p. 32) but this creates potential inconsistency from one certifier to the next. It does **not** create a predictable and reliable system, which is critical for prefabrication to be cost effective. The staging of critical certification could be replaced/clarified via use of a standardised third-party certification scheme to enable prefabricators to issue a certificate of compliance for the off-site construction. The project certifier would no longer need to inspect it or create their own prescriptive certification needs but rather, simply obtain the certificate from the prefabricator.
4. The position paper talks about certification schemes but delivers very little content or detail regarding this. This is an important omission as certification schemes (typically inclusive of QA and QC undertaken by the prefabricator and assessed/audited by a third party) are considered critical in efficiently dealing with prefabrication compliance. Options need to be developed for certification but reference points for this include: the International Codes Council's 1200 series of Standards and the Built Ready scheme in New Zealand. The ABCB's CodeMark scheme could also be potentially adapted for this purpose. Other options also exist.

The position paper is thought to overly weight (Builder/Trade) licensing as a catch-all for certifying the compliance of prefabrication work. Whilst licensing is useful it should not be overly weighted or prescriptive but instead should be a component sitting within the abovementioned certification schemes (i.e. within a broader QA/QC approach).

- The proposed definitions of off-site building work and associated concepts appear to narrow and may limit future development. The likes of 'home building work' would simply include one or more of these seven categories. It allows still other categories to be classified under 'building products'. There is arguably also a case to create a third category for complex products, which would sit between (holistic) building works and relatively simple building products (i.e. currently off-the-shelf, mass-produced products).
- Duplication of costs and risk is a concern if the manufacturer was deemed to be a building contractor meeting all the requirements of doing 'building work'. For instance, this carries head contractor-based company overheads. Care must be taken to avoid duplication of these costs/risks (by head contractor and manufacturer) for lower levels of prefabrication (pre-manufacture) in order to retain cost competitiveness.
- Further, a key intent of off-site construction is to reduce on-site preliminary costs (false work, scaffolding, sheds, staff, hoardings) and so the regulatory system must avoid the creation of circumstances that cause the head contractor and manufacturer to be working at cross purposes (due to lack of synthesis and lack of agreed perspective of risk).

The review of Queensland's building regulatory framework, particularly against the backdrop of off-site construction practices, uncovers critical areas needing refinement to better accommodate off-site construction. For instance, the Building Approval (BA) process in Queensland poses challenges for off-site construction due to a lack of clarity in the application requirements (drawings and specifications) and inspection process. The BA process in Queensland does not typically concern itself with the operations of off-site manufacturing companies. While the manufacturing company is responsible for producing off-site components or any building products, the BA process focuses on the compliance and regulatory approval of the construction project where these components will be used.

There is also an ambiguity surrounding the definition and regulation of building products, and whether it include off-site assemblies or not that can lead to inconsistencies in compliance and safety standards. Another significant gap is the ambiguity of the adoption of the risk-based approach for inspecting class 2 to 9 buildings, by classifying risk levels. This method relies heavily on the judgment of the certifier, potentially introducing subjectivity into the determination of the number and frequency of inspections. The risk matrix aims to simplify assessments by categorising projects into low, medium, and high risk, yet it might not fully capture the complexities of diverse construction projects, especially those using novel technologies or off-site construction. Investigating how off-site construction affects risk levels for buildings in classes 2 to 9 is essential. If off-site construction is found to increase complexity and risk, a revised inspection schedule for these buildings might be necessary.

According to the Queensland regulatory framework for inspections, it is essential for building certifiers or authorised competent persons to conduct visual inspections to ensure that the on-site construction accurately reflects the documented designs and meets regulatory standards. However, these inspections may need to be adapted to accommodate the specific requirements of off-site construction, including the challenge of identifying construction within sealed assemblies. To address this, modifications might include performing visual checks at the manufacturing site to confirm that components comply with documentation and standards, and at the construction site to ensure that assembled components match design intentions and fulfill building approval criteria. Adopting self-certification or third-party certification during the manufacturing stage could decrease the need for certain inspections by building certifiers, thus streamlining the inspection process.

In the proposed risk matrix, a critical risk factor identified is the incorporation of fire safety systems as performance solutions instead of adhering to Deemed-to-Satisfy (DtS) solutions. This risk becomes more significant when fire safety performance solutions are combined with off-site assemblies, introducing additional complexity and potential hazards. To mitigate these risks, it is essential to establish an inspection schedule aligned with production for off-site construction. This inspection schedule may also align with the QFES inspection requirements and referral process, involving the certifier to facilitate early detection of non-compliance.

Victoria's framework, while robust in terms of traditional building inspections and compliance for fire-related performance solutions, also lacks specific guidelines for off-site construction. The current procedures focus heavily on mandatory on-site inspections and performance solution documentation without addressing how these processes should be adapted for prefabricated components produced off-site. In Victoria, the off-site construction of plumbing systems, such as bathroom pods, is the only off-site construction method regulated and enforced by the Victorian Building Authority (VBA). Systems must comply through one of two pathways: as ‘plumbing work’ or as a ‘plumbing product’. The chosen method dictates how the system is regulated and inspected, but the on-site installation must still adhere to all relevant regulations under the Act. This makes plumbing systems unique as the sole off-site construction approach currently addressed by the VBA.

The availability of the Notice of Direction for wet area pods provides a valuable foundation for shaping future legislation aimed at standardising the regulation of off-site construction, ensuring consistent compliance and mitigating risks associated with integrating innovative construction methods. The structured approach outlined in the notice, which categorises prefabricated modules as either purpose-built products or regulated work, establishes a precedent that other regulatory bodies can adopt to create clear and consistent guidelines for managing off-site components. Moreover, the notice’s focus on maintaining certification and ongoing compliance through the WaterMark Scheme for purpose-built modules, underscores the need for a similar, comprehensive certification framework tailored to off-site construction more broadly, addressing the specific complexities these systems introduce.

CHAPTER 7 - THE IMPORTANCE OF FIRE PERFORMANCE AS A REGULATORY ISSUE

A widely reported area of regulation that has significant ramifications for off-site construction, concerns fire safety. For instance, the Grenfell Tower fire in London is a particularly well-known example of poor fire performance of panelised cladding systems that has since impacted fire regulations around the world[132]. Similar fire incidents within Australia also exist and include the Lacrosse apartment tower fire in 2014 and the Neo200 residential tower fire in 2019[133].

Risk locations in Fire Design

In trying to improve fire regulation for modern methods of construction, Meacham (2022) undertook a survey of the Inter-jurisdictional Regulatory Collaboration Committee (an international body dedicated to effective collaboration concerning best current practices in building regulatory systems)[134]. Their study aimed to check existing methods regarding fire regulation and whether modified approaches should be considered in the future. A key finding from his paper is that gaps, voids, joints and connections between and within penalised and volumetric construction represent high-risk areas in modern methods of construction. Underlying materials maybe combustible, hidden combustion can occur, and structural connectors can be compromised. Subsequently, these locations require extra oversight in terms of specific parts of the construction including the spread of fire, smoke, and hot gases through void spaces[135].

Of note, this same emphasis is raised in the Australian context where the *Handbook for modular design* identifies discontinuities and interfaces (between modules and where the same modules meet in situ construction), as being particularly important for fire engineering (as well as acoustic performance and thermal regulation). These locations are subsequently seen as representing higher risk in terms of proving/checking compliance for off-site construction.

Dorrah et al. (2019) found that obtaining a construction permit and meeting compliance requirements represented the main impediment for the uptake of new off-site construction methods such as mass timber construction. Linked to this, Design costs typically increase with charges for consulting engineers who require extra time to manage code compliance; the need for a dedicated fire engineering; additional charges for the agency handling approval due to the novelty of the issues involved[136]. To mitigate problems, some major Canadian cities have taken steps to encourage mass timber construction with examples such as Toronto creating a special committee to oversee approvals to save time and improve simplicity, in areas relating to fire protection. Some of the case studies used by Dorrah et al., used a two-stage reporting process based on submitting a fire engineering brief (strategy and objectives) and a fire engineering report (formulation of analysis and solutions), whereby the latter could include discussion with the regulator to help ensure an agreed position on compliance and reduce the risk of rejection[136].

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[132] https://www.grenfelltowerinquiry.org.uk/evidence

[133] https://inside.strata.community/combustible-cladding-in-australia-where-are-we-up-to-five-years-after-the-grenfell-tragedy/

[134] https://www.ircc.info/AboutUs2.html

[135] *Meachan, B.J. (2022). Fire performance and regulatory considerations with modern methods of construction. Buildings & Cities. Vol. 3. Issue 1. Pp. 464-487.*

[136] *Dorrah, D. H., & El-Diraby, T. E. (2019). Mass timber in high-rise buildings: Modular design and construction; permitting and contracting issues. Modular and Offsite Construction (MOC) Summit Proceedings, 520-527.*

Australian Fire Engineering Guidelines

The Guide (2021) is a non-mandatory support document called up in the NCC to provide information for the fire safety design of buildings and to be of use to appropriate authorities in carrying out their role of approving building designs (p. 3). It must be paired with appropriate fire engineering judgment that can be applied to situational contexts from one project to the next. Its focus is on life safety but may also be useful in property protection, business continuity and post fire incidents (as seen applicable by the stakeholders involved)[137].

Fire resistant construction is a critical issue for off-site construction because the preparatory interviews, meetings and case studies in this study, identified that such assemblies to easily require (NCC) performance solutions, which typically increase cost and time as a compliance pathway. Typical contexts are where off-site assemblies are joined together on-site or where assemblies butt up against in situ construction where tolerance issues cause hidden voids or inadvertent gaps (e.g. where a prefabricated wall abuts an in situ concrete slab).

The document states that level of fire safety provided in the NCC is not explicitly stated and this can lead to difficulties in interpreting both performance requirements and related acceptance criteria (p. 8). Related to this, risk of injury, fatality, and damage to adjoining structures represent central issues in meeting both performance solutions and linked acceptance criteria, however, the document indicates subjectivity and variability commonly impact at project level due to individual fire reengineering judgments and potential difference in opinion on what those judgments should be (p. 8)[137]. Clearly, this adds potential compliance risk for off-site construction.

Subsequently, early stakeholder involvement (including those in involved in fire engineering assessment and compliance) is advocated by the guideline in developing acceptance criteria to minimise variability. As part this, agreement on gaps between DTS Provisions and Performance Requirements can potentially act to simplify the scope of any need for performance solutions to fill such gaps (pp. 8-9)[137.]

The Guideline suggests preliminary or trial designs as a design testing strategy; other aspects covered by the document are more post construction oriented (e.g. checking at commissioning of the finished construction (pp. 14-15) albeit that these latter options do not really address upfront risk for design compliance.

Another area of design interest concerns discussion on Third Party review, which may be a requirement under State legislation insofar as performance solutions are being referred to the State Fire authority (e.g. fire commissioner) for review. It aims to assist and resolve issues between the approval authority and the project fire engineer. The second part of the guide focuses on the fire engineering process and is depicted in Figure 14. It meshes in with NCC performance solutions processes.

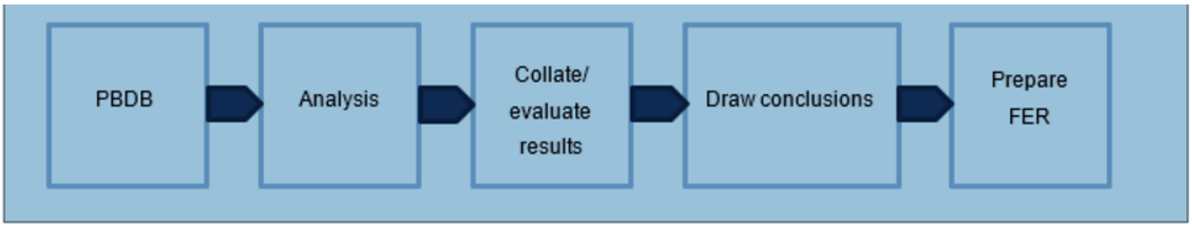

Figure 14 Typical fire engineering process

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[137] *Australian Building Codes Board. (2021). Australian fire engineering guidelines (AFEG). Accessed at: https://www.abcb.gov.au/resource/guideline/australian-fire-engineering-guidelines-afeg. Retrieved in May 2024.*

Importantly, the *Performance-based design brief* (PBDB) sets the scope of work, the framework and the basis for analysis agreed upon by the stakeholders. From this point, an iterative process of trial designs is analysed, results are evaluated, and conclusions are drawn; ultimately a fire engineering report (FPR) is developed for the purposes of attaining NCC compliance (p27)[138]. Because of the significance of the PBDB, it involves a stated sub-process shown in Figure 15.

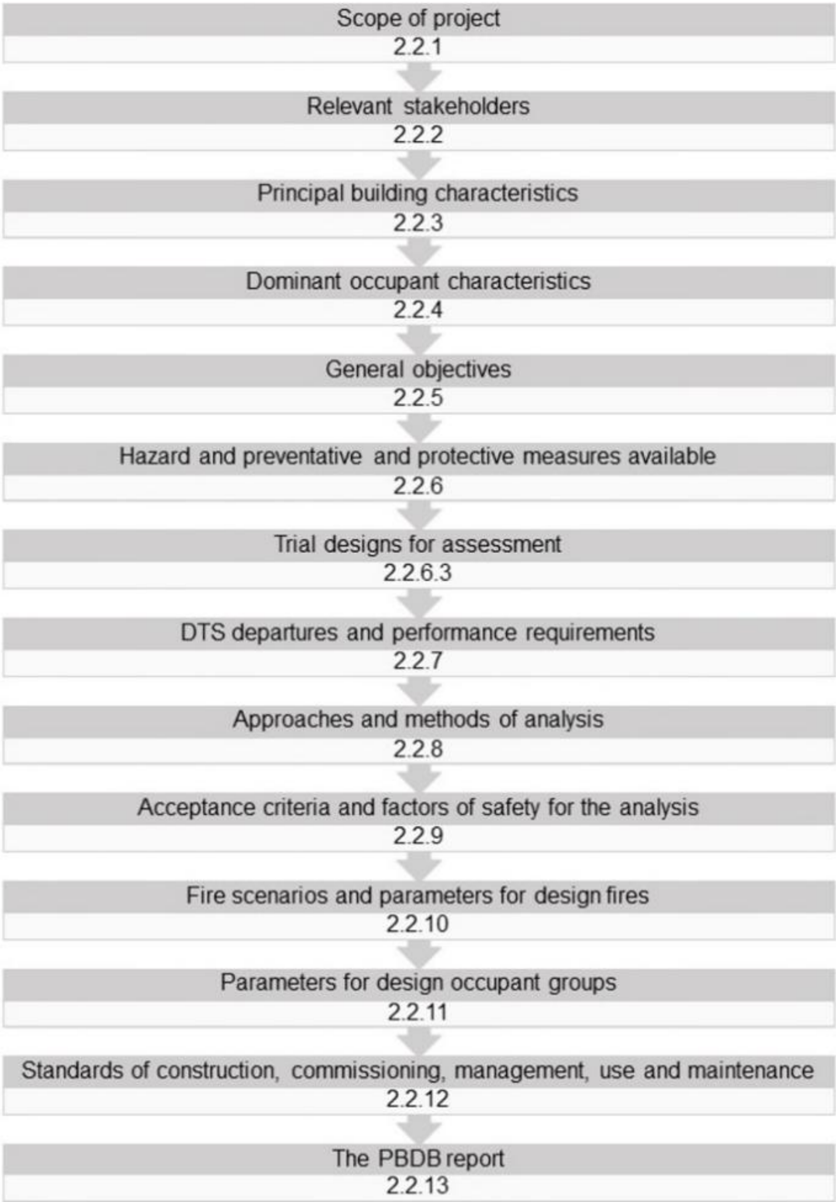

Figure 15 process for developing a PBDB

Use of a PBDB is typically called up by legislative requirements i.e. as part of the process for submitting and seeking approval for performance-based solutions. The process typically includes the authorities involved, the stakeholders who should be consulted, and the timeframes that may

[138] *Meachan, B.J. (2022). Fire performance and regulatory considerations with modern methods of construction. Buildings & Cities. Vol. 3. Issue 1. Pp. 464-487.*

impact on different approval options; for instance, time pressure may preclude the viability of performance-based solutions (p. 32)[139].

Conclusion

The above discussion highlights fire safety as representing the main compliance issue likely to impact off-site construction – especially for larger-scale buildings. As per earlier discussion, QA/QC systems are thought to offer the best means of providing proof of compliance.

Creating greater certainty and more streamlined approval systems for off-site construction is particularly important. Based on previous discussion in this report, it seems that DtS Solutions represent the most direct and readily available means of achieving this but would mean that DtS Standards would need to focus more on the interfaces between existing DtS construction systems, more so than within those existing systems. For example, no DtS details exist for the interface between a site poured in situ concrete slab (DtS using AS3600) and a prefabricated timber framed wall panel (DtS AS1684). Organisations representing separate building material groups would therefore need to work more collaboratively in address this and similar instances.

The main conclusions from the Fire Design Guideline concerns issues surrounding performance solutions as a pathway of compliance. Figure 14 and Figure 15 show a considerable number of steps in the performance solution process. Timeliness poses a problem insofar as each step contains its own individual time period and in addition are time frames for related administrative processes, buffer times and coordination times. Of most concern is the expectation in the Handbook that there will be variability in opinion and outcome concerning fire performance solutions. If it is accepted that off-site construction is more likely to require a performance solution, then this variability adds considerable risk for off-site construction. This risk is significant to the extent that stakeholders may perceive lost time and cost in attaining compliance approval, may outweigh expected savings during construction. For instance, each fire design iteration in seeking approval, implicates other designers (architects, structural engineers, acoustic consultants), which will potentially have a ripple effect on their designs as well. In doing so, extra cost and process time are incurred. Testing too many design options in search of an acceptable fire performance solution is therefore likely to be undesirable.

As a remedy, it seems that compliance risk caused by performance solutions is best dealt with as early as possible in a project; a focus on more streamlined upfront processes may assist this cause. Also, DtS solutions are clearly faster and cheaper and so increasing them may decrease the need for performance solutions, if they can be created in a timely way. Along a similar vein, early stakeholder debate could focus on checking for equivalences with DtS solutions to help limit which parts of the design require dedicated performance solutions.

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[139] *Meachan, B.J. (2022). Fire performance and regulatory considerations with modern methods of construction. Buildings & Cities. Vol. 3. Issue 1. Pp. 464-487.*

CHAPTER 8 - THE ROLE OF BUILDING SURVEYORS, CERTIFIERS AND CERTIFICATION IN REGULATORY FRAMEWORKS

Building surveyors, certifiers, certification and quality systems have an intermeshed and active role in regulatory compliance. Collectively, they provide a seamless and holistic basis for assessing compliance of off-site construction and how it fits in with on-site compliance.

Building certifiers and surveyors are prominent in the above by playing a central regulatory role in approving, inspecting and checking construction compliance in traditional on-site construction. State-based legislation empowers their roles and responsibilities albeit that specific features vary from one state to the next. As an example, details relating to NSW, Victoria and Queensland are provided below and in Table 3[140].

- New South Wales: Certifiers with full certification can act as a principal certifying authority (PCA), issue construction certificates, inspect at critical hold points, issue Occupation Certificates
- Victoria: Surveyors with full certification and Class A accreditation can issue building and development approval as Assessment Manager, inspect work, issue certificate of classification
- Queensland: Certifiers can issue building permits, inspect work at mandatory notification stages, issue Occupancy Permits or certificates of final inspection (where no OP is required)

Table 3 Roles of Building Surveyors and certifiers, (AIBS, n.d) [141]

	New South Wales	Queensland	Victoria
Legislation	Building Professionals Act 2005 (BPA) Accreditation scheme Environment Planning and Assessment Act 1979 (EPA)	Building Act 1975 and Building Regulations 2006 QBCC Act 1991 and Regulations 2003	Building Act 1993 and Building Regulations 2018
Registration/ Accreditation categories	Accredited certifier – building surveying A1, A2 & A3 Accredited certifier – building inspecting – A4 detailed requirements set out in accreditation scheme	Private certifier (Class A) – development approval endorsement Private certifier (Class B) no development approval endorsement Also have building certifier categories levels 1, 2 and 3. 1 is unlimited, 2 up to 3 storeys and no more than 2000m2 unless supervised by level 1. Level 3 class 1 and 10 buildings only.	Building Surveyor unlimited Building Surveyor limited – up to 3 storeys max 2000m2 Building inspector unlimited Building inspector limited - up to 3 storeys max 2000m2

[140] *Note: Some variance may exist in accordance with a certifier/surveyor's level of accreditation*
[141] *Australian Institute of Building Surveyors (AIBS). (N.D). Registration and Licensing. Registration and Licensing (aibs.com.au), Retrieved on October 2024.*

Who appoints/ engages the private surveyor/ certifier?	EPA s109E – Only the person with the benefit of development consent (usually the property owner) can engage a principal certifying authority, and must sign a written contract with them before any work starts. Councils cannot refuse an appointment	Any person can engage private certifier – 'client' s138(5)	s17 – appointment by or on behalf of owner s78(1A) domestic building work - builder cannot appoint on behalf of the owner
Requirement for separation from design	BPA s66 must not issue Part 4A certificate or complying development certificate if certifier has been 'involved in the design' (s67) or is related to a person involved in the design is or is related to the applicant for the certificate (offence). S66(2) &(2A) can issue a compliance certificate if not the PCA.	NONE	s79 must not act if surveyor or a related person prepared design, was engaged by designer in past 12 months, has pecuniary interest in body that prepared the design (offence)
Requirement for separation from builder	BPA s66 must not issue Part 4A certificate or development certificate if certifier has been involved in the carrying out of work or is 'related to' (s68) the applicant for the certificate (offence) s66(2) & (2A) Can issue a compliance certificate if not the PCA	S136 conflict if certifier is to carry out the building work, is engaged by the owner or builder other than to perform building certifying functions.	s79 must not act if surveyor or a related person has pecuniary interest in building or building work or anybody carrying out the building work (offence)
Provisions which refer to performance solutions	Performance solutions on fire safety systems must be developed by competent fire safety practitioners.	S68A if an alternative solution is used and approved, assessment manager must issue a written statement with details of how the AS differs from DtS and list docs relied on to make the decision. S26 required content for alternative solution. A103 certificate of classification (class 2-9) must include any requirements from a AS	r121 – surveyor cannot assess performance solution relating to fire performance requirements unless they hold qualifications Ministerial Guideline says surveyor may require independent assessment of complex designs. R 38 –BS must document assessment of PS with specified details R124 registered building practitioner must document PS in a certificate of compliance with specified details BP, OP and CFI to include details of any PS
Certifications by others that surveyor/ certify can rely on with immunity	EPA s109C – Part 4A (Division 6.5, 6.16) certificates can be issued by various persons – s109P can rely on Part 4A certificates and are not liable for loss or damage arising from a matter for which a certificate was issued. Competent fire safety practitioners must be involved in design of fire safety systems	S60 certifier may rely on compliance certificates by any person whom they consider to be a 'competent person'. Regulations about how this is determined. For certain types of design or work, a competent person must be licensed.	S238 prescribed persons may issue certificates on prescribed matters. S128 surveyor has immunity if they rely on a s238 certificate in good faith

Problems for off-site construction potentially arise from certain aspects of the above. For instance, a certifier/surveyor must carry out inspections at specific hold points (especially State-defined mandatory inspection points) and a problem for off-site construction is that no regulatory direction is provided concerning what a certifier/surveyor should do when these on-site inspections become redundant because off-site/prefabricated construction is being used instead.

Lack of clear direction likely creates perceived risk for a certifier/surveyor. Inconsistent approaches are likely to result. It is worth exploring the subsequent options that may apply.

- The on-site certifier/surveyor inspects the off-site production i.e. inspection of the holistic production system or inspection of a production sample relating to a specific project. Both have been found to occur in the wet area pod case study detailed later in this report.
- Self-certification by the prefabricator i.e. to some extent self-certification already exists as is apparent in **Error! Reference source not found.** where immunity is granted for a certifier/surveyor relying on allowed certification by others. Within States such as Victoria, this is apparent where specialist trades such as plumbers certify plumbing work and again, this is detailed further in the wet area pod case study, later in this report.
- Third part certification i.e. a third-party organisation such as a 'Conformance Assessment Body (CAB)' assesses a standardised production system. It enables the prefabricator to issue a certificate of compliance that production for a given project conforms with the overarching system.

In analysing these options, a key concern with Option 1 is the added time and effort (cost) in the onsite certifier/surveyors travelling to, and then assessing the off-site production facility, which could be inter-state and may need to be done on a project-by-project basis by each certifier/surveyor. Checking the production system as a whole appears considerably more realistic than checking individual production on each and every project. Indeed, the former is an option set out in the ICC case study, reported later in this report. The latter is a more problematic (in practicality, timeliness and cost terms) insofar as the economies of prefabrication are based on a continuous flow of production, which would almost certainly be thwarted if reliant on project specific inspection by an external certifier/surveyor.

Option 2 approximates a type of quality assurance insofar as the self-certifier aims to provide (administrative) proof of compliance (a certificate of compliance), which replaces technical quality control inspection done by the certifier/surveyor. Self-certification programs aim to help prefabricators demonstrate that their products or processes meet specific performance standards and comply with building codes. These programs include setting up quality assurance procedures that align with building regulations and conducting audits through a series of tests[142]. Quality aims to be thoroughly checked at each stage of production using checklists to identify and rectify errors early, which saves time and money. Internal audits help monitor the execution process at different production stages to ensure they adhere to standards. The approach aims to be comprehensive and according to research by Gharbia et al.[142] self-certification is a common option at an international level, based on their survey work including countries such as Sweden, Switzerland, the United Kingdom, China, and Singapore[142]. Even so, a key concern with self-certification is how reliable it is, as proof of compliance and related proof is actually being achieved in practice, in construction contexts. For instance, even though self-certification is used for specialist trades it is still a step up to apply it to larger-scale prefabrication operations; it also appears to be relatively under-developed as a formally documented and standardised approach. A related concern with this option is that confidence in the reliability of self-certification is somewhat dependent on adequate penalties if non-compliance and carelessness continue to occur. This is typically dealt with via a number of potentially statutory means, including loss of practice license, loss of the ability to be obtain necessary insurance, or loss of accreditation.

[142] Gharbia, M., Chang-Richards, A., Xu, X., Höök, M., Stehn, L., Jähne, R. & Feng, Y. (2023). *Building code compliance for off-site construction*. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction. Vol. 15. 2nd edn. 04522056. Retrieved on June 2024.

Option 3 is also used internationally and is portrayed by Garbia et al. as being important for a healthy and functional compliance system[142]. Manufacturers can choose to use certified third-party inspectors to ensure their products meet quality standards. These independent entities, which can be either government agencies or private organisations, conduct audits and issue certificates confirming compliance with specific standards. Inspections follow a predetermined schedule, and successful compliance results in certification. Manufacturers who pass these certification programs receive a performance label, indicating that their products meet the required standards for housing performance evaluation**Error! Bookmark not defined.**. Such systems may also include product i dentification and traceability, industry-led quality assurance systems, product authentication, and insurance schemes. The ACRS scheme provides an Australian/NZ based example of third-party certification[143]. They conduct eight areas of review on the conformity of steel product requirements that cover an array of separate standards[144]. The scheme focuses on conformity as a voluntary approach, but the same fundamentals can be applied to mandatory compliance as well. The organisation is accredited by and regularly audited by JAS-ANZ[145] (being the government-appointed accreditation body for Australia and New Zealand), who are responsible for providing accreditation of conformity assessment bodies (CABs) in the fields of certification and inspection[146]. ACRS covers product certification, sustainability and quality management systems (ISO 9001). It includes end-to-end treatment of the construction supply chain and traceability therein. A strong incentive for such schemes is that they are undertaken by neutral third parties who have no conflict of interest with the commercial motives of those first parties selling a given product.

QA and QC Systems to Underpin Product Certification

Confidence in regulatory compliance is closely associated with quality management systems insofar as both aim to ensure that an initial design meets necessary standards and then provides reliable and defect free construction/production. Quality management systems are the main tool enabling the likes of construction prefabricators to certify their work as being compliant. In both onsite and off-site construction, quality management systems tend to revolve around two core approaches: quality control (QC) and quality assurance (QA).

QC is primarily based on inspection, which is reactive insofar as it involves checking what has already been produced to make sure it has been done correctly and is free of defects[147]. Even so, sole reliance on this approach can inadvertently promote an attitude among poor builders of ‘catch me if you can’, rather than an attitude of ‘pride in work’. In such instances, confidence in compliance is obviously reduced.

In contrast, QA is more focused on pro-actively avoiding defects and creating reliability upfront, by designing and planning products and production processes in ways that make it difficult for mistakes to occur[147]. It is particularly common in manufacturing where standardised processes exist, but this is often harder to achieve in traditional construction due to the one-of-a-kind nature of projects. Notwithstanding this, QA is still relatively achievable for off-site construction where repetitious processes are more common than in traditional construction. QA is a formally structured approach to management systems, and this is apparent in standards such as ISO 9000. Such standards tend to suit large manufacturing processes but can potentially be overkill for relatively small businesses that are only undertaking semi-repetitious forms of prefabrication. Of note, the small businesses that are known to predominate in the Australian building construction industry[148] will likely find it difficult

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[143] https://steelcertification.com/

144 https://steelcertification.com/about-acrs

[145] https://www.jasanz.org/what-is-accreditation *”JASANZ accreditation is a formal process based on measurable evidence. It’s an independent third-party assessment of your competence as a certifier or inspector”*

[146] https://steelcertification.com/about-acrs-certification

[147] *Hoyle, D., 2007, Quality Management Essentials, Routledge, London*

[148] https://www.centreforwhs.nsw.gov.au/research/small-business-in-construction

to afford large sale QA schemes and so scaled-down versions are perhaps more realistic depending on the order of scale and repetition involved.

In support of QA/QC schemes, Meacham's (2022) research across multiple countries makes the point that most regulatory systems have a complex set of interconnected regulatory and private-sector checks and balances but because of the hidden nature of off-site construction, the main option for compliance is auditable QA/QC systems.

A similar position is taken in taken in the Australian context, insofar as the Modular Construction Code Board Handbook[149] takes the position that without evidence of conformance/compliance there can be no confidence that production requirements have been assessed or attained. It sets out key parts of a QA/QC framework for off-site construction; such an approach could be used to supplant traditional on-site construction inspection.

Features in the Handbook for QC call for inspectors to be independent of the production teams and have different reporting lines. The handbook emphasises the use of Inspection and Test Plans (ITPs), Inspection and Test Records (ITRs) and Inspection Checklists.

Delving further into the above, Hold points, Witness Points and Review Points are suggested prior to detailed design, manufacture, high value adding points, completion of regulated works, transportation, export, installation, and post installation[150]. Still further, the essential elements of an Inspection and Test Plan (ITP) should include, Inspection details (checklists and reference drawings), Relevant work package/module(s), Inspection timing, Reflecting construction sequencing, Sample collection frequency, Required testing extent , Acceptance criteria, Related Works Method Statement, Responsible inspection personnel, and completed Inspection Test Reports (ITRs) or Checklists to be included in as-built or handover packages[151].

The Handbook supports verification of compliance (for supplied parts) from an approved independent source, and traceability that stretches the length of the supply chain is important because of the complex combination of products that typically exist in off-site assemblies[151].

It is apparent that prescriptive and performance-based approaches exist in adopting such systems. For instance, Meacham (2022) points out that in prescriptive regulatory systems like the US, details may include things such as facility layout, inspection procedures, record keeping. In performance-based systems with strong government oversight (such as Singapore), there is still significant review, guidance documents, and acceptance frameworks for MMC. Accreditation schemes for manufacturers are used. In systems with less oversight, like the UK, responsibility lies more with the developer to ensure regulations are met.

In general, the greater the confidence in proactively using QA to design out problems, the less need there is to reactively inspect as QC. This is more of a ratio than an eradication of one over the other; in reality, the two are necessary and work in a combined way to provide a holistic approach to quality and confidence in compliance.

Conclusion

From this chapter it is concluded that building surveyors and certifiers are central to the regulatory framework, acting on behalf of governments for preconstruction compliance approval, followed by

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[149] Modular Construction Codes Board. (2017). Modular Construction Code Board Handbook: A Guide to Offsite Construction. Monash University. Accessed at: https://builtoffsite.com.au/emag/issue-04/modular-construction-code-board-handbook. Retrieved on June 2024.

[150] Refer Figure 8 of handbook

[151]Modular Construction Codes Board. (2017). Modular Construction Code Board Handbook: A Guide to Offsite Construction. Monash University. Accessed at: https://builtoffsite.com.au/emag/issue-04/modular-construction-code-board-handbook. Retrieved on June 2024.

checking of compliance during construction. Even so, these roles and responsibilities are fragmented as they differ from one State/Territory, to the next. This potentially creates a problem for the off-site construction perspective in terms of inconsistent requirements. Further, the role of building surveyors and certifiers is largely structured for traditional on-site construction including the expectation of mandatory site inspection points and also the sequencing of these inspections, which are not generally suited to off-site production programs. Of note, clarity is lacking about what to do and how to adjust, if off-site construction is being used. It is concluded that to create clarity and certainty for all involved, compliance certification of off-site work offers the best path forward. This should include preconstruction and postproduction compliance. Three certification options were outlined and from this, it is concluded that third-party certification is most appropriate. This would include the role of CABs in underpinning the validity and reliability of certification.

Assuming this is acted upon, there is also an important need to create clarity/certainty for building surveyors and certifiers about how they should accept and/or what they should do when off-site production is involved in a project. This should clarify their exposure to risk in acceptance or otherwise of off-site certified products.

CHAPTER 9 - CASE STUDIES DELVING INTO KEY ISSUES AND REAL-WORLD APPLICATION

To gain a deeper understanding of industry practices, a number of targeted case studies were conducted to gather feedback on key issues identified earlier in this report, as well as potential strategies for future regulatory reform.

Case Study 1 - An Industry Snapshot of Fire Compliance Issues

Earlier parts of the study identified fire safety compliance as a key area of risk, uncertainty and compliance pathway problems in Australia. This section presents a series of case studies examining real-world challenges and regulatory complexities encountered in off-site construction projects, particularly concerning fire compliance. Drawing from various project experiences, these case studies highlight the unique difficulties faced in achieving compliance under the current NCC and the limitations of existing solutions.

Post and Plate- Modelling a construction system for compliance

This case study section primarily aimed to provide a snapshot of real-world fire compliance issues faced when using off-site construction. It involved feedback from four separate projects which are presented under the issues-based headings below.

DTS and Managing Fire Compliance for Timber Construction Systems

This case focused on modelling the process of attaining compliance for a new mass timber construction system termed ‘post and plate’. The system primarily uses thickened cross laminated timber floor panels that are supported directly by large glue laminated timber columns via shear connectors (typically in a 4 to 6m column grid). The system aims to remove the need for beams between columns and offers a minimal kit of standardisable parts i.e. columns, floor panels and sheer connectors that could suit streamlined compliance, the likes of CodeMark.

In general, that system aims to offer design simplicity, spatial flexibility, and improved installation productivity and in doing so represents the next generation in multi-storey timber buildings. For the purposes of modelling, application focused upon a model 10-storey mixed use building with a glass curtain wall exterior (NCC Class 5 and 6) consisting of office upper floors and a retail lower floor. Based on the NCC it would be categorised as type A construction being the highest level of fire resistance.

A workshop was undertaken with 10 experts in both mass timber construction and NCC design compliance e.g., design engineers, mass timber manufacturers, constructors, technologists, and academics. The workshop was led by a presentation of the main compliance issues[152]. Compliance pathways were explored including significant detail surrounding the feasibility of DtS solutions and alternative performance solutions.

The main NCC compliance issues were identified as: Structural; Acoustics and Fire performance. Fire was identified as the most complex area and the most difficult for attaining a DTS solution under the NCC. Instead, it was agreed during the workshop that Performance solutions were too readily

[152] *The presentation was by Andrew Dunn, Managing Director of the Timber Development Association*

needed for fire-related issues, which created significant extra process and tended towards uncertain outcomes during the design and construction phases of a project.

For instance, structural compliance[153] can mainly be dealt with using AS1720.1 where glue laminated columns are directly dealt with in the standard, whilst CLT floors were identified as likely to be forced to utilise Clause1.3.1 (h) which calls up Appendix D of the standard. It defines a method of prototyping or proof loading for materials that may have properties or types of adhesives not directly mentioned in the standard. Column connections may also utilise the prototyping protocol but where inadequate, a performance solution may be required. The above places an onus on the material supplier to provide the relevant property data in utilising the ‘Deemed to Satisfy’ compliance pathway.

For acoustic performance, the NCC offers two pathways for compliance: the Verification Method, which involves field testing and the ‘Deemed-to- Satisfy’ Provisions, which involve laboratory testing. The workshop identified that most choose the latter option[154]. Again, the ability to utilise this relies on data from suppliers or acoustic consultants.

As mentioned, fire compliance was identified as the main area of risk if a DTS solution is sought. Regarding this, the NCC has multiple aspects that feed into a DTS solution, as follows:

- Concessions
- Fire resistance levels
- Escape pathways
- Sprinkler use
- Encapsulation to timber elements

It was found during the workshop that whilst the above areas provide breadth in application to a given project, there is also considerable complexity in concurrently meeting all needs including the compliance pathways available and the high level of detailed expertise in applying the knowledge of the NCC in proving a pathway to be viable. It was apparent that differences in interpretation and understanding may commonly occur and as a result, variability in agreement on how or if the system complies when applied to a given project.

To provide greater insight, the typical process (in practice) as used for deriving a ‘Deemed to Satisfy solution’ was presented at the workshop, as follows:

1. Determine the Type of Construction (A, B or C) based on the Building Classification and rise in storeys. This classification then influences which concessions apply[155]
2. Determine if the element is required to be non-combustible. Details regarding this were identified as being particularly important for timber products. Non-combustibility typically applies to targeted elements and whether they are loadbearing or non-loadbearing (e.g. external walls, common walls, lift pits and more). Encapsulation using non-combustible material such as gypsum provides the main means of addressing non-combustibility. Exposed structural timber adds further complexity where additional conditions apply that revolve around: the class of construction, rise of storeys, loadbearing or non-loadbearing elements, use of sprinklers and if one element is reliant on another for support.
3. Check if the element inherits non-combustibility (Specification 5 S5C3) via the need to support another part of the structure.

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[153] *The main NCC Performance requirement was identified as concerning “Determination of structural resistance of materials and forms of construction” (NCC Volume 1, clause B1D4).*

[154] *Part of the reason maybe that field testing involves increased real-world variables (flanking sound, interfaces with multiple construction elements)*

[155] *Example: C type construction maybe possible if a Class 2 building has at least two exits from a sole occupancy unit and can easily access to the road or open space*

4. Check for support of another part. If not applicable, then concessions may be allowed or non-combustible requirements removed
5. If still required to be non-combustible, consider fire-protected timber concessions.

In applying the above to the model building, it was identified that wall wetting sprinklers could be used to the advantage of seeking a DTS as no fire resistance level is required for curtain walls (as an external wall) when automatic wall-wetting sprinklers protect this wall. However, due to the effective height of the building (approx. 36m), the lift shaft has no timber DTS and so concrete could be used to retain a DTS solution, otherwise, a performance solution would be required if aiming to retain an all-timber solution.

From the above, it can be concluded that most of the model building can be dealt with under a number of DTS solutions but gaps between these solutions and certain practical issues, likely mean that one or more performance solutions would be required to fill these gaps.

It was apparent from the workshop that in trying to maximise DTS solutions, considerable skill and expertise is required - mainly around fire engineering - to take full advantage of the existing decision framework in the NCC and associated referenced standards. However, it was also apparent that relatively few project participants would likely have such high-level skills and expertise. This may include the certifier/surveyor approving a design for compliance. For these participants, it is conceivable that a conservative position regarding compliance approval may be adopted so as not to take unnecessary perceived risk relating to compliance i.e. of a relatively new and unknown form of construction. Subsequently, more performance solutions may be called for to deal with gaps between the DTS solutions or also because of an inability to agree on how DTS can be achieved (i.e. due the above complexity).

CodeMark potentially provides an immutable way forward for systems such as ‘post and plate’, to protect against the need for performance solutions and to streamline approval i.e. from one project to the next. For instance, a span table could enable the use of a limited set of standardised columns, floor panels and connectors. As discussed in the workshop, the main counterargument for CodeMark is its apparent high cost to set up and maintain. A less expensive version of the scheme would be one that could ideally operate at an overarching industry level so that separate companies producing/using the system could access and use the CodeMark compliance.

Fire-rated wall problems on a Residential Duplex Project

This case study concerned compliance problems for fire safety construction on a recent duplex development in Queensland, with each unit being 112 square meters, resulting in a total of 224 square meters for the duplex. Approximately 80% of the construction was undertaken off-site by a large modular prefabricator providing both factory complete and turnkey packages (also in Queensland).

The primary technical issues revolve around fire safety. While there are tested systems for fire rating, the modular prefabricator often relies on a combination of these tests, and expert judgment. Fire engineers typically overlay their judgment on the tested systems to confirm their suitability for modular construction. However, a significant challenge arises because many tested systems are designed for traditional on-site construction and do not fully address the needs of off-site construction, particularly from the floor down to the ground. The lack of tested fire rated wall systems that comply when applied to modular constructions, was highlighted on the duplex project. This gap necessitated extensive negotiations and custom engineering solutions to meet fire safety and acoustic standards involving a performance solution with multiple associated reports. Whilst the fire rating issue was ultimately resolved, it led to further issues regarding acoustic compliance.

The above compliance issues introduced significant additional costs primarily through consultancy, testing and development of engineering solutions. Also, delays occurred in the project timeline. In order to make the solution compliant, they utilised lab tests along with expert judgment. The prefabricator managed this challenge by early and continuous engagement with all project stakeholders, detailed pre-approval of designs, and adaptive responses to feedback during compliance checks.

The prefabricator has developed a comprehensive online Inspection and Test Plan (ITP) process that is tailored specifically for their off-site construction projects. This system is integrated into their Customer Relationship Management (CRM) software. Every subcontractor or installer involved in the project must complete a series of detailed questions and steps and take numerous photos to document and ensure compliance at every stage of the construction process.

For instance, the installation of fire-rated walls in a project involves a rigorous checklist that includes numerous compliance checks and photographs. These checks are recorded and monitored throughout the project's lifespan. If the project consists of four dwellings, for example, the system generates 16 comprehensive reports (4 per dwelling) that are then submitted to certifiers and fire engineers to confirm that all aspects of the construction meet compliance standards. The prefabricator is in favour of a robust quality and compliance system to demonstrate proof of compliance and in accordance with regulatory requirements.

Also, from the modular prefabricator perspective, most projects beyond Class 1A encounter compliance concerns primarily because they believe the NCC is overly oriented towards on-site construction and lacks sufficient provisions for off-site construction. These challenges often require project specific performance solutions as DTS does not sufficiently cover the context of off-site construction.

Regulatory challenges with Fire-rated walls

A series of issues were raised by one of the Australian modular companies, reflecting the general perceptions of some of their design leads regarding the fire-rated walls. A summary of these concerns is highlighted below.

The NCC requires floors in class A buildings to have a fire resistance level, but it does not specify how to test fire resistance from above the floor. Currently, fire tests are usually conducted from below, but some certifiers want proof that floors can withstand fire from above as well. This discrepancy means engineers often use their judgment to extend wall and ceiling fire test results to floors. This change could limit available compliant products. As such, many certifiers only need to see tested systems that include ceiling and floor and are tested from below as this is an actual test protocol. Others require a downward fire rating to be shown. So, a product like Promat, Fire Crunch or similar is used however, the compliance reports for these products largely rely on engineers' opinions, as they extend data from wall and ceiling tests to demonstrate conformity. In another instance, an inconsistent interpretation of what constitutes a wall or structural element requiring fire protection was raised. For example, there is ongoing debate about whether a beam beneath a wall needs to be fire-rated. Different certifiers have varying interpretations, leading to confusion and inconsistency in construction practices. This issue was particularly evident in feedback on exterior walls and load-bearing columns, where certifiers provided conflicting requirements.

The NCC defines what a fire-protective covering is but does not provide specific instructions on how to install it. Industry guidelines from companies like Gyprock and Knauf also do not offer detailed methods for installation. This lack of clear guidance leaves builders uncertain whether to use standard practices or if there are specific techniques required, potentially leading to non-compliance or inefficiency. For example, while the NCC defines fire-protective coverings and states they should be installed ‘in accordance with normal trade practice’, it is unclear whether this means following a 30/30/30 installation method (referring to 30 minutes of structural adequacy, integrity, and insulation) or if a simpler approach, like tightly placing square edge sheets without filling gaps, would be acceptable. This ambiguity can create confusion for builders.

In another example, it was mentioned that achieving Performance Solutions can be expensive and time-consuming, which is problematic for the modular construction industry that relies on being cost-effective and quick. Unclear codes extend design times and require additional on-site work to meet compliance, reducing the competitive edge of modular construction projects. Performance Solutions are highly dependent on regulators' discretion. For instance, a Performance Solution was developed for a school in NSW in regard to FRL based on previous acceptance by Queensland Fire and Emergency Services (QFES), but it was completely rejected by the NSW Fire Department, resulting in extensive rework, which minimised the expected efficiency of the off-site construction.

In another project, a double-storey classroom and office building, significant fire rating and acoustic challenges arose due to the modular components' inability to provide continuous fire-rated and acoustic walls from ground level to the roof. The nature of the volumetric modular construction interrupted the required vertical fire separation. To address this issue, a dwarf masonry strip wall was introduced at the footing and subfloor, along with complex detailing of the metal chassis frame to achieve the necessary fire resistance level (FRL). This process involved applying fire-rated materials to the walls, ceilings, and exposed steel columns, ensuring compliance with the building code. However, these solutions added time and cost to the project, diminishing the cost-effectiveness of using modular construction.

Problems with fire related performance solutions in a school project building

This problem manifested in a Prefabricate School building in NSW with three floor levels, a Gross Floor Area of 7,735m^2, class 9 building classification, and Type A Fire resisting construction. The off-site construction utilised wall panels and a hybrid floor system (i.e. GLT panels with site poured composite reinforced concrete construction on top). Despite significant preconstruction planning with the various stakeholders involved in compliance with the design, the need for unforeseen performance solutions arose during the construction process.

An initial problem was that the original (construction certified) design was based on prefabricator provided information about the compliance of both the wall and floor systems. Technical non-compliances were identified (e.g., untested interfaces between tested wall and floor systems) by the project certifier (PCA) and so the situation was referred to FRNSW as a performance solution. FRNSW did not appear to assess the proposal on its merits and instead recommended referral to an accredited testing laboratory. Despite expressing a view that FRNSW had taken an unreasonable stance, the PCA was unwilling to proceed without enacting this recommendation. This added time and cost to the process.

A second problem concerned fire protection at floor penetrations. Here, the contractor submitted two expert assessment reports based on proprietary bulkhead fire batts. The first assessment dealt with the general application of the bulkhead fire batt in the hybrid floor system and the second covered services passing through the bulkhead fire batt in either cross-laminated timber or in situ concrete. Since these two interfaces were not dealt with in a single report again, a performance solution was required by the PCA. However, given FRNSW’s stance on performance solutions involving variance to tested systems (discussed above), a NATA laboratory assessment report was again required.

The third problem concerned installation tolerances whereby the flooring system included up to 5 mm gap at floor junctions, but in practice, gaps onsite were up to 10 or even 15mm. Whilst construction tolerances were improved in subsequent floor levels, the first floor again required a performance solution. The relevant authority was unwilling to review performance solutions after construction had commenced. Again, this resulted in a convoluted path to compliance.

A number of significant cost, time and risk issues were apparent from the above including:

- Several pragmatic options were explored to deal with the above problems (such as fire resisting mastic at interfaces, the extrapolation of the existing data and the use of expert assessment) but in the end, the lack of support from FRNSW presented an unacceptable risk to the principal certifying authority.

- Required NATA-accredited laboratory testing impacts significantly on project time
    - Testing typically involves an approximate 12-week period.
    - Additional lead times that may occur including the likes of curing time for concrete components in the hybrid floor system
- In the case of construction tolerance issues, a performance solution was subsequently submitted to Fire and Rescue New South Wales for approval:
    - This added a significant additional period to the above and the prospect of additional iterations if unsuccessful on the first attempt.
    - In this case, Fire and Rescue New South Wales advised that they could not handle the performance solution submission (under the EPA regulation) because it occurred after a construction certificate had already been issued. They referred the contractor back to the local government for a pathway forward and suggested this could involve obtaining a 'Building Information Certificate'[156]– again involving additional process with uncertain outcomes[157].
- Liquidated damages clauses (in the contract) create an impetus to continue with work (and avoid significant expense) rather than wait for testing to be completed and the performance solution approved.
- Access to the affected construction (e.g. penetration gaps) potentially becomes difficult if trying to progress with construction rather than waiting until testing has taken place.

Of note, the contractor has undertaken many similar school projects to the above but found inconsistency in the treatment of such issues by the different principal certifying authorities involved, and by FRNSW. For instance, the same problems as above have not occurred to the same extent, on the other projects.

Conclusion

From the above industry snapshots, it can be concluded that:

- Fire-related compliance issues are common and lack of clarity leads to performance solutions rather than much simpler DTS solutions.
- Unexpected performance solutions can occur during construction (i.e. after design and after granting a construction certificate). This creates uncertainty for those involved and can significantly disrupt the intended speed of construction, thus compromising the intended advantages and commercial viability of off-site construction.
- Interfaces between different assemblies are risk locations that easily become performance solutions; where possible, these would be better dealt with as 'deemed to satisfy' solutions.
- Some of the performance solutions in this case study represent minor parts of the overall NCC solution but can be major in terms of impacting on time and process in fixing a problem, once construction has started.

Case study 2- Wet Area Module Production: in Practice

Wet area pods represent a common form of modular construction in Australia and subsequently provide a useful backdrop to understanding the context of off-site construction in practice.

Research pertaining to this utilised documents, observations and meeting with pod manufacturers, their clients and regulators. A specific focus was on two large manufacturers of wet area pods located respectively in Victoria and NSW. Collectively, they turn over more than 8,000 pods per year. The enquiry focused on understanding their production systems, compliance pathways, QA/QC systems, certification and any problems encountered around regulatory issues.

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[156] *A document issued by Council usually requested by buyers/sellers to make sure that what is being bought or sold will not be the subject of action by Council*

[157] *Ultimately this process was not followed as the project was under "Crown works" and therefore less dependent on State government regulatory systems*

Both manufacturers focus on a limited number of targeted markets primarily around Class 2, 3, 9a and 9c buildings (i.e. apartments, student housing, hospitals and aged care facilities). These types of buildings meet the manufacturers' need for economies of scale, predictable demand and repeat clients (i.e. developers and/or head contractors). Of note, neither company operates in the detached housing market (class I buildings) because of the limited ability for standardised design, lack of economies of scale and the potential for having different clients on every project. For instance, on the large projects that they typically service, they have early involvement in design with a view to creating a limited number of pod designs to attain in the order of 100 replications for each type.

In general, their clients appear to appreciate the predictable quality, reliability and construction speed afforded by pods. Both manufacturers aim to foster long-term relationships with their clients to develop an ongoing pipeline of work.

Regulatory and Compliance Framework for Wet Area Pods

Compliance issues manifest separately at Commonwealth and State regulatory levels. In the former instance, The Notice of Direction 2016/4.0 by the WaterMark Certification Scheme sets guidelines for the acceptance and regulation of prefabricated plumbing modules, such as wet area pods (inclusive of bathroom, shower, laundry and kitchen pods)[158]. The notice distinguishes between two categories: purpose-built bathroom modules which are a product and, prefabricated plumbing installations which are also known as 'regulated work'.

- Purpose-built modules are classified as products under the NCC and must be certified through the WaterMark Certification Scheme.
- Regulated work must comply with jurisdictional plumbing regulations[158].

For modules to be accepted as a product, they must be certified by an Approved Certifier and comply with the WaterMark technical specification WMTS-050:2018[159]. Here, manufacturers provide independent assurance that their pods comply with WMTS-050:2018 and to this end, a sampling and test plan are provided in the Appendices for use by an independent Conformity Assessment Body[159]**.** Additionally, the module must be installed by a licensed plumbing practitioner.

In contrast, if the prefabricated module is classified as regulated plumbing work, it must be completed within the same jurisdiction as the site of installation, adhering to local legislation. All component interconnections must be approved and installed by licensed plumbing practitioners, and any required components must be WaterMark certified.

In order to provide jurisdictional context, practice in Victoria has been studied further because it is the only State that has published specific regulatory requirements for off-site construction of plumbing systems (also known as prefabricated plumbing systems). Guidelines are provided by the Victorian Building Authority (VBA) and aim to address industry uncertainty around whether such off-site construction plumbing systems, fall under regulated plumbing work or are considered as plumbing products[160].

The VBA outlines two compliance methods, which reflect those already discussed, but the main qualifications include:

1. Regulated Plumbing Work: all work must be performed by licensed or registered plumbing practitioners, using certified materials, and meeting technical standards. A compliance certificate must be issued for this work and will be subject to the VBA's plumbing audit process and proactive inspection program[161].

[158] *Australian Building Codes Board. (2016). WaterMark Certification Scheme, Prefabricated plumbing modules.*
[159] *Australian Building Codes Board. (2016). WMTS-050:2018, Prefabricated modules.*
[160] *Victorian Building Authority. (2016). Regulatory requirements for the off-site construction of plumbing systems.*
[161] *Victorian Legislation. (1993). Building Act*

2. Plumbing Product: demonstrates compliance through evidence of suitability, typically via the WaterMark Certification Scheme mentioned previously. If a product falls outside the scope of WaterMark, alternate forms of evidence, such as an engineer's certificate, are acceptable. This compliance method does not require a licensed plumber for construction, but all work must meet defined product certification standards[162].

Further to the above, when pods are installed into the building, the regulatory requirements for on-site work remain unchanged regardless of their off-site construction method. This means that the plumbing system's on-site installation must be carried out by a licensed plumber, and a separate compliance certificate must be issued for the on-site work (self-certified by that plumber). Additionally, if the plumbing system is constructed outside Victoria, it must be treated as a product and comply with WaterMark[162]. When the plumbing system is constructed as a plumbing product, the VBA will verify its WaterMark certificate of conformance (or other proof of suitability if it is not listed on the WaterMark Schedule) during any compliance checks conducted after the system is installed on-site.

Choosing a Preferred Compliance Pathway and Implicated Issues

Both of the case study manufacturers opted for WMTS-50-2108 as a compliance pathway regarding plumbing aspects of their pod production. They also employ external plumbing contractors who are able to self-certify compliance under State regulations[163].

As this only covers part of the pod construction, other parts are dealt with via several methods that revolve around (NCC) DtS solutions and (as above) self-certification by the likes of electrical installation. Still further, one of the manufacturers holds multiple builder’s licenses to cover the different states that they operate in, which variously enable them to internally undertake and certify things like waterproofing and tiling work.

Both companies avoid performance solutions but mention they are occasionally needed to suit project specific needs. One example, was where a perforated aluminium angle upturn for waterproofing at the door threshold, was to be used instead of a solid angle; in this case, expert opinion provided a cost-effective means of meeting the needs of what was a fairly minor performance solution. If, alternatively, a performance solution required full-scale laboratory testing then such a solution would have made the project commercially unviable. The difficulty for the manufacturer is the uncertainty and perceived subjectivity, in not knowing how far they will need to go in providing evidence sufficient to satisfying Performance Solution requirements.

On a separate point, it was mentioned that CABs act as third-party assessors of a manufacturer’s system compliance (e.g. under WMTS-050:2018). Regarding this, one manufacturer was dissatisfied that they effectively needed to raise a separate WaterMark certificate for each bathroom design they created, even though differences between bathrooms were very minor (i.e. they had to have a WaterMark certificate for the overall system and then an individual certificate for each individual model on a given project). They felt that costs and cumbersome administration caused by the above, made them less competitive.

Further, there appears to be a degree of uncertainty among building certifiers about what their statutory responsibilities are concerning mandatory inspections where off-site construction is involved. At times, uncertainty was said to create unnecessary and cumbersome processes that ultimately add cost to a project. As an example, one of the manufacturers explained how a building certifier travelled very long distances (hundreds of kilometres) on a weekly basis to observe pod waterproofing at the factory, because of the regulatory need to look at 10% of the waterproof membranes on a multi-storey residential project. It was also mentioned by one manufacturer that it was common for them to particularly seek clarification about the wall-to-floor junction.

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[162] *Victorian Building Authority. (2016). Regulatory requirements for the off-site construction of plumbing systems.*
[163] *Australian Building Codes Board. (2016). WMTS-050:2018, Prefabricated modules.*

Application of QA/QC Systems

Both manufacturers adhere to Australian Standards that fall within the parameters of their pod production. Compliance is built into their processes through frequent checks, particularly via their structured QA/QC systems. These systems are based around the principles and methods commonly used in manufacturing.

In terms of QA, proactive problem avoidance is key and the most obvious manifestation of this is pre-production design and prototyping (refer to workshop 3). Another feature is the use of Standard Operating Procedures (SOPs) which manifests in examples like standard kits of parts provided to trades people in the production line to avoid incorrect use of materials or cutting of corners. Yet another aspect of QA is a focus on continuous improvement to repeatable production methods, which is less possible in traditional construction because it occurs in a less systematised way.

In terms of QC, Inspection and Test Plans (ITPs) are used to verify each stage of production. Plumbing water pressure measurements are included as part of compliance requirements, but important additional inspections (not undertaken in traditional onsite) include ultrasonic measurement of dry film membrane thickness, which significantly reduces the risk of waterproofing failures. Of note, such technologies are rarely used onsite because once waterproofing contractors apply a membrane, they do not generally return to test it after drying.

In terms of installation, the manufacturer maintains high levels of coordination and collaboration with onsite teams. The bathroom pods are designed to integrate appropriately with the in-situ construction, but this requires careful alignment particularly in terms of plumbing stack work and other penetrations in walls and floors. The manufacturer provides detailed installation instructions and templates for on-site construction. Use of precast glass reinforced concrete (GRC) floors enable the seating of the pods onto the structural floor followed by the injection of pumped grout to fill voids; the GRC base is also thin enough that it avoids significant floor level differences when transitioning from the pod to surrounding areas. Wall cavities are also intentionally created to allow for tolerance spacing between pod walls and abutting party walls i.e. to ensure fire and acoustic construction remains unaffected by the pod installation.

As an example of interaction with onsite staff, one manufacturer provides an SOP to the on-site contractor, and then, in addition, provides hands-on training for the initial installation of pods on site. They do this to make sure the pods are installed correctly and will then provide a QR code on each bathroom, which allows the contractor to complete an online inspection and test plan for the pod and provide any rectification directly to the company. The company will also do its own on-site inspection of a sample of the overall pods installed.

Designing-out problems and Use of Prototyping

Ad hoc design is common in traditional on-site construction, but a benefit of pod manufacturing is the far greater attention to detailed design and 3D modelling; it can be used to design-out problems. The first step in this process establishes the suitability of a given project to utilise pods. Early detailing of the design is an important issue because it provides the opportunity to refine how the pod will avoid poor interfaces with the on-site construction design. An example is the way that plumbing is designed to be accessible from the outer sides the pod, such as along unlined hallway walls that can be finished later, which enables easy access and inspection where required.

Prototyping is the main tool/technology used by both manufacturers to enable the above and also facilitates CAD/CAM continuity. This manifests, as follows:

- Creating a physical proof-of-concept models at the outset of each project to check feasibility, design-out quality problems, refine the design for efficient production and ensure interfaces with in-situ construction are both practical and meet compliance requirements.
- Using software such as Autodesk Inventor, to build virtual prototypes that incorporate all the structural, plumbing, electrical, and aesthetic componentry. This digital approach allows them to address potential issues well before

physical construction starts. By identifying and resolving design challenges in the digital model, the manufacturer minimises the risk of errors during the actual manufacturing process. This also enhances production efficiency, as it reduces the need for highly skilled tradespeople at the factory stage. Of note, such software differs from typical architectural software insofar as being more detailed for factory production i.e. specialising in complex 3D assemblies and simulations. It enables exact location, sizing and features of plumbing fittings, floor wastes and exact layouts.

Conclusions

The case study demonstrates that the compliance of pods can be conceived as either a manufactured ‘product; or as a quasi-on-site ‘process’ (i.e. regulated work). Respective perspectives are held by Commonwealth and State regulatory bodies. The product perspective appears to be the main focus of pod manufacturers but in holistic building terms, elements of both perspectives are involved. Streamlining and reduction in fragmentated or redundant requirements are recommended to avoid unnecessary time, cost, inspection and administrative procedure to off-site construction.

From a product perspective:

- Well-developed QA/QC systems are concluded to underpin the reliability of off-site product certification by virtue of managing the reliability of production processes. Assisting features include detailed prototyping, early involvement in design and attention to interfaces with in-situ construction. Off-site certification initiatives are recommended and discussed in more detail later in this report.
- A degree of provision for minor customisation in pods would be useful in simplifying WaterMark certification of pods. The ability to implement this is currently unclear but a systematic approach is considered necessary. Initiatives elsewhere in this report concerning uptake of ‘similars’ to streamline compliance, may be useful in addressing this situation.
- Performance solutions represent risk and are potentially cost sensitive were impacting the viability of pod manufacture. Increased DtS solutions to avoid common performance solutions would serve to address this problem and allow greater standardisation. Interfaces with in-situ construction appear to be a good starting point for investigation.

From the process perspective, the case study shows that:

- Off-site and on-site certification involve multiple stages of compliance. Care should be taken in defining boundaries, apportionment and allocation of risks and responsibilities to avoid complexity and redundancy. A compliance chain approach is recommended as distinct from large overlap and replication of responsibility across multiple parties. Some degree of overlap is likely unavoidable but like a batten change in a relay race, it should be streamlined and minimise redundancy wherever possible. Given the scale and complexity of pods, there is potential for increased (whole of product) compliance risk being placed on manufacturers and simplifying/contextualising subordinate compliance components (e.g. plumbing).
- Mandatory inspection expectations tend to be unclear where pods are involved. This potentially equates to risk for building certifiers/surveyors/manufacturers and clients. Lack of clarity creates cumbersome and costly processes.

Case Study 3 – Off-site Compliance Solutions practiced overseas

This case study section introduces three solutions practised internationally: the BuiltReady Scheme in New Zealand, the UK's Robust Details, and the International Code Council (ICC) standards in the US. Each scheme is comprehensively discussed in the sections that follow.

BuiltReady scheme in New Zealand

In this section, the BuiltReady scheme is explained based on available online information. This scheme is designed to address the challenges faced by non-traditional construction methods, particularly off-site construction, in complying with the New Zealand Building Code. BuiltReady is a certification system designed to ensure that off-site components meet the New Zealand Building Code requirements, providing a level of assurance for both the design and manufacturing stages. The scheme is not limited to New Zealand manufacturers, although they must build for the New Zealand market. BuiltReady was introduced as part of a broader legislative reform to make the building consent process more efficient and reduce costs and processing times associated with building consents and code compliance certificates. While the traditional building consent pathways remain available, these may involve more scrutiny and longer processing times, which could serve as an incentive for manufacturers to opt into BuiltReady for a smoother process. The mandatory NZ Building Information Requirements, which are part of this scheme, started in December 2023. Prior to this, the voluntary aspect of the BuiltReady scheme was launched in September 2022 and is currently still being rolled out. The scheme is funded through a structured approach where the Ministry of Business, Innovation and Employment (MBIE) employs JASANZ to administer it. JASANZ, in turn, accredits certification bodies[164]. These bodies are responsible for setting the fees for manufacturers seeking certification, with the flexibility to alter fees to encourage competition, as dictated by MBIE**Error! Bookmark not defined.**. Additionally, MBIE has prescribed registration fees for m anufacturers. BuiltReady certifies a wide range of components without limiting types or scale. However, more complex products require a more detailed evaluation. Components, regardless of their BuiltReady scheme status, still need on-site consent certification. Central to understanding BuiltReady is recognising that it aims to certify a manufacturer's system of production rather than the certification of individual projects produced within that system. This distinction is crucial as it underscores the scheme's comprehensive approach to ensuring that the entire process of off-site construction—from design (where applicable), through manufacture, assembly, transportation, and installation on-site—adheres to the highest standards of quality and compliance with the New Zealand Building Code. The scheme covers the entire off-site construction process, including design, manufacturing, assembly, transportation, and on-site installation, ensuring all steps meet the Building Code through third-party inspections, audits, and ongoing surveillance by accredited bodies[165].

The scheme shares some similarities with CodeMark; however, unlike CodeMark, which focuses on certifying products, BuiltReady certifies the manufacturing processes of modular components, indicating their adherence to quality standards and compliance with the Building Code. Also, BuiltReady scheme certification allows a degree of flexibility to deal with a relatively standardised system that is being applied to somewhat customised projects[166].

The scheme is open to those supplying modular parts for buildings. Manufacturers can seek certification either for just manufacturing or for both designing and manufacturing modular components. The scheme covers three main types of modular products: prefabricated frames and panels, volumetric structures, and whole buildings, excluding site-specific works like foundations. Certified manufacturers can issue certificates for their components, confirming compliance with the Building Code. This reduces the scope of inspections by building consent authorities to areas not covered by the manufacturer's certificate, like foundations and site work [166].

The scheme operates under a specific legislative framework, including the Building Act 2004, the Building (Modular Component Manufacturer Scheme) Regulations 2022, and the BuiltReady scheme rules. Key supporting documents include the international standard ISO/IEC 17065:2013, which sets requirements for bodies certifying products, processes, and services and is incorporated

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[164] *BuiltReady Scheme Guidance. (2022). Accessed March 2024.*
[165] *Building. (2023). About BuiltReady. https://www.building.govt.nz/. Accessed March 2024.*
[166] *Building. (2023). About BuiltReady. https://www.building.govt.nz/building-code-compliance/product-assurance-and-certification-schemes/builtready/about-builtready/. Accessed March 2024*

by reference in the scheme rules[167]. Within the Building (Modular Component Manufacturer Scheme) Regulations 2022, the term 'building product' refers to any product that either (a) can reasonably be anticipated to serve as a component within a building, or (b) has been officially designated as a building product by the Governor-General through an Order in Council. Prefabricated product is also defined as manufactured (in whole or in parts) off the site on which they are to be installed – although some on-site assembly or installation may be required; and is intended to be transported to another site for installation[168].

There are three step-by-step guides for different scenarios listed below to show how BuiltReady works within the building consent process. A building consent is a written approval to carry out specific building work on a specific site, which must comply with current regulations. It ensures that the proposed work is safe, durable, and does not endanger the health and safety of anyone using the building[168] .

Depending on how manufacturers meet specified certification and registration criteria, they may be certified to:

- Manufacture only[169].
- Design and manufacture (modular components make up part of a building)[170].
- Design and manufacture (whole buildings)[171].

The submission of a manufacturer's certificate is required for each scenario alongside the building consent application, serving as proof that the modular components or entire building comply with the Building Code. The Building Consent Authority (BCA) verifies the BuiltReady certification details, ensuring that the design and manufacturing information within the certificate aligns with the Building Code. The BCA is responsible for conducting inspections on parts of the construction not covered by the manufacturer's certificate. For whole buildings, the BCA's inspection regime and Code Compliance Certificate (CCC) issuance focus on site-specific works, whereas for modular components, the emphasis is on integrating these with traditionally built sections[172.]

Certified Modular Component Manufacturers (MCMs) are required to maintain a quality management system, including internal audits to ensure ongoing compliance. The MCM must produce and install modular components according to its quality plan, which must align with its certification scope and be submitted to the MCM Certification Body (MCMCB). Any modifications to this plan must be communicated within five working days167. The quality management system undergoes an annual review, with provisions for more frequent audits based on risk assessments encompassing design, manufacturing, and installation. Emerging issues necessitate adjustments to the quality assurance plan. Building certifiers and consent authorities linked to a particular project are excluded from this internal review process. Additionally, MCMs must ensure that the installation process involves proper training, competency assessments, quality control, technical support, and pre-certification checks, all of which must be documented[167].

Current implications and challenges (Progress to date)

The BuiltReady scheme involves more comprehensive tracking of certified products beyond just issuing certificates and listing manufacturers in a registry. However, currently tracking certified products poses significant challenges due to the presence of 67 building consent bodies in New Zealand and the absence of formal information-sharing requirements on certificate issuance and renewal. Despite these challenges, efforts are underway to improve tracking mechanisms. The

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[167] BuiltReady Scheme Guidance. (2022). Accessed March 2024.
[168] Building (Modular Component Manufacturer Scheme) Regulations. (2022). Accessed March 2024.
[169] BuiltReady guide - Manufacture only, Building Performance. (2022). Accessed March 2024.
[170] BuiltReady guide - Design and manufacture (modular components). (2022). Accessed March 2024.
[171] BuiltReady guide - Design and manufacture (whole building). (2022). Accessed March 2024.
[172] Building. (2023). About BuiltReady. https://www.building.govt.nz/. Accessed March 2024.

BuiltReady scheme focuses on the end-to-end certification of manufacturers, covering all stages from design and manufacture to storage and onsite installation[173].

In hindsight, the inclusion of more operational elements earlier in the design phase of the scheme would have been beneficial. The BuiltReady scheme was not motivated by issues of non-compliance but by complications in the consent process for off-site manufacturing of building products. One valuable lesson learned has been the importance of builders developing strong relationships with local councils. This collaborative approach can streamline the consent process and improve overall compliance.

Currently, JASANZ is preparing to accept applications from manufacturers, with an estimated 25-35 manufacturers expressing interest in BuiltReady certification. Although not all may achieve certification, benefits from the manufacturer’s point of view are that they have a marketing advantage they can use (i.e. BuiltReady provider gives a high level of assurance) and it is often easier to get consent; in some cases, it can reduce cost and the number of inspections.

BuiltReady certification is not restricted to specific types of components or scales of products. However, more complex products require more rigorous evaluation by certification bodies. All participants in the BuiltReady scheme must demonstrate end-to-end capabilities, including design, manufacture, storage, transport, and installation. Certification bodies oversee the manufacturer's processes to ensure quality and compliance, although they do not directly view testing reports but assess testing results as part of the management system.

Insurance is a critical issue, with a need to ensure manufacturers have adequate means for responsibility and that insurers are willing to update policies accordingly. Recent weather events, such as cyclones, have highlighted the advantages of off-site construction, particularly in providing temporary accommodation.

UK Robust Detail

Formed in December 2003, Robust Details Limited (RD Ltd) was established in response to the house-building industry's demand for an alternative to Pre-Completion Sound Testing (PCT). A PCT is mandated under Part E of the government's Building Regulations in the UK to ensure adequate sound insulation in residential buildings. This test, also known as a sound insulation test, involves assessing separating walls or floors to confirm they meet the required standards for blocking airborne noise (like speech or radio) and impact noise (such as footsteps). Testers must be accredited by bodies like the Association of Noise Consultants (ANC) or the United Kingdom Accreditation Service (UKAS)[174].

Opting out of a PCT is not possible unless a building is registered with Robust Details, a pre-approved construction scheme. While this scheme eliminates the need for a PCT, it restricts construction flexibility and strictly applies to new builds (not for any conversions, home extensions or building refurbishments). A Robust Detail is a type of wall or floor construction that RD Ltd has assessed and approved. For approval, each Robust Detail must not only meet but consistently exceed the relevant regulatory standards, be practical for on-site construction, and be forgiving of variations in workmanship. Any significant deviations detected during inspection can result in de-registration from the Robust Details scheme and necessitate a PCT[175].

These details ensure that structures such as cavity walls and associated components like Dacatie Cavity Closers provide optimal acoustic properties for new buildings, aiming for maximal sound

[173] This section highlights the key findings from the meeting between ABCB and BuiltReady NZ. The summary, shared by ABCB, outlines the major areas of discussion and includes an overview of BuiltReady’s responses.
[174] UK Government, Building Regulation, (2015).
[175] Robust Details Ltd. (2024). Robust Details. The alternative to pre-completion sound testing to meet Part E of the Building Regulations. Retrieved March 2024. Statutory guidance, Resistance to sound: Approved Document E. https://www.gov.uk/government/publications/resistance-to-sound-approved-document-e. Retrieved in May 2024.

resistance. The RD requires lab test as explained in the Handbook. It is also recommended to have an inspection on site – but if this is not possible, the builder can complete the Compliance Certificate to declare they have built in accordance with the Detail.

The RD scheme comprises four key elements:

- Assessment and approval by RD Ltd.
- Inclusion in the Robust Detail Handbook.
- Registration or certification of each building project utilising Robust Details.
- Ongoing performance management, including sample testing, inspections, statistical analysis, and adjustments based on feedback to enhance performance and inform industry

In the context of implementing robust details in construction projects, a comprehensive approach to both testing and inspection is crucial to ensure compliance with established standards and to maintain high performance levels.

In order to use RD, initially, an appropriate Robust Detail must be selected that meets all the necessary specifications of the project. This detail is then incorporated into the design drawings to guide the construction team. Following this, the plots for the construction must be registered with the Robust Details scheme. Essential to this process is the notification of building control, which must be informed through the registration documents before the onset of construction. This ensures that building control body is aware from the start that the project will adhere to the Robust Details standards. The final step in the process involves the ongoing verification during construction that all building activities conform to the Robust Details specifications, maintaining adherence through regular checks and inspections. This comprehensive approach not only streamlines compliance but also enhances the quality and efficiency of the construction projects involved[176].

Testing and Inspection Protocols for Robust Details

1. **Laboratory Testing**

- **Stage A Testing:** Initial laboratory tests are conducted on 8 prototypes to evaluate whether the design can meet the required performance standards. This includes assessing sound insulation capabilities and other relevant metrics.
- **Stage B Testing:** Further laboratory tests assess the consistency of the detail's performance under varied conditions, such as different site environments and workmanship levels for further 22 tests.
- **Stage C Validation:** Successful details are published in the Robust Details Handbook after proving their effectiveness and simplicity in construction through controlled testing. Once published in the Handbook, they can be registered for use on sites[177].

To ensure they continue to perform, the registered plots are randomly picked for monitoring. They can be either tested or inspected but not both. If the monitoring picks up any trends in poor performance, or the detail being built consistently wrong, this is fed back to the proposer. The Robust Details scheme includes provisions for independent consultants to perform monitoring. This typically involves visual spot checks and random sound tests on a percentage of registered plots to ensure ongoing compliance and performance[177].

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[176] *Robust Details Ltd. (2024). Robust Details. The alternative to pre-completion sound testing to meet Part E of the Building Regulations. Retrieved March 2024. Statutory guidance, Resistance to sound: Approved Document E. https://www.gov.uk/government/publications/resistance-to-sound-approved-document-e. Retrieved in May 2024.*

[177] *Robust Details Ltd. (2024). Robust Details. The alternative to pre-completion sound testing to meet Part E of the Building Regulations. Retrieved March 2024. Statutory guidance, Resistance to sound: Approved Document E. https://www.gov.uk/government/publications/resistance-to-sound-approved-document-e. Retrieved in May 2024.*

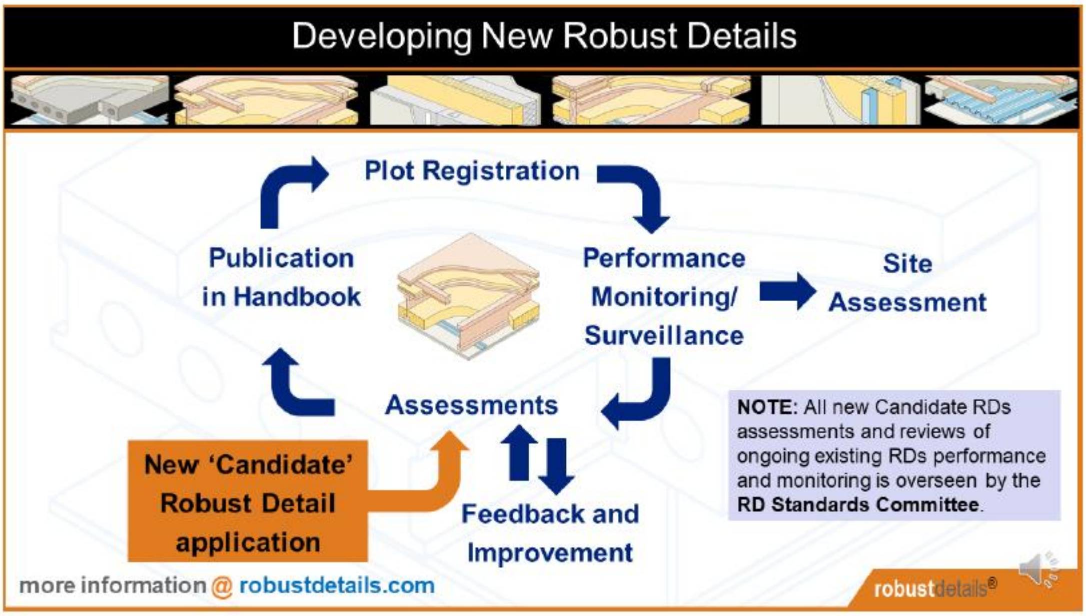

Figure 16 Developing new Robust Detail, https://www.robustdetails.com/plot-registration/, retrieved in 2024

Inspections at construction sites are conducted to ensure that these robust details are correctly implemented and performed as required.

While inspectors for robust details are not licensed to enforce Building Regulations directly, they verify that the construction adheres to the registered robust details. It remains the responsibility of building control body to ensure that the overall project complies with Building Regulations, including checking that plots are registered correctly, and constructions meet the specified robust detail standards[178].

International Code Council– compliance of off-site construction

The International Code Council has developed with the Modular Building Institute, three comprehensive standards to address off-site construction processes with a view to these being adopted by state and local regulators in the US and elsewhere. These standards aim to promote consistency around regulatory requirements for off-site construction processes, albeit that fragmentation in adoption, remains an obstacle[179]. The standards can be adopted by states and jurisdictions to streamline the approval process for off-site construction[180].

There are three standards in the suite including:

- ICC/MBI 1200-2021 Standard for Off-site Construction: Planning, Design, Fabrication and Assembly- This standard is designed to establish minimum requirements to ensure public health, safety, general welfare, and to address various challenges in both societal and industry aspects of the off-site construction process. It encompasses the planning, designing, fabricating, transporting, and assembling of commercial and residential

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[178] *Robust Details Ltd. (2024). Robust Details. The alternative to pre-completion sound testing to meet Part E of the Building Regulations. Retrieved March 2024. Statutory guidance, Resistance to sound: Approved Document E. https://www.gov.uk/government/publications/resistance-to-sound-approved-document-e. Retrieved in May 2024.*

[179] *Colker, R. et al. (2022). Codes Working Group: Brief. New Off-Site Construction Standards. Advanced Building Construction Collaborative. Accessed at https://advancedbuildingconstruction.org/wp-content/uploads/2022/07/ABC_Codes_Insight_Brief_Final_220715.pdf. Retrieved on June 2024.*

[180] *Colker, R. et al. (2022). Codes Working Group: Brief. New Off-Site Construction Standards. Advanced Building Construction Collaborative. Accessed at: https://advancedbuildingconstruction.org/wp-content/uploads/2022/07/ABC_Codes_Insight_Brief_Final_220715.pdf. Retrieved on June 2024.*

building elements. The aim is to bring consistency to off-site projects—for manufacturers, building teams and regulators.

- ICC/MBI 1205-2021 'Standard for Off-site Construction: Inspection and Regulatory Compliance' - deals with the plan approvals and inspection procedures, third-party review and inspection agencies. Inspections include both in-plant inspections and on-site inspections meaning that the construction must be verified both in accordance with the approved manufacturer's instructions and construction documents. In order to perform in-plant inspection, manufacturers should involve the third-party agencies, but prior to that, the third-party request should be approved by the states. The state or accreditation agency shall monitor the reliability of each evaluation agency at any reasonable time, with or without prior announcement. For registration of manufacturers and modular builders - Manufacturers and modular builders shall not engage in any business activity relating to the construction or location of modular buildings without being approved by the Authority Having Jurisdiction (AHJ). A manufacturer shall not construct for the state or locality until the manufacturing plant has been approved in accordance with this standard. This standard does not apply to manufactured housing regulated under the Federal Manufactured Home Construction and Safety Standards (24 CFR part 3280) (HUD). The inspection requirements for off-site construction are comprehensive, involving both in-plant and on-site checks to ensure full compliance with building codes and standards, including ICC 1205. In-plant inspections are primarily focused on verifying that the construction and testing within the manufacturing facility align with approved construction documents. This process involves ensuring the quality of materials and components, the accuracy of fabrication processes, compliance with testing procedures, and proper documentation of all construction activities and test results. On-site inspections and testing are crucial for verifying that the installation of off-site MEP (Mechanical, Electrical, Plumbing) system components is consistent with the approved manufacturer's installation instructions and construction documents. These inspections, conducted by the Authority Having Jurisdiction (AHJ) or other designated inspectors, cover several essential areas. Inspectors must verify that connections between off-site manufactured components are correctly made and that these connections meet both structural and functional requirements. They also need to ensure that off-site MEP components are properly integrated with site-built systems and that all connections are secure and compliant with structural codes. Further inspection is required for specific connections mandated by the AHJ, ensuring adherence to local jurisdictional requirements. Additionally, the installation of 'shipped loose' off-site items, which are components shipped separately and installed on-site, must be verified to confirm they are installed correctly according to the manufacturer's instructions. Connections between off-site MEP components and on-site utility services, such as water, electricity, and gas, are also inspected to ensure safety and functionality.
- ICC/MBI 1210-2021 'Standard for Mechanical, Electrical, Plumbing Systems, Energy Efficiency, and Water Conservation in Off-site Construction'. It is designed for adoption by government agencies and organisations, aiming to ensure uniform inspection and regulatory compliance of mechanical, electrical, and plumbing systems, as well as energy efficiency and water conservation in off-site construction. It covers the planning, design, fabrication, transportation, and assembly of the stated areas for both commercial and residential buildings. This includes the componentisation and modularisation of MEP system elements, integrating MEP systems into componentised, panelised, or modularised building elements, and meeting energy efficiency and water conservation standards in off-site construction.

Ryan Colker, VP of the ICC, says that while many States (35 states) of the United States have policies in place regarding plan review and progress inspection of off-site constructed buildings there is a need for more to adopt the standards. As an example, he cites the problem whereby inspection may typically fall to local officials who are not necessarily familiar with off-site construction techniques and therefore problems with acceptance and compliance ensue[181]. Similarly, Obando (2022) makes the point that the adoption of 1200 and 1205 in the US has been slow, with Salt Lake City being the first (in 2021). His projection for broad span uptake in terms of complete national US standardisation, takes at least 5 plus years, as 39 states have different modular programs and others leave it to local jurisdictions. He comments that modular builders are adjusting to variations in state codes for now

[181] *Colker, R. et al. (2022). Codes Working Group: Brief. New Off-Site Construction Standards. Advanced Building Construction Collaborative. Accessed at https://advancedbuildingconstruction.org/wp-content/uploads/2022/07/ABC_Codes_Insight_Brief_Final_220715.pdf. Retrieved on June 2024.*

but sees product standardisation helping to optimise and boost the industry over time. The ICC advocate for the uptake of the standards based on the following:

- regulatory barriers primarily exist due to fragmented building codes and lack of modular standards.
- the absence of modular codes means that projects must comply with local codes, which are not designed for off-site methods. These tentacles delays, and cost and impede the uptake of innovative methods.
- the standards aim to streamline approvals through consistent terminology, quality processes, factory/site inspections, and third-party reviews
- the standards aim to complement existing codes and therefore adoption can ease bottlenecks and risk
- Salt Lake City adopted the standards to enable off-site construction where previously not feasible. It helped accelerate affordable housing approvals[182].

Conclusion

The examination of the three international case studies on off-site construction compliance schemes provides valuable insights with potential applications for the Australian context. A significant example is New Zealand's BuiltReady scheme, which certifies the entire off-site construction process—encompassing design, manufacturing, assembly, transportation, and on-site installation—through third-party inspections, audits, and continuous surveillance by accredited bodies. This comprehensive approach ensures that all phases meet the Building Code, prioritising both quality standards and compliance.

Although BuiltReady shares similarities with Australia's CodeMark scheme, it differs significantly in scope. While CodeMark certifies individual products, BuiltReady certifies the entire manufacturing process of modular components, representing a potential shift in Australian regulatory practices if integrated into an updated version of CodeMark. By focusing on certifying a manufacturer's system of production rather than individual projects, an updated scheme in Australia can ensure ongoing compliance and quality. This systemic approach addresses a key limitation in Australia's current system, which tends to isolate certification to specific products or projects.

Importantly, a scheme like BuiltReady in Australia could coexist alongside traditional building approval processes but offers a more efficient and attractive pathway for manufacturers by simplifying the compliance pathways. This dual-path approach could encourage broader adoption and drive innovation within the sector.

The UK's Robust Details scheme effectively demonstrates the use of pre-approved construction details to ensure performance consistency, particularly for acoustic compliance. While this approach has traditionally been applied to on-site construction, its success indicates potential applicability in the context of off-site construction in Australia. Implementing this systematic method could improve quality control in Australian modular construction projects. However, integrating such a model into Australia's current building codes presents challenges, particularly due to jurisdictional variations and the need for cohesive enforcement across the country. Site inspections for these pre-approved details could remain the responsibility of surveyors or a third party for the installation quality insurance.

The ICC standards in the USA offer a comprehensive set of guidelines for planning, design, inspection, and regulatory compliance, promoting consistency in off-site construction. Although these standards have been adopted to varying extents across different states, achieving full national acceptance has been challenging due to local regulatory differences. The ICC standards could serve

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[182] *Colker, R. et al. (2022). Codes Working Group: Brief. New Off-Site Construction Standards. Advanced Building Construction Collaborative. Accessed at: https://advancedbuildingconstruction.org/wp-content/uploads/2022/07/ABC_Codes_Insight_Brief_Final_220715.pdf. Retrieved on June 2024.*

as an inspiring reference for Australia. However, developing a national standard that ensures consistency across all jurisdictions remains a significant challenge for the country.

Case Study 4 – The Potential of Image Recognition Technologies in Off-site Inspection Practices

Off-site construction necessitates stringent quality control measures to ensure that the prefabricated components comply with the specified standards. The onus on how to inspect compliance during prefabrication processes is important in dealing with the question of what-to-do and how-to-do, instead of traditional on-site inspection. For instance, significant parts of off-site construction are hidden/sealed during production making it difficult to inspect using traditional methods. Historically, such inspection relied on manual checks against drawings and specifications, but as with all manual inspection, run the risk of being forgotten or susceptible to human error[183]. This raises the question of what records exist to prove that the specified (compliant) construction design was undertaken correctly during production and how was this done in a way that provides reliability, accountability and traceability. Digital technology is the main option for consideration with a variety of options explored below.

Image capture technology provides a mature, easily stored, readily understood and relatively cheap strategy for achieving inspection needs. In addition, the data can also be easily shared with clients, inspectors and those along the supply chain.

Here, the advent of automated quality inspection systems, employing visual testing and sensor-based technologies, has markedly enhanced the precision and reliability of defect detection. Image-based systems have gained prominence for their affordability and ease of integration into smart manufacturing frameworks[184]. Quality control in manufacturing benefits from image recognition by enabling faster, more accurate inspection. Common applications include defect detection, dimensional measurement, and pattern recognition. Defect detection entails identifying and pinpointing scratches, cracks, dents, or stains on the surface or within a product. Dimensional measurement involves measuring the various dimensions of a product or component, including length, width, height, diameter, or angle. Pattern recognition is utilised to identify and categorise patterns such as logos, labels, barcodes, or characters on a product or package[185].

In image-based systems, a high-quality camera or scanner is essential for capturing images of the products or components under inspection. Moreover, a computer or device is required to process and store the images, as well as to execute image processing algorithms and applications[186]. Image recognition algorithms analyse these visuals to identify defects, inconsistencies, or deviations from the design specifications[187]. This automated process reduces the likelihood of human error and allows for continuous operation, thereby streamlining the quality inspection process.

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[183] *Darko, A., Chan, A. P., Yang, Y., & Tetteh, M. O. (2020). Building information modeling (BIM)-based modular integrated construction risk management–Critical survey and future needs. Computers in Industry. Vol. 123, 103327. Accessed at: https://doi.org/10.1016/j.compind.2020.103327. Retrieved on June 2024.*

[184] *Babic, M., Farahani, M. A., & Wuest, T. (2021). Image based quality inspection in smart manufacturing systems: A literature review. Procedia CIRP, vol. 103, pp. 262-267. Accessed at: https://doi.org/10.1016/j.procir.2021.10.042. Retrieved on June 2024.*

[185] *LinkedIn. (2024). How can you use image processing to improve quality control in manufacturing? How can you use image processing to improve quality control in manufacturing? Accessed at: https://www.linkedin.com/advice/1/how-can-you-use-image-processing-improve-xkqgf. Retrieved on June 2024.*

[186] *Somwang, P., & Muangklang, E. (2019). Image Processing for Quality Control in Manufacturing Process. In 2019 16th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON). pp. 782-785.*

[187] *Ravimal, D., Kim, H., Koh, D., Hong, J. H., & Lee, S.-K. (2020). Image-based inspection technique of a machined metal surface for an unmanned lapping process. International Journal of Precision Engineering and Manufacturing-Green Technology. Vol. 7. Pp. 547-557.*

For instance, in off-site construction, image capture could take place at each progressive stage on the production line. As an example, closed frame wall panels could potentially capture images at stages, such as, after framing where dimensional information including the size and spacing of framing members could be checked; a separate capture could then capture insulation installation in frame cavities; yet another capture could capture fixing patterns for linings, claddings and vapour barrier layers. Such data could potentially be retrievable for every wall panel on a given project, which could be easily activated using the likes of RFID or QR code technology.

Innovative image capturing methods from other industries, such as automotive, packaging, and food, can be adopted for the construction industry. Some of these innovative methods include:

- X-ray
- Machine vision
- Reality capture- Laser scanning

X-rays

X-ray testing serves as a pivotal non-destructive method that helps identify hidden defects in components such as wheel rims and steering gearboxes in the Automotive industry and can be applied in building products in off-site construction[188]. The defects such as bubble-shaped voids, fractures, or slag formations often invisible to the naked eye, can compromise the vehicle's safety if not detected and addressed promptly[188]. The automated defect detection in car manufacturing and X-ray testing introduces a newly developed dataset comprised of approximately 47,500 X-ray images, each labelled to indicate the presence or absence of defects. This dataset is instrumental for training and testing computer vision models, providing a robust framework for evaluating their effectiveness[188**Error! Bookmark not defined.**]. While qualitative visualisations in construction are helpful for v iewing details like cracks, concrete pores, and reinforcement fibres, quantifying data is essential for analysing structural simulations. X-rays can capture a 3D dataset that allows for deeper analysis[189].

Machine Vision

Machine vision is a branch of machine deep learning that interprets visual data, like images, videos, and signals from radar or sonar, for understanding scenes and extracting meaningful information[190]. Machine vision greatly enhances the efficiency, quality, and accuracy of defect detection[191]. Defect detection is crucial in machine vision and plays a significant role in quality control. By utilising machine vision technology, manufacturers can identify issues like contamination, scratches, cracks, blemishes, discolouration, gaps, and pit[191]. Through machine vision, there is potential for verifying building compliance and it can be significantly automated in inspection scenarios. Even so, it is mentioned here, more in the context of future technological opportunities rather than those that can be cost effective, and scalable when implemented in the short to mid-term.

Machine vision is a system that automatically captures and analyses images of real objects using optical devices and non-contact sensors[192]. The camera contains a sensor that converts light from the lens into electrical signals. These signals are digitised into an array of values held in pixels and processed to perform the inspection[192]. The resolution (precision) of the inspection depends upon

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[188] Mery, D., & Arteta, C. (2017, March). Automatic defect recognition in x-ray testing using computer vision. In 2017 IEEE winter conference on applications of computer vision (WACV). pp. 1026-1035.
[189] Plessis, A. & Boshoff, W. (2018). A Review of X-Ray Computed Tomography of Concrete and Asphalt Construction Materials. Stellenbosch University, South Africa.
[190] Konstantinidis, F. K., Mouroutsos, S. G., & Gasteratos, A. (2021, August). The role of machine vision in industry 4.0: an automotive manufacturing perspective. In 2021 IEEE international conference on imaging systems and techniques (IST) (pp. 1-6). IEEE.
[191] Ren, Z., Fang, F., Yan, N., & Wu, Y. (2022). State of the art in defect detection based on machine vision. International Journal of Precision Engineering and Manufacturing-Green Technology, 9(2), 661-691.
[192] Ren, Z., Fang, F., Yan, N., & Wu, Y. (2022). State of the art in defect detection based on machine vision. International Journal of Precision Engineering and Manufacturing-Green Technology, 9(2), 661-691.

the working distance, the field-of-view (FOV), and the number of physical pixels in the camera's sensor. A standard VGA camera has 640 x 480 physical pixels (width x height), and each physical pixel is about 7.4 microns square. From these numbers, resolution can be estimated for your 'real world' units[193].

The sensors used by machine vision cameras are highly specialised, and hence more expensive than a webcam. First, it is desirable to have square physical pixels. This makes measurement calculations easier and more precise. Second, the cameras can be triggered by the machine vision system to take a picture based on the Part-in-Place signal. Third, the cameras have sophisticated exposure and fast electronic shutters that can 'freeze' the motion of most parts[193].

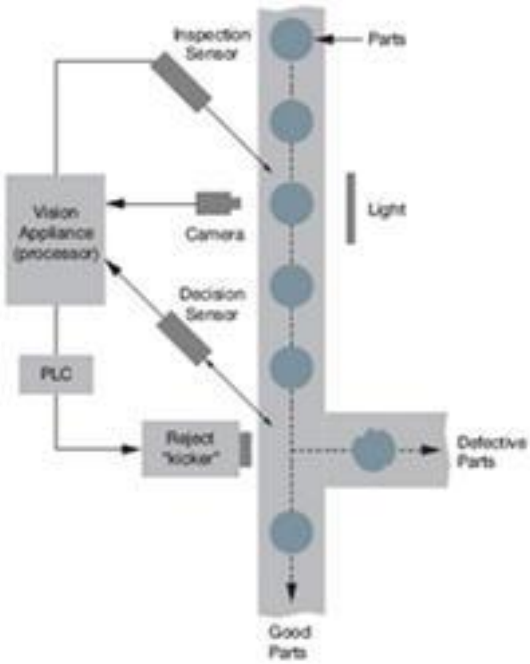

Figure 17 Machine vision system[193]

In high-speed production lines, offline verification audits, or robot-guided tasks, positioning tools are essential for effective machine vision. These tools, also known as locators or pattern finders, identify and determine the exact location and orientation of parts. They can send results directly to material handling equipment or adjust other tools required for inspection. This process, called 'landmarking', corrects for part movement.

[193] *Teledyne DALSA. (2024). Machine Vision 101. https://www.teledynedalsa.com/en/learn/knowledge-center/machine-vision-101-an-introduction/. Retrieved June 2024.*

Edge positioning | Pattern positioning | Part positioning | Model training interface

Figure 18 Machine vision- Camera's application in positioning the items in production line[194]

Machine vision allows the detection and analysis of tiny defects, often invisible to the human eye, such as those found in construction welds. It uses digital signal processors to analyse images by counting light and dark pixels, converting images to binary (black and white), and segmenting them to better identify individual pixels. Techniques like angle detection, pattern recognition, and size measurement help differentiate between similar pixels, making them useful for tasks like weld quality control and detecting faults on brick surfaces.

Since product and process flaws often occur randomly, machine vision flaw detection algorithms seek pattern changes, colour or texture variations, and specific connected structures. High-resolution, high-sensitivity image sensors and cameras capture high-quality images. Their powerful frame grabber/vision processor hardware and advanced software tools further down the imaging chain identify defects and empower quality control systems to respond appropriately[195].

Laser scanners & Reality capture

Terrestrial Laser Scanning (TLS) is a ground-based technology that captures dense 3D point clouds of its surroundings, using time-of-flight or phase-based distance measurement principles. These point clouds are enhanced with additional data like colour or intensity information for each point or supporting images, improving the visualisation of the raw point cloud. With single-point accuracy at the millimetre level and the capability to measure millions of points in minutes, TLS is highly suitable for various applications in the Architectural Engineering Construction and Facilities Management (AEC/FM) sector[196].

Laser scanning technology functions through triangulation, a geometric principle, to determine the location of an object in space. Developed by the National Research Council of Canada in 1978, it involves projecting a laser line onto the surface of the target object, which is captured by a camera. The camera identifies the line through its pixels and, based on its position relative to the laser source and object surface, calculates precise measurements. Nikon Metrology laser scanners follow this approach, translating the laser line into pixel data that yields an accurate depiction of the object's dimensions[197].

Considering the automotive industry, a manufacturer would typically have inspection programs created for every critical component that they are manufacturing. They would take a part out of production, put it on the laser scanning CMM, load up one of the measurement programs for that

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[194] Teledyne DALSA. (2024). Machine vision positioning. https://www.teledynevisionsolutions.com/solutions/machine-vision/positioning/. Retrieved on September 2024.
[195] Teledyne DALSA. (2024). Flaw Detection: Semiconductor, Print, Food, PCB. Accessed at https://www.teledynedalsa.com/en/learn/markets-and-applications/mv/flaw-detection/. Retrieved on June 2024.
[196] Aryan, A., Bosché, F., & Tang, P. (2021). Planning for terrestrial laser scanning in construction: A review. Automation in Construction. Vol. 125. 103551.
[197] Nikon. (2024). Laser Scanning: The Powerful, Flexible Tool of Choice for Advanced Manufacturing. Accessed at: https://industry.nikon.com/en-gb/case-studies/laser-scanning-the-powerful-flexible-tool-of-choice-for-advanced-manufacturing/. Retrieved on June 2024.

part, and then let it run completely autonomously. Shortly thereafter, a measurement report is available that reveals if there are any deviations on that part.

A noteworthy study in the cast extrusion manufacturing process, demonstrates the efficacy of a vision-based system for defect detection, employing specialised software for image analysis[198]. In this study, camera technology uses image sensors to take photos or videos for vision-based sensing, facilitating automated data collection for complex analysis and quality assurance. It employs various image processing and automation algorithms to extract environmental information. While humans may overlook a lot of information in images or videos, algorithms can analyse and understand this data, providing a basis for using vision-based sensing in construction management.[198.]

As an example of implementation, the report by Building 4.0 CRC (2023)[198], it is mentioned that US guidelines for utilising such technology involve certain options for verifying the authenticity of the building site being inspected including: (1) beginning the RVI at the exterior of the building; (2) showing the address of the building; or (3) using a mapping tool. Obviously, these fundamentals need to be adjusted for off-site construction. In doing so, there is an argument to dispense with the need for live stream in place of (point in time) image capture that can be mapped at stations along the production line; a QR code on the assembly could assist in verifying its presence on the production and also link it to a specific project including its intended in situ location in that project. Obviously, such an approach goes beyond inspection of an overall production system by providing project specific inspection information that can be provided to the certifier or inspector on that project (as part of the overall proof of compliance documentation).

The report also identifies how assemblies are categorised into geometric (measurable features requiring spatial information captures, such as dimensions, position, orientation, spacing, displacement, and deformation) and non-geometric (attributes assessed without spatial data, including environmental conditions and damage level).

Reality capture employs a range of sensors, including conventional RGB cameras, RGBD (depth cameras), infrared sensors, laser scanners, and ground-penetrating radar mounted on both stationary and mobile platforms[199]. Even while the broader context involves the process of collecting spatial data to create a digital model that accurately represents the object's geometry and appearance, this model can then be used to extract valuable inspection information. [199]It has become the most extensively researched method for technology-assisted inspection across various construction stages—such as excavation, reinforcement, framing, insulation, Mechanical, Electrical, And Plumbing (MEP), and façade inspection—providing detailed information on element position, dimensions, deformations, cracks, and other inconsistencies. Through RGB images, a dense 3D point cloud can be generated from multi-view imagery, however, due to the complexity of the construction sites (e.g., buildings with multiple rooms and occluded areas) this approach requires a large number of images with sufficient overlap. Stationary imaging using panoramic cameras can simplify the acquisition and reduce the complexity of the processing by taking multiple images from a single station[200]. After compiling the data, point cloud models work to capture detailed components and process 3D measurements of extracted profiles of component facades in the x, y and z axes for CAD use. In applying technical data in various programs such as Revit, documented information from a point cloud model allows parties to be informed in the coordination of lowered cost, and optimised efficiency of projects[200].

RGBD cameras or depth cameras capture both colour and depth information simultaneously. Unlike traditional cameras, RGBD cameras use additional sensors like Time-of-Flight (ToF) or structured

[198] *Gamage, P., & Xie, S. (2009). A real-time vision system for defect inspection in cast extrusion manufacturing process. The International Journal of Advanced Manufacturing Technology. Vol. 40. pp. 144-156.*
[199] *Building 4.0 CRC report. (2023). Evaluation of emerging technologies for remote inspections of building work.*
[200] *Zhengdao Li, C., Hu, M., Xiao, B., Chen, Z., Tam, W. & Zhao, Y. (2021). Mapping the Knowledge Domain of Emerging Advanced Technologies in the Management of Prefabricated Construction. Sustainability Journal. Accessed at: https://doi.org/10.3390/su13168800 Retrieved on August 2024.*

light technology to measure the distance between the camera and objects on site. By combining depth measurements with colour information, these cameras create a 3D representation. By analysing how the pattern is distorted by surfaces, the camera calculates depth information[201]. Depth data from various images are combined to create a 3D mesh model of the site. This mesh, integrated with panoramic images, forms a 3D panorama at each scanning point, allowing for precise 3D measurements of the images. RGBD cameras with cost-effective embedded lenses appeared to be a useful alternative for obtaining three-dimensional information to detect cracks in concrete by analysing the surface pattern[202]. At its most basic, the use of RGB or perhaps RGBD (If including dimension information of assembly) in off-site construction is a question of how much verification information is required from the remote inspection. The use of RGBD also raises the question of the scalability of such technology. For instance, high-cost technology may immediately impact adversely small-to-medium-size enterprises, which would not necessarily be beneficial for off-site construction.

Imagery recognition example in the production line - Auto Eye truss system

The SF022 Auto Eye Truss System is designed for the automatic production of roof trusses, blending high capacity with industrial-quality outcomes[203]. This system features an automatic press that visually identifies each roof truss and automatically picks, places, positions, and presses the nail plates onto the truss. The pressing force is tailored to each nail plate, ensuring consistent results. The system is versatile, and capable of handling any roof truss shape. In the production of roof trusses, the process begins with two operators placing timber on puck tables, guided by lasers to ensure accurate positioning. An automatic nailing bridge then inserts corrugated nails at all joints and marks the truss with production data using an inkjet printer. The roof truss is then automatically lifted and moved to a press station[203]. The press, equipped with 30 magazines of various sized nail plates, selects and feeds the correct plates. It visually checks the alignment of the truss and joints, accurately placing the nail plates even if the timber is slightly misaligned. The press applies precise force to secure the nail plates perfectly. After processing all joints, the truss passes through an optional roller press for extra quality assurance and is then automatically stacked. Once a complete package is assembled, it is bundled by an operator and loaded onto a truck. This automated system emphasises visual checks and precise placement to ensure high-quality construction of roof trusses (Figure 19). The imaging technology is supported by Beckhoff, which provides industrial cameras for machine vision.

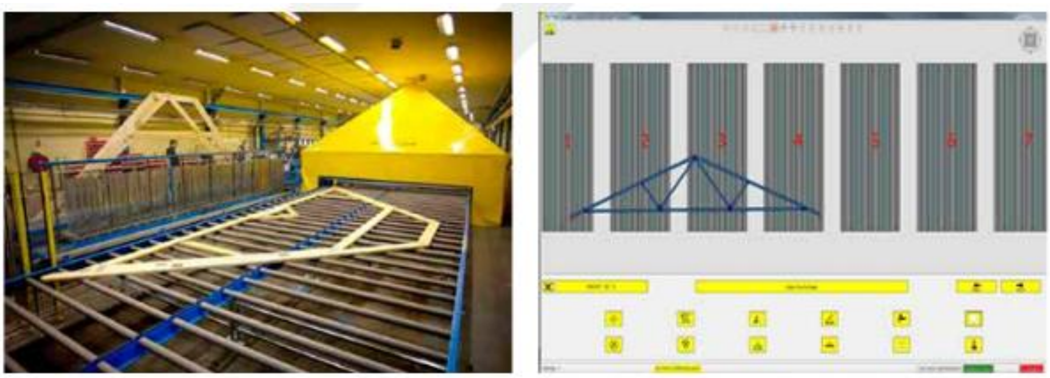

Figure 19 Auto Eye truss system

Similar to the Auto Eye Truss System, Trussmatic, currently operating in Finland, seeks to increase production efficiency and manage improvements in the safety and risk mitigation of construction (Figure 20). The Trussmatic production line in particular, uses automation control systems that

[201] *Building 4.0 CRC report. (2023). Evaluation of emerging technologies for remote inspections of building work.*

[202] *Kim, H., Lee, S., Ahn, E., Shin, M., & Sim, S. H. (2021). Crack identification method for concrete structures considering angle of view using RGB-D camera-based sensor fusion. Structural Health Monitoring. Vol. 20, 2nd edn. Pp. 500-512.*

[203] *Randek. (2024). Autoeyetruss System. Accessed at: https://www.randek.com/en/roof-truss-system/autoeyetruss-system. Retrieved on June 2024.*

enable one operator to manage the whole production process, inclusive of assembly from CAD files, installation and maintenance. A lumber scanner uses machine vision technology to identify rejected or deformed members and is assembled by two industrial Vekta robots via a conveyor belt, sawn to the size as shown printed onto the components – position dependent information that can be customised according to the design[204]. The final press and packaging are also completed off-site and stored until shipment[205].

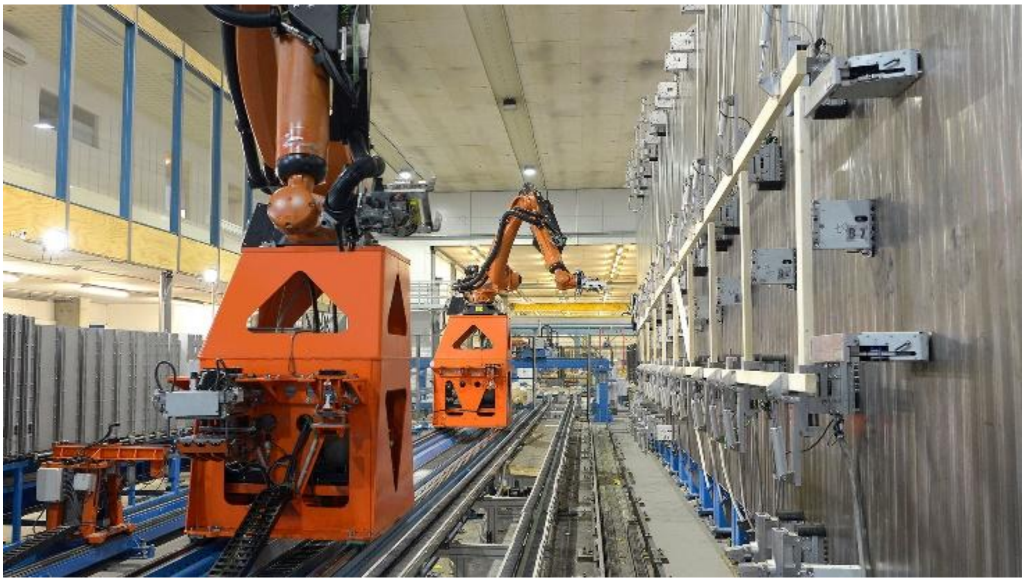

Figure 20 Trussmatic system – assembly

Table 4 Image Capture and Processing Technologies for Inspection and Defect Identification

Technology	Function	Potential implication
Machine Vision	Automates visual inspection using cameras and algorithms to detect defects.	Identifies defects invisible to the human eye, such as cracks and scratches, improving quality control and reducing human error in off-site manufacturing processes.
X-rays	Non-destructive testing to detect hidden defects.	Allows for deeper analysis of components, detecting voids, fractures, or other issues within materials, ensuring structural integrity in off-site-manufactured products.
Reality Capture (Laser Scanning, RGBD Cameras)	Laser Scanning- Captures 3D spatial data and generates digital models for inspection RGBD Cameras- Capturing colour information and depth measurements from the camera to the object	Provides accurate digital 3D models for quality control, inspection, and compliance verification of prefabricated components, improving production efficiency.

Conclusion on the Potential Use of Image Recognition Technologies in Off-site Construction

[204] *Vekta Robotics. (2024). About Vekta Products. Accessed on https://vekta.com.au/products/category/cutting/ Retrieved on August 2024.*
[205] *Trussmatic. (2024). About Trussmatic. Accessed at https://trussmatic.com/about-us/ Retrieved on August 2024*

The adoption of image recognition technologies in off-site construction offers substantial potential for improving quality control and ensuring compliance with construction standards. The study highlighted that the use of these technologies in off-site construction inspection has been overlooked. However, insights from other industries show that technologies like image capture, machine vision, and X-ray can provide an accurate approach to inspecting prefabricated components, addressing the limitations of traditional manual inspections. These technologies enable real-time defect detection, dimensional measurement, and verification of complex assemblies, while also reducing human error and enhancing traceability throughout the production process.

By integrating these technologies into off-site construction workflows, manufacturers can ensure a higher standard of quality and transparency, ultimately improving both production efficiency and the safety of final construction projects. In addition, the scalability of technologies like machine vision and X-ray inspection allows for continuous monitoring without disrupting production, providing a critical advantage for maintaining the integrity of hidden or hard-to-inspect components.

Case Study 5 – Chain of custody and Product Traceability

Establishing a robust chain of custody within the supply chain forms the cornerstone of effective Quality Assurance (QA) and is therefore relevant to compliance in off-site construction[206]. Chain of custody ensures the traceability of construction materials throughout their lifecycle, enabling verification at every stage of their journey[207]. Traceability refers to the ability to track a product's history, source, and movement through its supply chain. Digital traceability uses technology to monitor products as they progress along the supply chain. This system marks products and stores key data elements—such as attributes, location, and certifications—in a digital framework that can be easily shared and accessed by all stakeholders[208].

Arguably, the main relevance of this issue is that off-site construction commonly involves closed panels and other forms of hidden construction, so there is a need to know the details of components inside a complex assembly to declare and consequently check compliance. There is also the process of transitioning from an off-site manufactured assembly through the stages of storage, delivery, installation and service life on-site. A lack of information and quality assurance during these stages risks the occurrence of low quality and non-compliant products to enter the market[207].

Therefore, close collaboration that can facilitate traceability between the involved entities in off-site construction and with manufacturers is essential to demonstrate that products meet regulatory standards and design specifications and are suitable for their intended use. Such collaboration mitigates regulatory pressures and diminishes risks for all parties in the custody chain.

In off-site construction, an understanding of the chain of custody and the traceability of components becomes crucial in the following areas:

- **Quality Assurance:** Knowing the chain of custody allows building professionals to verify that the products they use meet relevant Australian standards.
- **Risk Mitigation:** helps protect both builders and customers by ensuring that the materials are safe and free from defects.
- **Verification Processes**: When procuring building products, the following scenarios should be considered:
    - Domestic product sold by the manufacturer: the verification process for products manufactured domestically and sold directly by the manufacturer is understood.

[206] *Prayudi, Y., & Sn, A. (2015). Digital chain of custody: State of the art. International Journal of Computer Applications, 114(5).*
[207] *Batista, D., Mangeth, A. L., Frajhof, I., Alves, P. H., Nasser, R., Robichez, G., Silva, G. M., & Miranda, F. P. d. (2023). Exploring Blockchain Technology for Chain of Custody Control in Physical Evidence: A Systematic Literature Review. Journal of Risk and Financial Management, 16(8), 360.*
[208] *ISO 9001: 2015 Quality Management System – retrieved in September 2024*

- Overseas product distributed through an importer: The exploration of methods to verify products imported from overseas and distributed by an importer is conducted.
- Client supply of an imported product as part of a contract: When clients supplied imported products, compliance with the National Construction Code (NCC) is ensured[209].

In traditional archiving systems of construction projects, an abundance of data needs to be shared and recorded for its life cycle, typically exchanged verbally or on paper[210]. Without an adequate data management system, tracing information throughout the project lifecycle risks high cost and energy with time extensions leading to additional payments and conflicts. If the classification of disputes is subjected to scrutiny, the cause of most claims is rooted in the category of 'the engineer's instruction to change'. The change in orders leads to changes in design, coordination, code and technique, and modifying because of errors in design, mistakes in material selection, and lack of coordination in the documentation. Another study points out that when the scope of the contract is not drawn in detail, the person responsible for the substandard performance is not known, and therefore unable to eliminate defects. Therefore, some disputes arise because of ambiguities in contract documents, scattered information of site reports such as an inaccurate bill of quantities, and poorly written contracts. Moreover, unclear documentation can jeopardize any chance of settling a dispute out of court because its outcome cannot be predicted with certainty. In an insecure centralised system, uncertainty results from a lack of awareness of project status and the actions of other stakeholders.

Recording documents traditionally with a combination of electronic and hard copies of data also presents challenges for project managers to monitor progress, or correctly identify discrepancies between as-planned and as-built activities. Traditional data storage systems also compromise the creation of accurate daily reports, subjecting the project to the loss of valuable information essential to the investigation of failures. Limited transparency in identifying each stakeholder's contributions and responsibilities and failing to find a way to avoid copyright infringement in large projects, can generate serious disputes. Therefore, a prominent weakness in a centralised system that needs to be overcome is a lack of intellectual property protection for the construction designer of BIM models.

Progress meetings of construction projects held regularly are essential mechanisms for exchanging data, discussing issues, and reaching agreements on the most effective action. These face-to-face meetings are a forum for all stakeholders to become aware of the project status. However, face-to-face interaction does not always lead to expected results. Despite the massive amount of time and energy consumed, the outcome is likely to be affected by positive and negative emotional climate. A complex process such as a construction project relies on extensive data exchange. In this level of complexity, information must be transferred on time and accurately among project participants to facilitate collaboration among the participants. The construction industry needs to have a system of information exchange without compromising the quality of processes. Many conflicts are derived from poor communication rather than delays in performance. An effective collaboration needs trust; however, the current systems to improve communication and store a record of transactions suffer from a lack of trust because of non-transparent corporate ownership. Other problems in a traditional contract system rooted in unsuccessful collaboration include slow down team workflow due to poor access to data, contract misinterpretation, late or incomplete information received, slow client response to a decision, and misunderstandings[211].

High-quality documentation therefore has a positive impact on the overall efficiency of construction projects. A report by University of Auckland in 2019, highlights the experiences across six countries,

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[209] hang-Richards, A., Gharbia, M., & Xu, X. (2019). From lessons to practice: Compliance and assurance prototypes for manufactured buildings. BRANZ.
[210] arko, A., Chan, A. P., Yang, Y., & Tetteh, M. O. (2020). Building information modeling (BIM)-based modular integrated construction risk management–Critical survey and future needs. Computers in Industry, 123, 103327.
[211] *Mahmudian, D., Arashpour, M. & Yang, R. (2022). Blockchain in construction management: Applications, advantages and limitations. Automation in Construction. Retrieved on August 2024.*

underscoring the benefits of third-party or self-certification, when paired with traceability systems and accreditation, offers to manufacturers of prefabricated components[212].

The adoption of Blockchain in the traceability system provides one means for implementing chain of custody; it can also enhance quality assurance and assist a smoother certification process in prefabricated buildings[213].

Prefabricated buildings have supply chains that are more complex than those of traditional ones[214]. A transparent and metadata-rich infrastructure is required to trace the source of product problems within such a complex supply chain[215]. Blockchain technology, characterised by its decentralisation, distributed storage, traceability, openness, and tamper resistance, potentially revolutionises quality management across the supply chain's various stages, including design, production, transportation, and construction[215].

A decentralised system is a network whose members can be comprised of manufacturing machines, robots, or humans, where no one has complete control over the system and every party has access to the data. In addition, the cryptographic protocol of block chain data guaranteed the authenticity of data by allowing only authorised participants to exchange information, linking the transaction to previous ones, such that historical information cannot be changed or tampered with. In also providing an audit trail of transactions, this accountability and transparency in data exchange allows members to trace data with verifiable timestamps[216]. This approach enables the detailed recording of process data, such as material specifics, manufacturing details, and logistics. Moreover, it facilitates the adoption of a uniform coding system, streamlining information exchange across different jurisdictions[217].

Blockchain seeks to support distributed, encrypted and secure logging of digital transactions. In construction, Blockchain allows for component traceability of smart contracts and documents that can be achieved by combining RFID technology and tracking the payment of suppliers in the supply chain network by using integrated electronic proof of delivery, effectively address issues relating to payment, documentation and collaboration[218]. At the start of the project, the employer deposits an amount of money to the network, which is blocked until delivery time. After validating the quality of the delivered job, an automatic payment is made. In relying on self-executing codes, neither participant nor the developer who has written the codes can manipulate the contract or delay the payment. When all contractual clauses are formalised and converted into computer-executable code for a smart contract, tasks are automated for triggering interim payments after achieving consensus. The authorised participants can input a payment application, and a consensus system can check the application to prove validity before releasing remuneration. The blockchain ledger records the history of information lodged and voids the requirement for a third party.

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[212] Gharbia, M., Chang-Richards, A., Xu, X., Höök, M., Stehn, L., Jähne, R. & Feng, Y. (2023). Building code compliance for off-site construction. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction. Vol. 15. 2nd edn. 04522056. Retrieved on June 2024.

[213] Wu, H., Zhang, P., Li, H., Zhong, B., Fung, I. W. H., & Lee, Y. Y. R. (2022). Blockchain Technology in the Construction Industry: Current Status, Challenges, and Future Directions. Journal of Construction Engineering and Management, 148(10).

[214] Wang, Z. L., Shen, H. C., & Zuo, J. (2019). Risks in prefabricated buildings in China: importance-performance analysis approach. Sustainability, 11(12), 3450.

[215] Xu, J., Lou, J., Lu, W., Wu, L., & Chen, C. (2023). Ensuring construction material provenance using Internet of Things and blockchain: Learning from the food industry. Journal of Industrial Information Integration, 33. https://doi.org/10.1016/j.jii.2023.100455

[216] Mahmudia, D., Arashpour, M. & Yang, R. (2022). Blockchain in construction management: Applications, advantages and limitations. Automation in Construction. Retrieved in August 2024.

[217] Bakhtiarizadeh, E., Shahzad, W. M., Poshdar, M., Khalfan, M., & Rotimi, J. O. B. (2021). Blockchain and information integration: Applications in New Zealand's prefabrication supply chain. Buildings, 11(12), 608.

[218] Zhengdao Li, C., Hu, M., Xiao, B., Chen, Z., Tam, W. & Zhao, Y. (2021). Mapping the Knowledge Domain of Emerging Advanced Technologies in the Management of Prefabricated Construction. Sustainability Journal. Accessed at: https://doi.org/10.3390/su13168800. Retrieved in August 2024.

The blockchain framework in a smart contract application also provides a system that allows for the tracking of progress and management of transactions, where persons responsible can be defined. For example, in a cladding design process, after paying in advance to the vendor, transporting the equipment to the predefined place is the vendor's responsibility. Since the transaction fee paid by the vendor and the data of equipment delivery are recorded in the blockchain, the reason for delays is traced. In offering a way for users to securely collaborate, organise and transact, the blockchain framework makes responsibilities clear, workflow paths are specified in projects, leading to trust and cooperation. This collaborative process subsequently requires less bureaucracy, leading to greater collective awareness of the site's status[219].

Drawing inspiration from the food industry, which has successfully implemented international coding systems and exploited the Internet of Things (IoT) and blockchain for provenance management, the construction sector could benefit significantly from these technologies [220]. The IoT provides an integration of various sensors and objects that can communicate directly with one another without human intervention [221]. The integration of a standardised coding system, coupled with the continuous monitoring capabilities of IoT devices and the secure, immutable record-keeping provided by blockchain, equips the construction industry with the means to achieve higher levels of transparency, efficiency, and quality control in its supply chain operations for off-site construction.

Development of a Product Traceability Framework

The construction industry is undergoing a significant transformation towards innovation and digitalisation, with a particular focus on addressing supply chain complexities and ensuring compliance with regulatory standards. The development of a comprehensive traceability framework, led by the National Building Products Coalition, was driven by the recommendations of the Building Confidence Report (BCR)[222]. This report presents systemic issues identified by the Building Confidence Report such as inadequate product certification and a lack of traceability, which have contributed to compliance failures and construction defects[222.] This guide applies to all building products as being 'any material or component incorporated within, or that could be incorporated within a building or building work. Building products can take the form of materials, systems and components'. They may also be referred to as 'components,' 'construction product,' 'forms of construction,' 'materials' or, 'systems'[222].

This digital traceability framework represents a significant step forward in ensuring regulatory compliance within the construction industry, particularly in off-site construction. By addressing gaps in product certification, traceability, and compliance, the framework aims to create a more transparent, efficient, and reliable construction supply chain, supporting the broader goals of Construction 4.0.

The traceability framework consists of five key elements:

1. **Strengthened NCC Evidence of Suitability Requirements:** Ensuring that products meet risk-based verification standards and are supported by robust documentation, as outlined in the updated ABCB Handbook.
2. **Information Obligations for Manufacturers and Suppliers:** Requiring manufacturers to provide verifiable evidence supporting the intended use of their products, with minimum standards for industry conformance schemes.

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[219] Mahmudia, D., Arashpour, M. & Yang, R. (2022). Blockchain in construction management: Applications, advantages and limitations. Automation in Construction. Retrieved, August 2024.
[220] Xu, J., Lou, J., Lu, W., Wu, L., & Chen, C. (2023). Ensuring construction material provenance using Internet of Things and blockchain: Learning from the food industry. Journal of Industrial Information Integration, 33. https://doi.org/10.1016/j.jii.2023.100455
[221] Alaba, F. A., Othman, M., Hashem, I. A. T., & Alotaibi, F. (2017). Internet of Things security: A survey. Journal of Network and Computer Applications, 88, 10-28.
[222] National Building Products Coalition. (2024). Traceability and digitalisation of building product information. Retrieved in September 2024.

3. **Product Traceability and Identification:** Establishing a national traceability system that ensures consistent product labelling and transparency throughout the supply chain. This system focuses on assigning unique digital identifiers to products, which are updated at every stage from manufacturing to installation, ensuring compliance with Australian standards.
4. **Improved Surveillance, Research, and Information Sharing:** Establishing a national body to oversee the system, monitor product standards, and address product failures through enhanced reporting tools.
5. **Strengthened Compliance and Enforcement:** Targeting the entire building delivery chain to ensure rapid action on non-compliant products, with a focus on improved legislative powers for auditing and enforcement[223].

For off-site construction, where products are manufactured in controlled environments and then transported to sites for assembly, the framework's emphasis on digital traceability is crucial. It ensures that off-site-manufactured components, such as prefabricated systems, meet all necessary regulatory standards before being integrated into final structures. This is achieved through a digital ledger system that captures key data points, including manufacturing details, compliance certificates, performance attributes, and installation records. This traceability ensures that every product used in construction projects can be tracked and verified for compliance with the NCC, reducing the risk of defects and non-compliance.

The framework also integrates tools like Building Information Modelling (BIM) to further enhance the visibility and traceability of products throughout the supply chain. BIM enables stakeholders to view and manage product data in real-time, improving coordination between manufacturers, contractors, and regulators. Additionally, third-party certification bodies play a key role in verifying that products meet the performance and safety standards required by the NCC, providing an extra layer of assurance in off-site construction projects.

Conclusion on Traceability for Off-site construction

The integration of robust traceability system is essential for ensuring compliance and quality assurance in off-site construction, particularly given the complexity of the supply chain and the hidden nature of many prefabricated components. Establishing a chain of custody allows stakeholders to track materials and components throughout their lifecycle, ensuring transparency and accountability. Off-site construction often involves closed panels and assemblies that cannot be inspected in the traditional on-site manner. As such, digital traceability systems provide a means to verify compliance with regulatory standards, ensuring that prefabricated components meet design specifications and quality requirements at every stage of production, storage, transportation, and installation. This is particularly important in mitigating the risks associated with poor-quality products entering from overseas, which can compromise both safety and compliance.

The establishment of a national traceability system, as proposed by the National Building Products Coalition, with unique identifiers for off-site construction products, could significantly enhance transparency and accountability by enabling thorough tracking of components from manufacturing to installation. This approach fosters confidence in off-site construction compliance, supporting its wider adoption across the industry. Additionally, creating a dedicated national body to regularly monitor this system would help identify and address inconsistencies or failures, further strengthening trust in off-site construction practices.

Chapter’s Conclusion

In this chapter, a series of case studies were analysed to identify the common challenges in off-site construction, as well as international solutions for off-site assemblies, certification, standardisation, and technologies for off-site inspection. A theme in case study1 concerned the challenge of fire-rated walls and compliance, which often led project teams to adopt performance-based solutions,

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[223] *National Building Products Coalition. (2024). Traceability and digitalisation of building product information. Retrieved in September 2024.*

which, although technically sound, were more complex, time-consuming, and costly compared to simpler DTS options. The unpredictability of these performance solutions disrupted construction timelines, especially when they emerged during or after the design phase, undermining the speed and efficiency advantages of off-site construction and compromising its commercial viability. Furthermore, critical risks associated with interfaces between different assemblies were apparent. These interfaces were frequently addressed with performance solutions, though managing them with DTS approaches would have been more efficient and less risky. This underscores the need for clearer regulatory frameworks and more streamlined compliance approaches through DTSs, particularly for interface integration, to preserve the benefits of off-site construction.

The case study on wet area pods examined the WaterMark Certification Scheme guidelines at federal and state levels, along with offering key insights into modular construction compliance through two major manufacturers in Victoria and New South Wales. Advanced QA/QC systems, prototyping, and 3D modelling were identified as essential for ensuring reliability and efficiency in these two examples. Pod compliance can be approached as either a manufactured 'product' or a quasi-onsite 'process', with respective oversight by Commonwealth and State regulatory bodies. While pod manufacturers primarily focus on the product perspective, a combination of both approaches is often necessary to address holistic building requirements. Streamlined compliance processes and clear allocation of responsibilities were recommended in this case study to reduce costs and complexity, though unclear inspection expectations remained a significant challenge.

International examples of off-site construction regulatory schemes, such as New Zealand's BuiltReady, the UK's Robust Detail, and the ICC standards in the US, demonstrated the importance of standardisation, and certification of the manufacturer. The BuiltReady scheme in New Zealand highlighted the value of certifying entire manufacturing processes rather than individual components, while the UK's Robust Detail scheme showed how pre-approved DtS methods can ensure consistent performance, particularly in areas like sound insulation. The ICC standards in the US provided a framework for promoting regulatory consistency across off-site construction processes, though challenges in adoption due to fragmented local codes remain an issue.

Another key lesson is the overlooked potential of image recognition technologies in off-site construction inspection. Technologies such as image capture, machine vision, and X-ray can provide real-time defect detection and dimensional verification, improving the accuracy and reliability of inspections, particularly for hidden or hard-to-inspect components. Integrating these technologies into off-site construction workflows could improve production efficiency, reduce human error, and ensure compliance with regulatory standards, enhancing both the safety and transparency of final projects.

Finally, the case study emphasised the critical importance of a robust traceability system in off-site construction. Establishing a chain of custody for materials and components ensures transparency and accountability, particularly given the complexity of the off-site construction supply chains and the hidden nature of many prefabricated elements. A national traceability system, as proposed by the National Building Products Coalition, could enhance industry confidence in off-site construction by allowing thorough tracking from manufacturing to installation. Such a system, supported by a dedicated national body for monitoring, would help address inconsistencies, mitigate risks from poor-quality products, and support the wider adoption of off-site construction practices across the industry.

CHAPTER 10 - WORKSHOP #1 - IMPROVING NCC COMPLIANCE FOR OFF-SITE CONSTRUCTION

Approach

This chapter presents findings from the first of three workshops conducted in collaboration with the ABCB. It focuses specifically on problematic issues for off-site construction compliance under the NCC, and potential solutions.

In the first part of the workshop, a brief presentation was provided to underpin the validity of the topic and to support directed discussion/debate from the session. In broad terms, this canvassed the way that the NCC focuses on performance criteria for individual elements and individual parts/layers within such elements, as distinct from more complex assemblies. Physical interfaces between elements being joined together into more complex assemblies were identified as a problematic area. Deemed to satisfy solutions did not exist in such areas. The analogy of a 'patchwork quilt' was used to demonstrate how DtSs represented individual patches but at times, the interfacing edges did not join together properly, or worse, missing patches created the need for more expensive and complicated performance solutions to enable approval of overall assemblies. For instance, performance solutions are usually employed on individual projects whereas DtS solutions can be used liberally and regularly across the entire industry - hence making them simpler and more cost-effective to utilise. The above problems with the so-called 'patchwork quilt' approach meant that uncertainty/risk was primarily felt by the project inspectors/certifiers in trying to approve the assembly. This could realistically mean that risk is deferred back to the applicant – via the completion of a performance solution – where gaps occur in the DtS quilt. Hence, off-site assemblies easily require performance solutions that effectively make off-site assemblies more expensive, slower to approve and with greater uncertainty. Increased approval times potentially compromise fast construction later in the project stop.

In addition to the above, a categorisation of assemblies utilised in the United Kingdom (refer to Chapter 2 for details) was posed to the group as an example of something that could be used in Australia to help provide greater specificity and product profiling for off-site assemblies. The intention was that categorisation could result in simplified compliance for such assemblies and enable a large national dataset to assist other areas of related market adoption and confidence e.g. risk management, warranties and insurance. Following the above, the questions were posed for debate/discussion amongst workshop attendees:

- **Q1.** Is a greater focus on assembly compliance a good idea?
- **Q2.** How important is it to hasten/simplify/de-risk compliance?
- **Q3.** Is addressing DtS for interfaces between elements a good start?

Because of the large number of attendees at the workshop, the main group was divided into three roughly equal subgroups, with each one focusing on a nominated question above. Following this, the subgroups were drawn together as a central group to debate overall findings.

Findings

Greater focus on assembly compliance

The first focus group was conducted to answer the following questions:

- **Q1-** Is a greater focus on assembly compliance a good idea?

- **Q1a-** Gapless DtS for assemblies?
- **Q1b-** Is categorisation of assemblies a good idea?

The group discussed the idea of having gapless DtS provisions for assemblies (i.e. a gapless patchwork quilt). The consensus was that while having gapless DtS is a good aspiration, it also can be challenging, and many gaps may become evident. So, a systematic and targeted approach may be needed to address these challenges.

The group spent time discussing whether the categorisation of assemblies would help or hinder the process. The overall view was that categorisation is a positive thing definitionally, as it helps in understanding and managing assemblies better. However, there was no consensus on whether it was the right solution. The group agreed that further clarification is needed to fully understand its impact and reached a consensus that transformative change should occur through gradual steps, rather than all at once.

The other main themes discussed in the focus group were as follows:

1. Liability of licensed professionals to oversee installations
2. Difference between the compliance requirements in different states
3. Challenges of Current Building Codes and regulations for Assembly Compliance and Interface Management in both traditional on-site construction and off-site construction
4. Lack of clarity and consistency in the evidence of suitability and the required information for off-site construction and the need to bring consistency in the required information and using the digital platform
5. Warranties and Legislation
6. Transformative change should occur through gradual steps

- **Liability for licensed professionals to oversee installations**

There were differing opinions regarding off-site assemblies, such as pods, where licensed professionals, like plumbers and electricians, must manage the installations and certify the work. One participant highlighted this concern by stating, 'If you're not ensuring compliance with the pod's installation, it's not safe, and we will not assume liability for plumbing or electrical work done by others'. This statement underscores the challenge faced by on-site plumbers in overseeing these installations and self-certifying the work, as is required for licensed plumbers in Victoria, who assume responsibility and liability rather than the product manufacturer. The boundaries of work and responsibility between the pod manufacturer and the on-site plumber remain unclear, as neither party may assume responsibility for the other's work.

- **Difference between the compliance requirements in different states**

An example was discussed regarding bathroom pods and the varying jurisdictional requirements for their compliance. In this case, compliance differed between states, with bathroom pods built in Queensland needing to be licensed and certified in Victoria. As a result, Queensland builders were required to obtain a Victorian license to ensure their work met that state's regulatory standards. This adds complexity, time, and cost to the project, while also creating administrative and logistical challenges when managing projects across multiple jurisdictions.

- **Challenges of Current Building Codes for Assembly Compliance and Interface Management**

The participant expressed concern about whether current building codes could sufficiently address assembly compliance, particularly the interfaces between different trades and systems, such as cladding and waterproofing. They were worried that compliance and installation issues might already exist with these systems in traditional on-site construction, even before factoring in the added complexity of prefabrication. There was concern that the codes may be inadequate in setting clear requirements for managing these interfaces, suggesting a broader, more systemic issue beyond just off-site construction. The group emphasised the need for a more integrated approach to regulatory compliance, one that specifically addresses these interface challenges to ensure seamless coordination between systems in both traditional onsite construction and off-site construction.

- **Lack of clarity and consistency in the evidence of suitability and the required information for off-site construction**

Current regulations specify the types of product information needed to demonstrate suitability, but there is often a lack of clarity and consistency in these requirements for off-site construction. Digital systems and platforms offer an effective means to collect and share this critical product information. By establishing a clear and accessible baseline of required information, these platforms can significantly enhance the regulatory process. '*As we move forward, it's essential to define this baseline set of information clearly before building on it to ensure consistency and reliability in evidence of suitability*.'

- **Warranties and Legislation**

During the focus group discussion, the topic of regulated warranties highlighted the complexities surrounding product warranties, particularly in relation to building defects and consumer protection in off-site construction. It was noted that different components of a single product may necessitate distinct warranties due to varying legal requirements. Another participant pointed out, that this issue extends beyond warranties alone; it encompasses broader concerns about building defects and safeguarding consumer interests. So, it is crucial to ensure that consumers are adequately covered against potential defects and issues arising from building products.

- **Transformative change should occur through gradual steps**

In the analysis of results, it was noted that while DtS provisions are intended to provide clear compliance guidelines, their rigid structure can limit flexibility and responsiveness to evolving industry needs. Participants expressed that the slow pace of developing new DtS solutions hinders innovation and adaptation. These provisions can create bottlenecks, leading stakeholders to face lengthy approval processes. This situation highlights that although significant change is desired, the current mechanisms in place may not support abrupt shifts, indicating that transformation may need to happen gradually.

Hasten/simplify/de-risk compliance

In parallel to the first focus group, a second focus group was conducted, focusing on the second set of questions and sub-questions as follows:

- **Q2-** How important is it to hasten/simplify/de-risk compliance?
  - **Q2a-** Is equal and objective compliance knowledge a good start (certifiers/designers/clients/contractors/others)?
  - **Q2b-** Is Native DtS in the NCC a good way to hasten/simplify things?

The findings and insights from a different focus group are summarised below.

- **Equal and Objective Compliance Knowledge**

The discussion highlighted the critical need for equal and objective compliance knowledge among all stakeholders, including certifiers, designers, clients, contractors, and others. '*Extending Deemed-to-Satisfy (DtS) solutions and educating industry participants about accepted practices can create a shared understanding of compliance standards*.' Encouraging funding for educational initiatives will help foster a more knowledgeable and competent industry. This shared understanding is crucial for creating a foundation on which simplification and de-risking efforts can be built.

- **Importance of Simplifying, and De-risking Compliance**

In the analysis of the focus group, it was emphasised that simplifying and de-risking compliance are crucial preliminary steps for any effective improvements to the process. Participants agreed that the industry is not yet equipped for accelerated processes without first tackling these foundational challenges. The consensus is that a streamlined and less risky compliance framework will naturally lead to more efficient processes.

During the discussion, one participant proposed a new certification method called 'CodeMark Plus', designed to enhance confidence in Modern Methods of Construction (MMC), including off-site construction, by ensuring quality integration at interfaces. CodeMark Plus would align with ISO quality assurance standards (or similar), establishing a rigorous benchmark for safety, quality, and performance. This certification would allow certifiers to rely on assemblies that already meet high standards, especially at critical junctions like floors, walls, and roofs. Additionally, it would provide both builders and certifiers with a trusted list of pre-approved manufacturers who have the CodeMark Plus certification, ensuring consistent quality and compliance in MMC projects.

The idea also includes creating a system where builders and certifiers can easily access information about pre-approved manufacturers and systems. This system would provide a list of manufacturers that have already been evaluated and approved based on their adherence to high standards e.g. ISO and CodeMark Plus. By having this information readily available, builders and certifiers can save time and cost, knowing that the components they are using meet the necessary quality and compliance requirements.

Addressing DtS for interfaces between elements

In the third focus group, question 3 was discussed to explore the feasibility and implications of addressing DtS provisions for interfaces between elements in off-site construction. The session started with a reference to a useful template found on www.robustdetails.com, which provides standardised solutions for interface issues in the UK. The 'Robust Detail' scheme has been thoroughly explained in the case study chapter in this report.

- **Q3-** Is addressing DtS for Interfaces between elements a good start?
- **Compliance vs. Design Risk**

The discussion was initiated by questioning if the interface between elements, such as a bathroom pod and the rest of the building, is a vulnerability. The participants from a large bathroom pod manufacturing company, mentioned that while interfaces are a design risk, they are not typically a compliance risk for them due to rigorous quality assurance processes. They highlighted a distinction between compliance and design risk. For instance, it was indicated that while design risks exist, their internal processes and licenced tradespeople help mitigate these issues, thereby reducing compliance risks. Contrasting views were also presented during the discussion. Some participants expressed concerns about the broader compliance risks associated with interfaces in modular construction. They argued that without standardised guidelines or Deemed-to-Satisfy (DtS) provisions for these interfaces, there could be inconsistencies in how different manufacturers address these connection points. This lack of standardisation could potentially lead to compliance issues, especially if the interfaces are not designed and executed properly.

Conversely, other participants saw potential benefits in adopting DtS provisions for interfaces, especially for segments where standardisation could streamline integration and enhance overall construction quality. For example, those working with more complex modular assemblies, such as prefabricated wall panels and structural components, highlighted the challenges of ensuring consistent and reliable connections between different elements. They believed that DtS provisions could provide clear guidelines, reducing the need for custom solutions and performance-based designs, which often require additional time and cost.

Some participants noted that certain aspects of off-site construction, such as the integration of waterproof membranes and fire-rated assemblies, could benefit from more explicit DtS guidelines. Ultimately, the group acknowledged that the applicability and usefulness of DtS provisions for interfaces would vary across different industry segments. While some participants preferred the flexibility of performance-based approaches, others saw value in prescriptive standards to ensure consistency and reliability. This diversity of perspectives underscored the need for a balanced regulatory approach that accommodates the unique requirements of various construction methods and products while promoting overall industry improvement.

- **Standardisation and Innovation**

The focus group discussion explored the complexity of establishing new regulations for off-site manufactured components. A key point raised was the challenge of developing new rules that address the unique aspects of these components. The conversation suggested that rather than creating entirely new sets of rules for off-site manufacturing, the focus should be on the actual interface connections between these components.

Participants emphasised the importance of allowing manufacturers the freedom to innovate and develop their own systems. This ability to create unique systems is often a significant competitive advantage for manufacturers, as it enables them to offer bespoke solutions that cater to specific needs and improve efficiency. Imposing rigid, uniform standards could stifle innovation and reduce the diversity of solutions available in the market.

For example, the discussion referenced how different manufacturers might develop proprietary methods for ensuring that their bathroom pods, walls, and roofing systems connect seamlessly and safely. These methods are crucial for maintaining structural integrity and ensuring compliance with safety standards. The participants highlighted that while standardisation is beneficial, it should not come at the expense of flexibility and innovation, which drive the industry's progress and competitiveness.

The consensus was that any new regulatory framework should balance the need for standardised interface connections with the flexibility for manufacturers to innovate.

- **Simplification and Responsibility**

In the focus group discussion, the issue of interfaces in off-site construction was likened to the ‘glue’ that binds DtS solutions together. Participants highlighted that this ‘glue’ represents the crucial connections and interactions between different building components and systems. The complexity of creating multiple solutions for each interface was acknowledged, and it was suggested that this might be better managed by principal contractors or designers who integrate these components.

One participant pointed out that in NSW, the responsibility often falls on an integrator role, while in Queensland, the contract responsibility and risk tend to reside with the principal contractor or designer. This approach was seen as a way to simplify and streamline the process, avoiding the creation of a complex matrix of solutions that could complicate construction projects.

Additionally, it was noted that manufacturers should state their installation and connectivity requirements clearly. This would help ensure that the components are compatible and can be integrated smoothly into the overall construction. By doing so, manufacturers can enhance the usability and acceptance of their products.

The discussion also touched on the potential of standardising these interface solutions to reduce the burden on individual projects. This would involve creating a library of tested and approved details for how different components can be connected, thereby providing a reliable reference for builders and designers. This approach aims to strike a balance between allowing innovation and ensuring consistency and reliability in construction practices.

- **Prototype and test**

In the focus group discussion, the idea of building prototypes to test how different components fit together in practice was raised as a potential solution to address interface issues. This concept involves constructing a scaled-down or partial model of the final building, incorporating various prefabricated components to observe and test how they integrate. Participants believed that this approach could identify potential problems in the interfaces and connections before full-scale implementation, thus avoiding costly mistakes and ensuring smoother construction processes.

One participant highlighted that some off-site manufacturers already use this method by building entire prototypes, not just individual pods or components. For instance, a manufacturer might construct a section of an apartment building, including bathroom pods and kitchen units, to see how these elements fit together and interact with other parts of the structure. By doing so, they can test the waterproofing, fire resistance, and structural integrity of the interfaces in a controlled environment.

The discussion emphasised that while building a full-scale prototype of a large structure like a 20-storey apartment is obviously unfeasible, constructing smaller sections or specific areas could provide valuable insights. For example, testing a single storey or a specific type of connection within a smaller prototype can reveal how well the components work together and highlight any areas that need adjustment.

Another participant mentioned that this approach could help address the compliance challenges associated with prefabricated components. By testing the interfaces in a prototype, manufacturers and builders can ensure that the connections meet all necessary standards and regulations before they are used in actual construction projects. This pre-emptive testing can also aid in securing approvals and certifications from regulatory bodies, making the overall construction process more efficient.

The idea of prototypes was seen as a proactive measure that aligns with the broader goal of improving productivity and reducing risks in off-site construction. It allows for the refinement of designs and methods, ensuring that by the time the components are ready for full-scale use, any significant issues have already been resolved. This step-by-step validation process helps in achieving a higher quality of construction and greater confidence in the final product.

Overall, the focus group concluded that building prototypes could be a practical and effective strategy for addressing interface issues, facilitating smoother integration of prefabricated components, and enhancing the overall quality and reliability of off-site construction projects.

- **Deemed to satisfy vs. Performance Solutions**

During the focus group, participants discussed the potential benefits of standardising interfaces (as DtS solutions) between prefabricated components to streamline the construction process. This approach could help reduce the reliance on complex performance solutions for every project, potentially lowering costs and improving productivity.

One of the primary challenges identified was the difficulty in integrating components from different manufacturers, each with its own compliance and performance requirements. By developing standardised interface solutions, the industry could create a common framework that simplifies these connections, ensuring that components from various manufacturers can be integrated more easily without extensive custom design and testing.

The group suggested that standardised details could be documented and made available in a comprehensive library. Builders and certifiers could reference this library to connect prefabricated elements confidently, knowing that the details have been tested and approved. This would save time and reduce uncertainty and risk associated with custom interface solutions.

It was also noted that standardising interfaces could foster greater collaboration between manufacturers and builders. A shared set of standards would encourage manufacturers to design their products to fit within these predefined guidelines, promoting interoperability and consistency across the industry. This could lead to more predictable project timelines and budgets, as well as improved quality control.

The discussion highlighted that standardisation could support the scalability of modular construction methods. As the industry moves towards more widespread adoption of prefabricated and modular building techniques, standardised interfaces would make it easier to replicate successful projects on a larger scale, enhancing efficiency and potentially driving down costs.

However, participants acknowledged that developing and implementing these standards would require careful consideration and collaboration across the industry. Ensuring that the standards are flexible enough to accommodate innovation and advancements in technology while providing necessary consistency for seamless integration was deemed crucial.

Identified Case study-based problems with off-site construction

Participants were invited to share the regulatory challenges they had encountered with off-site construction at the conclusion of the workshop. One of the major challenges discussed was the inconsistency in performance solutions across different jurisdictions. There was an example from Queensland where a three-storey building solution was approved by local authorities but faced additional scrutiny when presented to fire authorities in New South Wales. The lack of standardisation across states results in repeated assessments and revisions, adding unnecessary complexity, cost and time to projects.

The discussion revealed that performance pathways often vary significantly between projects, even when similar solutions are applied. Different certifiers and authorities may have varying concerns and interpretations, leading to inconsistent approvals. This subjectivity makes it difficult to apply the same solution across multiple projects, as participants expressed uncertainty about whether previously accepted solutions would be approved again.

Several participants raised concerns regarding client expectations, particularly government clients. Clients often prefer DtS solutions over performance-based approaches due to perceived risks. One example cited was the NSW Department of Education, which aimed to introduce all-gender bathrooms but ultimately chose the minimum DtS requirements due to budget constraints. Performance solutions are frequently seen as inferior, even though they may offer similar or better results. This perception creates additional hurdles for adopting innovative construction methods in off-site projects.

A recurring theme throughout the workshop was the knowledge gap between various stakeholders in off-site construction. It was highlighted that there is a need for a better understanding of DtS and performance pathways across the supply chain. Similarly, another participant noted that manufacturers often struggle to get consistent approval for their products, as different certifiers may interpret evidence of suitability differently. This inconsistency creates frustration and delays in project delivery.

There was a consensus that standardised definitions and clear communication between stakeholders are essential for reducing these knowledge gaps. One of the participants called for more education and training for both industry professionals and regulators to ensure a shared understanding of off-site construction processes and standards.

Table 5 Focus area key themes discussed findings/issues identified in workshop #1

Focus area	key themes	Summary of the FG discussion

	Licensed Professionals Overseeing Installations	
	State-to-State Compliance Variability	Varying State Compliance Requirements Drive Up Complexity, Costs, and Project Timelines
	Challenges with Building Codes for Assembly Compliance	Building codes do not sufficiently address assembly compliance or interface management between trades and systems in both traditional and off-site construction
	Gapless Deemed-to-Satisfy (DtS) Provisions	Gapless DtS provisions are desirable but challenging to achieve given current code gaps.
	Categorisation of Assemblies	Categorisation helps manage assemblies but needs further clarification to fully understand its impact.
	Lack of clarity and consistency in the evidence of suitability	Digital systems and platforms offer an effective means to collect
	Warranties and Legislation	Complex warranties and legal requirements and consumer protection.
	Transformative change should occur through gradual steps	New DtS limit flexibility and responsiveness to evolving industry needs. Change should occur incrementally.
	Equal and Objective Compliance Knowledge	Equal and objective compliance knowledge among stakeholders (certifiers, designers, contractors) is critical for simplification.
	Importance of Simplification and De-Risking	Simplifying and de-risking compliance is necessary for speeding up processes.
	"CoreMark Plus" Certification Method	Enhanced confidence in CoreMark Plus-certified manufacturers, particularly for seamless interface integration in MMC.
	Compliance vs. Design Risk	Interfaces (e.g., bathroom pods) present design risks, but not necessarily compliance risks if internal quality control is maintained.
	Standardisation and Innovation	Standardisation is important but should not stifle innovation. Flexibility for manufacturers to innovate while adhering to standards is necessary.
	Simplification and Responsibility	Principal contractors or designers should manage interface responsibilities.

	Prototype and test	Proactive Prototype Testing to address the integration issues
	DtS vs. Performance Solutions	DtS interface solutions reduce reliance on performance solutions, lowering costs and improving productivity.
Issues Raised at the End of the Workshop	Inconsistency in Performance Solutions Across Jurisdictions	Performance solutions are inconsistently approved across jurisdictions, adding complexity (e.g., Queensland vs. NSW fire authorities).
	Perceived Inferiority of Performance Solutions	Clients, especially government, prefer DtS solutions due to the perceived risks of performance solutions, adding hurdles for off-site construction adoption.
	Knowledge Gap Across the Supply Chain	Knowledge gaps across the supply chain in understanding DtS and performance pathways cause approval delays.

Workshop #1 conclusion

Workshop#1 provided valuable insights regarding challenges with DtS solutions, the value of the standardised guidelines, State Variability, prototyping and interface management, the chain of responsibilities especially in interface integration of the wet area pods, and ‘gapless’ DtS solutions.

During this workshop, while some stakeholders suggested the standardised guidelines could help mitigate compliance risks, streamline manufacturing processes and reduce the need for custom solutions, discussions also emphasised that any regulatory changes should not impede a manufacturer’s ability to create proprietary solutions to meet specific client needs, thereby fostering industry competition. In this respect, participants expressed a preference for a regulatory framework that establishes guidelines without imposing rigid solutions that would stifle the development of advanced off-site systems. It was suggested in discussions that assemblies could be categorised in a fashion similar to strategies adopted by the United Kingdom, streamlining compliance by providing clarity and uniformity in regulatory requirements for identifiable and well-known assembly profiles. However, additional work is required to address the challenges associated with practical implementation to ensure alignment with the unique demands of the Australian building industry. This was particularly prevalent when focus groups highlighted the issues related to the variability in compliance requirements across states and interface management within current building codes. This variability adds complexity, time and cost to projects, particularly those involving off-site construction. Workshop participants noted that a more consistent approach, potentially leveraging digital platforms, would facilitate easier access to regulatory and compliance information. This potential shift towards more digitisations would also support the standardisation of quality assurance protocols for off-site components. Prototyping also emerged as a recommended strategy to address interface challenges and ensure compliance before full-scale implementation. Building smaller prototypes could allow manufacturers to test the integrity and performance of connections, thereby reducing project risks, improving construction quality, and easing regulatory approval. This iterative approach could be especially beneficial for complex modular systems that require rigorous testing to meet safety and performance standards.

In terms of liability and responsibility, particularly for licensed professionals responsible for overseeing installations, the consensus indicated a greater need for clarity across jurisdictions in off-site assembly transportation, guidelines for warranties and consumer protection. It was identified that current regulations fall short of defining the responsibilities for who verifies compliance during installation, creating additional potential gaps in accountability. ‘Integrators’ or principal contractors were suggested as being responsible for overseeing interface management in the construction process. Additionally, participants discussed the importance of simplifying and de-risking compliance processes by emphasising a more accessible compliance framework.

Providing a list of pre-approved manufacturers and systems accessible to builders and certifiers could also further reduce costs and streamline project timelines.

Another major discussion area in Workshop 1 was about the complexities in achieving NCC compliance for off-site assemblies. Such assemblies typically include multiple components and elements configured in various ways that may differ in design from one project to the next. An ad hoc ‘patchwork quilt’ analogy serves to explain the way that multiple (traditional) ‘Deemed-to-Satisfy’ solutions are commonly used to demonstrate compliance for the various components/elements involved in an off-site assembly (Figure 21).

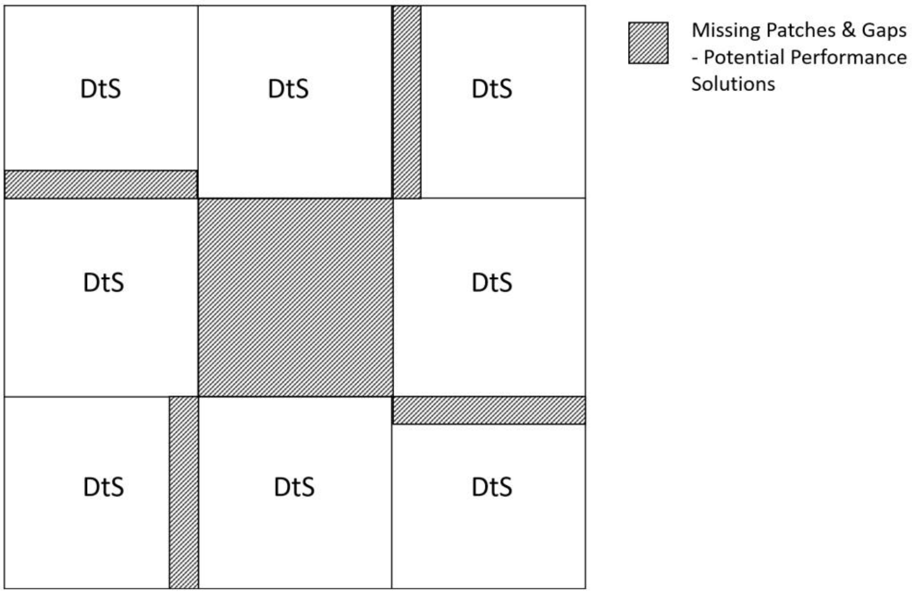

Figure 21 DTS Patchwork Quilt analogy

It is concluded that DtS solutions have the compliance benefit of reflecting standard construction, convenient specification and well-known inspection regimes. They are fast, simple and to implement and integrate readily into existing supply chains.

Despite the above benefits, it is concluded that a significant problem concerns compliance gaps that commonly occur in the patchwork quilt for parts of the assembly not covered by existing DtS solutions. Workshop feedback suggests that such gaps may be under more scrutiny (by approval authorities) for off-site assemblies, than traditional on-site construction. Either way, such gaps create compliance risks for certifiers/surveyors and subsequently, performance solutions are subsequently common in dealing with such gaps. The onus of the solution is placed on the applicant on a project-by-project basis (e.g. owner, builder, designer) in order to meet the certifier/surveyor's requirements. It was found that such performance solutions usually become disproportionately expensive, slow and process intensive in obtaining overall compliance approval for an off-site assembly. This may be the case even if the gaps are relatively small in terms of contributing to the overall compliance solution. A further client risk is that the first attempt at a solution may be unsuccessful and so, unwanted iterations in the process, may follow. An observation is that the above problems with performance solutions burden each individual project whereas the development of DtS Solutions have the significant benefit of being amortised and spread over thousands of projects.

To improve on the above, it is concluded the patchwork quilt must be modified to provide 'gapless DtS' in within the patchwork quilt. By doing so, it should avoid performance solutions completely. Once achieved, this approach essentially offers a modular method of meeting compliance insofar as patches can be joined together to suit the needs of an assembly including a degree of flexibility to suit project specific needs.

Notwithstanding the above, the workshop identified that new DtS solutions take considerable time to develop through the formal technical standards process and then the subsequent process of being formally referenced in periodic updates to the NCC. Subsequently, the 'gapless DtS' patchwork quilt is likely to be a mid-term strategy unless the DtS solutions addressing gaps can be provided at a faster rate. One option pertaining to this is consideration of the 'Robust Details' case study (refer to Chapter 9), which provides an approach where individual complying construction details are added to a web portal without needing to be a published within a much broader and less regularly updated, technical standard. A second option for consideration is for 'native' development of DtS solutions within the NCC. A third option for consideration is for States and Territories to become involved in approving solutions via their ability to use Certificates of Accreditation as *evidence of suitability,* in the NCC. All of these options require considerable developmental work to confirm practical feasibility.

It can be concluded from the workshop that other improvements to compliance pathways appear necessary. Ideally, these would provide shorter-term implementation and suit contexts that fall outside the typical application of the Gapless DtS quilt approach. Two broad concepts are suggested:

1. Reduce the cost/time/effort/process associated with Performance Solutions by reducing the rework required on a project-to-project basis. This could be achieved by harnessing past performance solutions as 'similars'; these would aim to provide supportive data, reusability or a basis for modification on a new project. The aim would be to reduce, rework and to streamline the performance solution process by agreeing on an advanced standing by virtue of the pre-existing data. Such 'similars' could be defined via a database, which could be structured around the issue at hand and in addition, similar: prefabrication classification, class of building, scale of building, type of construction, interfaces involved. A new applicant could also potentially use past consultants and experts with known input into past 'similars'.
2. Provide a more tailored solution for repetitious, innovative and/or fully integrated assemblies. This would approximate a 'pattern' approach to compliance instead of the more ad hoc, patchwork quilt analogy, discussed above. CodeMark Plus was raised as a relatively undefined concept during the workshop but the intent appears to be consistent with modifying the existing CodeMark scheme to meet 'pattern'-oriented prefabrication needs. Desirable features arising from the workshop and to be included in such a scheme include speed, certainty and holistic approval of a given assembly. Quality assurance of production to enable off-site certification should occur over all; in workshop 1, stakeholders highlighted the need for incremental regulatory improvements that focus first on simplifying and standardising compliance processes and leveraging technological advancements in digital information sharing, and prototyping. As such, by addressing regulatory gaps, promoting the sharing of compliance knowledge and establishing clear guidelines for liability, a supported evolution of assembly compliance for off-site construction in Australia can be facilitated.

CHAPTER 11 - WORKSHOP #2 - REGULATORY CHALLENGES AND PROPOSED SOLUTIONS IN WET AREA PODS

This chapter presents findings from the second of three workshops conducted in collaboration with the Victorian Building Authority (VBA). The VBA directed focus, upon allowing professional bodies, associations and conformance assessment boards (from the plumbing supply chain), to voice their concerns and potential remedies concerning the manufacture and installation wet area pods (also known as Prefabricated Plumbing Systems).

Approach

This workshop effectively acted as an extended inquiry to the previously reported Case Study on Wet Area pods (refer Case Study 2). In total, 13 people attended the workshop including research team and VBA representatives who primarily facilitated plumbing industry participation.

The workshop aimed to enable open discussion about such issues and to understand both the context and interplay between NCC compliance and various aspects of Victorian State regulation (inclusive of trade licensing, self-certification and statutory consumer warranties). Ultimately, interactive dialogue among the workshop participants was achieved. Issues canvassed included:

- Robustness and relevance of the WaterMark scheme;
- Certification by licensed plumbers (for regulated plumbing elements and for components manufactured off-site);
- Off-site manufacturing warranty vs plumbing insurance requirements;
- Certification by licensed plumbers involved only in installation on-site;
- Regulatory oversight of off-site manufacturing ;
- Importation quality and reliability issues;
- Variability with conformance assessment;
- Liability/Warranty periods?

Of note, prior to the workshop, preparation was undertaken via a number of detailed meetings with VBA and others; briefing material on regulatory issues was also provided by VBA to the research team. This pre-work enabled a more structured and progressive workshop agenda during the workshop, than would have otherwise been possible.

Execution of the workshop was structured according to a brief introductory presentation by the research team for participants and included issues, observations and findings in the project to date. Data was collected through the recording and transcription of the entire session, followed by analysis of key challenges, and proposed solutions by participants.

Regulatory context for Wet area pods in Victoria

Regulatory context pertaining to the workshop is summarised below and provided in greater detail in the previously mentioned case study.

In general, Victoria has quite a specific licensing and regulatory framework for plumbing installations that places responsibility for the finished plumbing work on the licensee - who conforms to a code of conduct for self-certifying compliance of the finished work. This certification triggers statutory consumer warranties if non-complying work occurs.

Regulatory compliance for the construction of Prefabricated Plumbing System (PPS) in Victoria is accepted through one of two compliance pathways[224]:

1. Construction of a PPS as plumbing work. If the PPS is constructed as plumbing work, the work must be carried out by a registered or licensed plumbing practitioner. All products and materials used in in the work must be fit for purpose. The work must comply with prescribed technical requirements and standards and a compliance certificate must be issued at the completion of the work.
2. Construction of a PPS as a plumbing product. If the PPS is constructed as a plumbing product, then evidence of suitability must be obtained, i.e. WaterMark certification where required under the scheme, or where a product is not WaterMark certified, other forms including a report from a recognised expert or certificate from an engineer.

The application of WaterMark (managed by the ABCB) is also of particular relevance to the Workshop discussion. The ABCB's Notice of Direction 2016/4.0 by the WaterMark Certification Scheme sets guidelines for the acceptance and regulation of prefabricated plumbing modules, such as wet area pods (e.g., bathroom pods and Kitchen modules)[225]. Two categories exist: purpose-built bathroom modules, which are regarded as a product, and prefabricated plumbing installations, which are regarded as regulated work. Purpose-built modules are classified as products under the National Construction Code (NCC) and must be certified through the WaterMark Certification Scheme. On the other hand, regulated work and must comply with jurisdictional plumbing regulations e.g. Victorian State jurisdiction[225].

Findings

Discussed Challenges

In general terms, the key theme of discussion primarily focused on perceived inconsistencies and challenges surrounding the WaterMark certification system, which participants believed had been inappropriately applied to large, complex products such as wet area pods. There is no monitoring of whether or not the pod contains appropriately WaterMarked sub-components (e.g. fittings) and there is no checking mechanism to make sure that the joining of those individual sub-components has been executed correctly as would occur if done by a licensed plumber on-site. Participants thought this led to significant risks in compliance, quality control, and consumer protection.

The participants also identified concerns with the WaterMark certification system, which was originally intended for specific plumbing components (e.g. fixtures and tapware), but had now been misapplied to larger and more complex products, such as pods. Participants stated that while individual components might carry WaterMark certification, the installation and connections between these products as would occur with a pod, do not necessarily meet the required standards. They believe this has caused misuse of WaterMark certification and has allowed non-compliant systems to be installed, often by uninsured tradespeople, effectively bypassing state legislation and the consumer protections provided by licensed tradespeople. Additionally, the shorter warranty period for WaterMark-certified products—typically only six months— does not compare favourably for pods, relative to the six to ten years required for plumbing work completed by licensed plumbers in Victoria. This leaves consumers at risk of facing reduced statutory warranty periods. The issue here is that relatively short warranties were originally set up for components plumbing products but are now by default, being applied to larger and more complex products, such as pods.

One of the main concerns was the perceived inconsistent application of work standards across the industry. While some pod companies employed licensed plumbers, others were perceived as exploiting loopholes by using unskilled labour for plumbing tasks. This resulted in reduced quality

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[224] *Extracted from the Victorian Building Authority's fact sheet: Regulatory requirements for the off-site construction of plumbing systems (accessible at https://www.vba.vic.gov.au/__data/assets/pdf_file/0017/133019/PlumbingFactSheet-Regulatory-requirements-for-the-off-site-construction-of-plumbing-systems.pdf)*

[225] *Australian Building Codes Board. (2016). WaterMark Certification Scheme, Prefabricated plumbing modules.*

and exposure to unenforceable warranties, leaving end users vulnerable to future problems. Participants suggested that semi-skilled workers could perform certain plumbing tasks, but only under the supervision of a licensed plumber who would be responsible for conducting final checks and pressure tests. This would help ensure that the work meets the required standards and maintains the integrity of the plumbing systems. Even so, in Victoria, the regulations clearly state that only qualified/registered tradespeople are permitted to perform plumbing work. However, confusion surrounding the interpretation of these rules, particularly with regard to the WaterMark product certification of pods, has led to the misuse of unlicensed labour. This confusion has created a potential loophole, allowing for inconsistent enforcement and subsequently, the risk of compliance problems.

Another concern raised was the effect of transportation on the durability of off-site pods. Since the pods are constructed off-site and then transported, the standards that apply to static plumbing work, such as AS3500, may not be fully applicable. Participants noted that transport and handling can affect the integrity of the plumbing systems, leading to potential failures. Also, the absence of proper regulation and inspection during the installation of these pods—especially those imported from overseas—raises concerns about the long-term reliability and safety of these systems.

The conversation during the workshop also addressed a fundamental issue regarding the overlap between WaterMark certification and installation standards, where the latter are regulated by the Victorian Building Authority (VBA). Participants expressed concern that the regulatory framework creates gaps in compliance and oversight, particularly where the WaterMark system certifies products, but not the installation process associated with production of it. Pods have allowed for the installation of entire systems without adequate inspection or certification, exacerbating the risk of non-compliant systems.

Participants also felt that accountability for plumbing systems differs between traditional on-site work and off-site construction. When plumbing work is performed on-site by a licensed plumber, every component must be WaterMark-certified, and for instance, a plumber in Victoria must self-certify by issuing a certificate of compliance. However, this process is less clear for pods where off-site production should require a compliance certificate and then this should be clearly delineated from the on-site compliance work i.e. where a separately contracted on-site plumber is essentially only connecting a WaterMark-certified pod as part of their onsite installation work. However, the concern here is that the onsite plumber who connects the pod is potentially held accountable for the entire off-site pod production, despite not having supervised this production process. Their concern is that deferral of responsibility creates significant risks, as the initial construction of the pod may not meet the same stringent standards as the on-site installation. Another major issue discussed was the plumber's responsibility to ensure that only WaterMark-certified products are used in installations. While it is not illegal to purchase non-certified products, the plumber bears full responsibility for selecting compliant components. However, this becomes problematic if entire pods are WaterMarked without sufficient scrutiny of their internal components.

Participants called for legislative changes to address the discrepancies in the current system. They noted that WaterMark testing for products occurs only every five years, which is insufficient for ensuring that systems remain compliant over time. More frequent manual compliance checks and a higher frequency of WaterMark certification renewals were suggested to close the regulatory gaps.

Lastly, the workshop addressed the challenges associated with redesigning pods with new materials, which would require new WaterMark certifications. Participants made the point that the infrequency of WaterMark testing leaves gaps in quality control, as pods (and seemingly traditional onsite plumbing as well) can be modified during this period without adequate oversight. This mainly highlights the need for regularly updated standards for WaterMark-certified plumbing products inclusive of pods.

Proposed Solutions

To improve the quality assurance of wet area pod installation, workshop participants advocated for legislative changes across all States and Territories for both WaterMarked components and holistic pod installations. Currently, WaterMark testing is only completed every five years and should therefore require a higher frequency of compliance approval. Additionally, any design changes to a pod, such as those needed to fit different building configurations, should require a new WaterMark license under current regulations. Regular testing and quality checks at the off-site factory should be included in this regime.

There was also a call for greater attention to prototyping, design, and thorough documentation to ensure that all components and connections meet regulatory requirements and integrate seamlessly with site-based work. The key point is ensuring that the pods connect properly with existing infrastructure and services on-site. The process should involve QC to ensure the design meets its intended specifications.

It was suggested that a registered tradesperson is required at each stage of the off-site plumbing production process to perform quality assurance and assume that responsibility. Regardless, all plumbing work should be signed off by a licensed plumber. It was also proposed that a compliance certificate be generated at each stage of the construction process - from the design stage, to the off-site production stage, and then on-site installation stage. Such an approach approximates a chain of custody approach. This was proposed as being enacted by licensed plumbers, which means WaterMarked components/pods are checked for authenticity along the chain and fall under a plumber's self-certification of compliance, as covered under state statutory plumbing requirements (albeit that this would likely impede national consistency).

The discussion concluded with a call for stronger consumer protection measures and a more robust regulatory framework pertaining to the safety and reliability of plumbing systems in off-site construction.

Workshop #2 Conclusion

Workshop 2 provided insights on regulatory challenges and quality control issues concerning plumbing systems, in the context of wet area pods.

A key conclusion from Workshop 2 is that there is a division within intersecting compliance requirements that occur between Commonwealth and State-based regulatory approaches. For instance, NCC compliance conceives the pod as a technical specification that arrives on-site as a finished product; State regulation conceives compliance as (more) involving correct installation of the subparts in producing the same finished product albeit that this production takes place off-site as an off-site assembly. In simple terms, the difference in emphasis is between a product versus process perspective where lack of continuity between the two causes clashes and causes confusion in interpretation. It is therefore concluded that greater attention to harmonising the two is important and in doing so, due attention should be given to the prospect of inter-state applicability to allow lower costs via economies of scale.

Further to the above, in the State-based context, trade licensing and self-certification appear to be the main basis for QA/QC systems (inclusive of professional insurances, design responsibility and long-term consumer statutory warranties). Whilst these mechanisms may serve well for traditional on-site construction, it is considered that they should be reviewed to better suit QA/QC systems, based around manufacturing principles. Here, responsibility for the product (pod) typically lies with the finished product's producer more so than one of its subcontractors. Consequently, licensed tradespeople should be part of the overall QA/QC system but should not take a high-level role in leading it. Instead, QA/QC should place greater emphasis on the likes of third-party process certification; a topic dealt with later in Workshop 3. Under such QA/QC systems, trade involvement could primarily be in terms of technical checking, design expertise and systems development, more so than being a separate entity taking responsibility for compliance and its certification. It would also seem logical that licensed tradespeople would not necessarily want to undertake low skilled and basic repetitious plumbing tasks on a production line; rather, they have capacity to be supervising or managing semi-skilled workers that are trained and certified for designated production tasks.

Notwithstanding the above, the workshop discussions still underscore the potential limitations of the current WaterMark certification system regarding wet area pods. To some extent issues raised during the workshop resulted via the perceived misalignment between Victorian regulations and Watermarked certified pods where the latter was seen as allowing lower quality output to pass through the system unchecked and making use of loopholes that were not allowable under traditional State-based plumbing regulation. The abovementioned QA/QC systems emphasis could ideally be reviewed in a way that is inclusive of WaterMark certification and State-based requirements.

The workshop concluded with several proposed solutions aimed at enhancing regulatory oversight and consumer protection. Suggestions included legislative reforms to the WaterMark certification system, with more frequent testing and renewal intervals to ensure compliance, as well as the introduction of multi-stage certification processes involving compliance certification at design, off-site production and site installation stages. These suggestions are useful and can potentially be merged congruently with the above conclusions. Of note, the emphasis on detailed design compliance (including prototyping, detailed documentation, and improved design controls) tends to provide a QA-based alternative that is needed because design under traditional onsite work tends to be executed in an integrated way with the onsite work. The summary of the challenges and proposed solutions is outlined in Table 6.

Table 6 Summary of the key challenges, and solutions provided by participants

Challenges	Inconsistent application of Watermark certification for complex products like wet area pods.
	Lack of monitoring to ensure pods contain Watermark-certified sub-components and correct installation of these components
	Use of unskilled labour for plumbing tasks, leading to reduced quality and unenforceable warranties.
	Ambiguity in the interpretation of regulations regarding Watermark certification and labour qualifications.
	Inadequate six-month warranty periods for Watermark-certified products compared to longer statutory warranties for on-site plumbing.
	Concerns over the impact of transportation on the durability and integrity of pods, with existing standards not fully applicable.
	Onsite plumbers are being held accountable for off-site-produced pods, which they did not supervise, posing compliance risks.
	Infrequent Watermark testing, which is conducted only every five years, leads to quality control gaps.
	Challenges in certifying new materials used in pods due to infrequent testing, allowing potential modifications without oversight.
Solutions	Establishment of consistent Watermark certification of components and entire pod installations across all States and Territories.
	Increase the frequency of Watermark certification renewals and conduct regular manual compliance checks.
	Require registered tradespeople to oversee each stage of off-site plumbing production for quality assurance.

[redacted]	Ensure comprehensive design documentation and prototyping to confirm pod designs integrate seamlessly with on-site systems.
	Implement compliance certificates for each stage of the pod construction process, from design to production and installation.
	Apply a chain of custody approach where licensed plumbers verify Watermark certification and self-certify compliance throughout the production and installation process.
	Develop stronger consumer protection measures and a robust regulatory framework to ensure the long-term safety and reliability of off-site plumbing systems.

CHAPTER 12 - WORKSHOP #3 - WHAT HAPPENS WHEN OFF-SITE CONSTRUCTION MAKES ON-SITE INSPECTION REDUNDANT

This workshop was the last in a series of three workshops. It focused on how best to check that compliance had been reliably achieved during off-site production and how this contextually fitted in with traditional on-site inspection regimes. For instance, in principle, the more that construction takes place off-site, the less need there is for traditional on-site inspection. A key question is, therefore, what is the latter replaced with?

Approach

Given the above purpose, the workshop specifically explored the status and development of various models of certification for off-site production. Local options included developments at Standards Australia and practical implementation used by a large pod manufacturer (as reported in a previous Case study). International options included developments at the International Codes Committee and progressive implementation of the Built Ready Scheme in New Zealand.

During the first part of the workshop, the project context and related issues were presented to the participants by the research team. To gain a deeper understanding of the current landscape and regulatory challenges in off-site construction, a survey was conducted via a QR code embedded in the presentation slides. This was followed by presentations from speakers representing the above organisations. Participants then engaged in a debate and discussion around these schemes and practices. QA/QC schemes formed an integral part of this debate as well as the notional comparison between off-site and on-site inspection. Issues such as dealing with hidden/sealed construction during off-site production, were canvassed as were potential improvements to the ABCB's WaterMark/CodeMark schemes to better accommodate off-site construction.

Findings

The survey aimed to capture the perspectives of industry professionals, academics, and policymakers on the critical issues impacting the implementation of off-site construction. The survey questions were formulated based on findings and knowledge gained from previous stages of the project. Participants were asked to share their opinions using a 5-point Likert scale, ranging from 'strongly agree' to 'strongly disagree', on the factors listed in Table 7.

Table 7 Survey Responses on Key Issues and Perspectives in Off-site Construction

Key Issues and Perspectives in Off-site Construction	Sample Size (out of 51 participants)	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Absence of specific inspection protocols for off-site construction.	35	40%	49%	9%	0	3%
Adaptation of Certification Schemes CodeMark/WaterMark.	31	23%	55%	23%	0%	0%
Better defining categories for off-site assemblies to avoid forced definitions	33	41%	41%	19%	0%	0%

such as ‘Products’ or on-site ‘Installation’.						
Concern about on-site inspection regimes being inefficiently applied to off-site construction.	30	33%	53%	7%	7%	0%
Confusion between product warranties and building work warranties in off-site construction.	29	29%	43%	25%	4%	0%
Shift from reactive quality control (on-site) to more proactive quality assurance off-site.	31	43%	43%	13%	0%	0%
The importance of choosing between alternative approaches to certification.	31	16%	45%	39%	0%	0%
Using technology (smart photography, digital traceability) to increase confidence in off-site compliance.	31	33%	53%	10%	3%	0%
Utilisation of existing trade licences/endorsed licenses for off-site production.	32	17%	53%	20%	10%	0%

The survey results provide a comprehensive overview of the key concerns and challenges in off-site construction. It is important to note that response rates varied (sample size of 53) for each question, suggesting that some respondents may have lacked sufficient knowledge on certain topics. This variation should be taken into account when interpreting the results, as lower response rates might indicate more specialised concerns or areas where respondents have limited experience or understanding. Despite this, the overall response rate ranged between 57% and 69%, demonstrating strong engagement with the survey.

The highest response rate (69%) was recorded for the issue regarding the absence of specific inspection protocols for off-site construction. Notably, within this group, 89% of respondents agreed or strongly agreed that this was a significant issue. This highlights widespread recognition of the problem and underscores the relevance of inspection protocols as a key concern in off-site construction.

The question addressing the confusion between product warranties and building work warranties had a smaller response rate of 57%. However, 72% of these respondents agreed or strongly agreed that this was a concern. For the adaptation of certification schemes (CodeMark/WaterMark), the response rate was 60%. With 78% of respondents in agreement, this reflects strong support for modifying current certification schemes to better fit the off-site construction environment.

The issue of better defining categories for off-site assemblies had a response rate of 65%, with 82% of respondents agreeing or strongly agreeing. This indicates a clear need for more precise language and categorisation to improve compliance and reduce ambiguity. Notably, no respondents disagreed, underscoring the importance of moving away from unclear classifications in off-site construction.

When analysing concerns regarding the application of inefficient on-site inspection regimes to off-site construction, 59% of respondents participated, with a significant 86% agreeing or strongly agreeing. This finding underscores an industry-wide recognition that traditional inspection practices are inadequate for off-site construction. The strong support for a different approach highlights the need to evolve regulatory frameworks to address the unique challenges of inspecting prefabricated or modular structures.

The question regarding the shift from reactive quality control on-site to proactive quality assurance off-site had a response rate of 60%, with another substantial 86% agreeing that this is an important transition. This level of agreement reflects a clear preference for integrating proactive quality assurance practices early in the off-site construction process.

Interestingly, the question on the importance of choosing between alternative approaches to certification received mixed responses. Of the 60% of participants who responded, 39% were neutral, while 61% expressed positive views on the significance of selecting alternative certification methods. This suggests a lack of consensus on the best approach to certification within the industry.

The use of technology, such as smart photography and digital traceability, to improve off-site compliance had a response rate of 60%, with a strong 86% of respondents expressing agreement. Despite the moderate sample size, this high level of support indicates that technology is widely viewed as a valuable tool for enhancing compliance and building confidence in off=site construction.

Lastly, for the utilisation of existing trade licences for off-site production, the response rate was 62%, with a mixed response of 17% strongly agreeing, 53% agreeing, 20% neutral, and a notably higher disagreement (10%) compared to other questions. This variance indicates that there are differing views on the applicability of existing trade licences to off-site production.

The participants were invited to suggest additional factors to complement the solutions and challenges identified by the research team. The following areas were highlighted:

- Skills required for on-site certification
- Design a system that starts with consumer protection and clarifies the accountability of various involved parties.
- Ensure that new definitions for the categories and terms do not restrict future developments in the sector.
- Regulations must be forward-looking to incorporate this evolving perspective.
- Problem with trade licenses, which are not harmonised or not required in some states.
- Issues with confidence in CodeMark certification following problems with flammable cladding.
- Ensuring that future certification supports existing manufacturing compliance schemes and frameworks.

QA, QC and Compliance Practices - Insights from a Leading Pod Manufacturer in Australia

The analysis in this section is based on observations made by the research team during the workshop and tour of the host manufacturer. It is important to note that no formal feedback, such as surveys or polls, was collected at this stage. The manufacturer’s presentation, along with the subsequent discussion between the audience and manufacturer’s representatives, reinforced the compliance pathway analysis outlined in Case Study 2. These complementary findings on various aspects of the manufacturer’s compliance, QA, and certification processes are elaborated below. Since 2013, the workshop host manufacturer has embarked on a transformative journey in the construction industry, focusing on off-site manufacturing to change traditional construction practices. Over the past 11 years, this facility has built 29,000 pods and has expanded its operations across Australia and New Zealand, catering to various sectors. The company’s mission is to enhance efficiency, quality, and scalability in construction projects.

The company placed a strong emphasis on upfront design work to anticipate and address potential challenges in construction before they arise. This proactive approach is fundamental to QA where non-compliances and defects are avoided by designing out problems. It contrasts with traditional construction inspection which focuses on retrospective inspection to identify problems once they have occurred, being a form of QC. The company's strategy involves thorough planning and design to prevent problems, thereby streamlining the construction process and ensuring compliance with construction regulations.

- **Upfront Design and Technological Integration**

The pod manufacturer places significant emphasis on upfront design to find potential challenges before they arise during the construction process. This contrasts with traditional construction practices, where problems are often addressed reactively, after a defect is found. The manufacturer uses advanced tools such as Autodesk Inventor to create detailed 3D CAD models, representing every element of the pods, including tiling, plumbing, and structural services. These models enable precise planning, ensuring all components fit seamlessly during construction.

The integration of additional software tools, such as B Solid for joinery and woodwork, further enhances the manufacturer's ability to maintain consistency and quality across the manufacturing process. This end-to-end integration allows for efficient management of various materials, from steel frameworks to tiles, ensuring alignment with design specifications.

- **Quality Assurance and Compliance**

Quality Assurance (QA) processes present a key aspect of their manufacturing approach. For large multi-storey residential projects, the company typically produces one to three prototypes, depending on complexity, to identify and rectify any potential issues before mass production begins. This proactive approach, coupled with compliance with Australian standards, ensures that it maintains high levels of quality and regulatory adherence across all projects.

The manufacturer’s reliance on Standard Operating Procedures (SOPs) to standardise production processes was pointed out during the workshop. These SOPs govern all aspects of production, from framing to tiling and plumbing, ensuring consistency and quality control throughout the process. Any project-specific details not covered by the standard SOPs are incorporated as ‘builder words’ specific to each project, allowing for flexibility while maintaining high standards.

In response to the question, ‘How does the manufacturer handle inspections and certifications with different consultants and Principal Certifying Authorities (PCAs)?’, the company’s representative explained that they maintain standard sets of procedures but are adaptable to the specific requirements of different PCAs. They welcome on-site inspections and collaborate with consultants to ensure compliance with local regulatory frameworks.

- **Off-site Manufacturing and On-site Integration**

The manufacturer's off-site model centres on leveraging controlled factory environments to mitigate the risks associated with on-site construction variability. This method enhances both the quality, consistency and reliability of the final product. They also use Computer Numerical Control (CNC) technology, ensuring that even unskilled workers can perform tasks with minimal error, further streamlining the manufacturing process.

The manufacturer has developed robust transport protocols to protect the pods during delivery. Pods are carefully wrapped and secured to prevent damage during transportation, addressing concerns raised during the workshop about how they ensure the protection of components during transit. Upon delivery, the manufacturer conducts inspections to identify any potential damage, before the pods are installed on-site.

The manufacturer's upfront design process also helps ensure a smoother installation process on-site. By addressing potential challenges during the design phase, the manufacturer minimises disruptions and delays once the pods reach the site. In response to the question, ‘How does the manufacturer ensure collaboration with other trades to prevent integration issues?’, the manufacturer emphasised the importance of early engagement with the project’s plumbing and hydraulic consultants to align the pods' design with the broader building system.

- **Feedback Mechanism and Continuous Improvement**

The manufacturer actively incorporates client feedback into their quality assurance processes. Following delivery and installation, the company conducts thorough audits/inspections to ensure the pods meet all in-situ quality standards. Defects identified during these inspections are promptly rectified under the manufacturer's warranty system. Of note, such warranties by the manufacturer are significant including 20 years cover for the prefabricated glass reinforced concrete floor structure and 15-20 years for the waterproofing systems.

It was noted that the manufacturer's feedback mechanism is designed to ensure continuous improvement. If a defect is identified, the manufacturer investigates the root cause and implements changes in future projects to prevent similar issues from recurring. This commitment to learning from past projects helps the manufacturer maintain high standards and enhances its overall operational efficiency.

- **Resistance from Certifiers and Consultants**

The wet area pod manufacturer has encountered resistance from Principal Certifiers (PCs) and consultants who are skeptical of non-traditional construction methods, such as the manufacturer's unique waterproofing systems. During the workshop, they explained that they frequently engage in detailed discussions with project stakeholders to demonstrate the compliance of their methods with local standards.

In response to the question, '*How do you handle resistance from certifiers and consultants who are reluctant to accept your methods?*', the representative highlighted their collaborative approach. By bringing in third-party verifiers and working closely with consultants, their methods meet performance requirements and gain the necessary approvals.

- **Use of Licensed Trades and Apprentices**

The manufacturer strictly adheres to state regulations requiring the use of licensed tradespeople for plumbing and electrical work, which enables self-certification of compliance by these people, for respective parts of their work. They employ licensed professionals for all critical tasks, ensuring compliance with legal and regulatory standards. Apprentices are allowed to assist under the direct supervision of experienced tradespeople, which helps develop future workforce capacity while maintaining high standards of workmanship.

Their commitment to using certified professionals was observed to be a key factor in ensuring the compliance of their installations.

Insight into the BuiltReady scheme

The BuiltReady Scheme has been thoroughly detailed in earlier sections. During the workshop, a scheme representative provided further insights and engaged in discussions with the audience. It highlighted how BuiltReady addresses challenges related to non-traditional construction methods, particularly off-site construction. By certifying manufacturers instead of individual products, the scheme ensures compliance with New Zealand's Building Code. BuiltReady is part of legislative reforms designed to streamline the building consent process, aiming to reduce costs and processing times—key benefits for manufacturers looking to scale operations efficiently

- **Supply Chain and Overseas Products**

A significant point of discussion during the workshop revolved around how the BuiltReady scheme regulates supply chain integrity, particularly when dealing with overseas suppliers. While BuiltReady does not directly regulate these suppliers, it was noted that manufacturers under the scheme are required to implement robust policies and procedures to prevent the introduction of inferior products into the supply chain. These policies, according to the workshop presentation, are critical in ensuring that any substitution or imported components do not compromise the overall quality of the construction project. The ongoing surveillance mechanisms employed by certification bodies under the scheme were also observed to be an effective means of maintaining compliance throughout the production process.

- **Consumer Protection and Accountability**

The research team discussed how the scheme embeds consumer protection and accountability into the process, particularly when dealing with international suppliers. Manufacturers are required to demonstrate that they have the capacity to cover civil liabilities, offering a sense of security to end consumers. This requirement ensures transparency in the supply chain and provides a clear path for consumers to claim warranties. This traceability of components, from production to installation, was highlighted as an essential aspect of consumer protection within the BuiltReady framework.

- **Compliance and Quality in a Voluntary Scheme**

Another area of observation focused on the voluntary nature of BuiltReady. While the scheme is not mandatory, once a manufacturer opts in, compliance is strictly enforced through audits and monitoring by regulatory bodies. This ensures that manufacturers who voluntarily join the scheme adhere to high standards. It was recognised that traditional building consent pathways remain available, but these may involve more scrutiny and longer processing times, which could serve as an incentive for manufacturers to opt into BuiltReady for a smoother process.

- **Hybrid Construction and Regulatory Integration**

The challenges that hybrid construction models encounter when they combine off-site manufacturing with traditional on-site construction presents under the BuiltReady scheme. The scheme provides detailed documentation and installation instructions to ensure that all parties involved, from manufacturers to on-site teams, understand their roles and responsibilities. This was seen as crucial for maintaining compliance with the building code, particularly when multiple stakeholders were involved. Clear communication between off-site and on-site teams is essential for successful integration under the scheme.

- **Economic Feasibility of the BuiltReady Scheme**

The economic implications of the BuiltReady scheme were also discussed during the workshop. Although a cost-benefit analysis was included in the initial policy development, recent changes in the economic landscape, particularly following the impacts of COVID-19, may necessitate a reassessment of these models. Balancing regulatory rigour with commercial viability remains a challenge, and ensuring the scheme’s long-term feasibility will be essential for its adoption by manufacturers of all sizes.

Insights into the ICC scheme

The background section of this report includes information about the International Code Council (ICC). In addition, the Managing Director of ICC Oceania represented the ICC as a speaker at Workshop #3 in Melbourne. This section summarises the key topics covered by the ICC representative. The presentation emphasised the regulatory framework, the process-oriented nature of off-site construction, and the challenges and opportunities of standardising approaches to off-site construction practices. The lessons drawn from the US experience provide guidance for how Australia might develop its own regulatory frameworks for off-site construction.

First, the fragmented nature of the off-site construction industry in the United States was highlighted. In the US, individual states and even individual local government jurisdictions have developed different processes and requirements for regulating off-site construction. Despite the common perception that Australia’s states and territories have varied approaches to construction regulation, it was noted that the fragmentation in the US is significantly more pronounced.

It was discussed that a paradigm shift is required in understanding off-site construction, with a focus on the process rather than the final product. The ICC's process-oriented approach was described, with the emphasis placed on accrediting systems in the design, fabrication, and assembly stages instead of solely certifying the final product.

The ICC's work with the Modular Building Institute was referenced to highlight how advocacy efforts in the US focus on promoting this process-oriented model to governments. It was stated that, in many cases, the technical standards used in on-site construction are adequate for off-site construction as well. Thus, it was suggested that the Australian regulatory approach could similarly focus on accrediting administrative processes rather than duplicating technical requirements.

It was further noted that the ICC has developed standards for off-site construction, particularly through the 1200 series of standards. As detailed in an earlier case study (refer Chapter 9) these standards were introduced to provide a framework for planning, design, fabrication, and assembly, ensuring compliance and consistency across jurisdictions. The importance of standardisation was stressed to foster a uniform understanding of off-site construction practices. It was suggested that Australia could adopt similar standards within the NCC to achieve consistent administrative arrangements across states and territories.

Improper inspection regimes were mentioned as a potential risk that could undermine the productivity benefits of off-site construction, and it was suggested that inspection frameworks in Australia be aligned with the unique requirements of off-site practices.

It was emphasised that off-site construction offers significant economic and time-saving advantages when regulated efficiently. The potential benefits of addressing housing affordability and faster project delivery were noted. However, it was cautioned that these benefits could be negated if regulatory frameworks are poorly designed.

Third-party Conformity Assessment Bodies (CABs) were highlighted as playing a key role in providing independent oversight of off-site construction processes. The economic benefits of faster market access, facilitated by these bodies, were discussed. The adoption of a similar approach in Australia was recommended to streamline certification and compliance processes, ensuring that the economic benefits of off-site construction are maximised.

The importance of ongoing education and training for professionals involved in off-site construction was highlighted. In the US, credentialing programs have been implemented by the ICC to ensure continuous training for those responsible for administering and enforcing off-site standards. The role of education was stressed as critical for both construction professionals and regulators, ensuring a high standard of practice and compliance across the industry. The implementation of educational initiatives in Australia was recommended to support the growth and regulation of the off-site construction sector.

Final discussion

In the final part of the workshop, a concluding discussion took place between the participants and speakers to gather their insights on potential challenges, solutions, and future directions that had not been covered in the earlier sessions.

- **Licensing Challenges Across States and Territories**

The conversation highlighted significant challenges posed by varying state and territorial licensing requirements within Australia. Again, a process-related issue insofar as licensees variously take responsibility for the products they use and how they are installed. Participants discussed the difficulty of aligning off-site construction practices with the differing regulatory frameworks across regions. One speaker pointed out the 'crazy' state of licensing, emphasising the need for a more unified approach that recognises limited scopes of work for off-site manufacturing. The suggestion of a mutual recognition system that could operate across different jurisdictions was seen as a potential solution. This would allow off-site manufacturers to operate under a limited license while maintaining consumer protection through regional oversight.

This issue of disparate licensing frameworks presents a significant barrier to scaling off-site construction practices. The participants recognised that achieving greater efficiency in construction will require not just technical innovation but regulatory reforms to ensure consistent oversight and compliance across the country.

- **The Role of Licensed Trades in Off-site Manufacturing**

The group debated the role of licensed trades in off-site manufacturing processes. Whilst only one participant expressed concern that off-site construction might reduce the involvement of licensed trades, others suggested that the supervision of licensed trades could be minimised for certain repetitive tasks. The idea of employing licensed trades more strategically, particularly for quality assurance (QA) and quality control (QC), rather than for every step of the production process, was proposed.

The consensus seemed to support a hybrid model in which licensed trades are involved where necessary, but less qualified workers, under supervision, can handle routine tasks. This approach would address the looming skills shortage in the construction industry while ensuring that critical aspects of production are overseen by qualified professionals. The discussion also touched on the use of technology, such as robots, in production lines and whether these systems could replace some of the roles traditionally filled by licensed trades.

- **The Role of Automation in Off-site Construction**

Automation emerged as a key solution to the challenges faced by the industry. It was discussed that how automation could be leveraged to address the skills shortage and improve efficiency in off-site construction. The concept of using robots for repetitive tasks in manufacturing processes, much like in the automotive industry, was presented as a potential game-changer for the construction sector. The discussion, however, acknowledged that while automation could reduce the need for highly skilled tradespeople, there would still be a need for oversight by licensed professionals to ensure compliance with regulatory standards. For example, in tasks like plumbing or electrical work, automated systems could be used for simpler operations, but a qualified supervisor would need to sign off on the work to ensure it meets conformance assessment standards.

This led to further discussion on how automation could be applied in modular construction systems, with a particular emphasis on ensuring that regulatory bodies and conformity assessment bodies are involved throughout the production process. It was observed that participants were concerned about the potential for errors in automated systems, emphasising the importance of quality management systems that can catch issues before the product leaves the factory.

- **Consumer Protection and Accountability**

Another key topic addressed was the issue of consumer protection in off-site construction, particularly in cases where products fail after installation. It highlighted the legal and financial difficulties faced by consumers when trying to hold manufacturers accountable for defective products, especially when manufacturers go out of business, or the costs of legal action are prohibitive.

A proposed solution was the introduction of run-off insurance, which would ensure that consumers are protected even if the manufacturer is no longer operational.

One speaker expressed concern about the difficulties consumers face when pursuing claims, especially when dealing with issues like waterproofing failures or plumbing defects in high-rise apartments. The lengthy legal processes and high costs associated with litigation were highlighted as significant barriers to consumer protection. The discussion pointed out that the current reliance on product warranties might not be sufficient to safeguard consumers, particularly in cases where the defects are not immediately apparent or occur years after installation. The group discussed potential ways to address these concerns, including enhancing the certification process to cover not only the product but also its long-term performance. This would involve holding manufacturers more accountable for the durability of their products, especially when used in complex assemblies like prefabricated bathroom pods. However, it is worth noting that this issue is not limited to off-site construction; it also remains a concern in on-site construction.

The participants also discussed the potential for standardised warranties and better integration of consumer protection measures in the design and manufacturing process. This would ensure that any defects identified post-installation are addressed promptly, reducing the financial and emotional burden on consumers. Participants stressed that the construction industry needs to take greater responsibility for ensuring the quality and safety of their products, rather than leaving consumers to bear the cost of defective work.

- **Design and Planning in Off-site Construction**

A recurring theme in the discussion was how to integrate off-site construction with traditional on-site methods. One participant highlighted the challenges posed by the shift from on-site to off-site work, particularly the loss of real-time design adjustments that tradespeople make during traditional construction. The need for more upfront planning and design in off-site construction was recognised as both a challenge and an opportunity.

There was agreement that off-site construction requires more rigorous design and certification processes to ensure that everything is done correctly before installation. The conversation emphasised that while off-site methods can streamline construction, they also demand a higher degree of oversight and planning to ensure quality and compliance with regulatory standards.

- **Reform in WaterMark and CodeMark Certification Schemes**

Certification schemes such as WaterMark and CodeMark were central to the discussion. Participants raised concerns about the current performance of these schemes, particularly CodeMark, which was described as; underperforming' due to issues with acceptance and reputational challenges. The group debated how these schemes could be improved to support off-site construction, especially for complex modular assemblies.

An important point raised was that construction risk is not solely associated with the product in off-site construction but also with its installation. A modular or prefabricated product with multiple points of installation may pose greater risks, necessitating enhanced certification processes. The idea of strengthening these schemes to ensure mandatory inclusion of high-risk products in the national register was discussed, with a focus on improving the transparency and traceability of certified products.

- **Complexity and Risk in Prefabrication**

The complexity of off-site assemblies was acknowledged as a significant factor in the discussion. Participants noted that prefabrication, especially for large-scale components like bathroom pods, introduces multiple points of interaction that can become points of failure. As the conversation moved toward risk management, the idea of enhancing the certification schemes to account for this complexity was discussed.

The conversation touched on how modular components, once installed, are difficult to access for repairs or replacements. This led to discussions about improving the reliability and durability of these components, as well as reconsidering the timeframes for which products should be certified.

Workshop #3 Conclusion

The central purpose of the workshop concerned the arising issue of what to do instead of an on-site compliance inspection, where it becomes redundant because of the construction alternatively taking place off-site.

It is concluded that compliance for off-site production would be best dealt with via neutral third-party certification of production processes. Possible approaches were demonstrated in the workshop via New Zealand's BuiltReady scheme and the International Codes Council's series of 1200 Standards. Both take administrative approaches to managing technical processes; certain features of each scheme are desirable, but larger scale uptake would require considerable adaptation to suit Australian conditions. Of note, a voluntary scheme like BuiltReady, with mandatory acceptance and a nationally unified approach, is consistent with streamlining and de-risking compliance for off-site construction. Such features would help support industry's transition and could establish a clear chain of responsibility and accountability that spans the entire construction project; this could also strengthen consumer protection in off-site construction.

Separately, the real-time factory tour of pod production conducted during the workshop, demonstrated tangible application of manufacturing-like production techniques and how such systems aim for repeatability and reliability in achieving confidence in compliance. Digital and physical prototyping along with CAD/CAM production are concluded to be useful in proactively designing out problems and demonstrating in detail how compliance will be achieved in practice.

Unsurprisingly, the above approaches revolve around the principles of QA/QC systems, common in manufacturing. It is concluded that such systems are the best approach for underpinning compliance certification for off-site production processes. Even so, this needs to be supported by neutral third-party assessment for specific production settings - as typically undertaken by Conformance Assessment Bodies (CAB). It would seem that for external validity, such a certification framework would need to be developed, overseen and administered at a regulatory level by government. It can be concluded that this would be most effective if achieving consistent uptake across all States and Territories.

On a related issue, CodeMark (in Australia) was identified during the workshop as currently underperforming and lacking acceptance as a certification scheme. Even so, its potential for adaptation to suit off-site construction was identified as a potential future compliance option. This was coined under the loosely defined name of 'CodeMark Plus'. It is concluded that such a manifestation of CodeMark could be explored further with a view to streamlining compliance pathways for off-site construction, including third-party certification of compliant production processes.

Caveats relating to the above include:

- There is a need for certification to contend with a degree of flexibility in production to suit containable project-to-project variations in production processes. Modularisation in the form of add-on processes could potentially serve to assist this end.
- Identification of off-site handover boundaries and/or 'batten change' responsibilities in the compliance chain, would be useful. This would aim to help delineate on-site installation responsibilities as distinct responsibility of the off-site product supplied to site. This may still include definition of overlapping responsibilities and quality checks i.e. where one link in the compliance chain checks the quality of another to help ensure their own compliance risks and that of the overall chain stays intact.
- Potential implementation of proportionate statutory warranties based on the scale of off-site value adding. For instance, the producer of a wet area pod should take greater warranty responsibility than its on-site installer.
- The involvement of all stakeholders, particularly building surveyors, is essential for ensuring that accountability is maintained throughout the construction process, from fabrication to on-site assembly.

- Strengthening certification processes to include the transparency and traceability of certified sub-products, where used in more complex assemblies.

It is concluded from the workshop that certain issues and complexities impact the abovementioned ideas and stated directions for certification. The debate mainly clustered around trade licensing and consumer protection, including crossover areas such as the confidence, length and implement ability of statutory warranties.

- Regarding trade licensing, it is concluded that there is a significant variance from one State or territory to the next. In certain ways, this inconsistency is unhelpful for off-site construction. For instance, if licensees have the capacity to self-certify their work, the tenor of the workshop debate sometimes suggested this was sufficient QA on its own, but the research team concluded this to be insufficient relative to the overarching QA/QC systems mentioned above. For instance, in off-site products, individual trades (e.g. plumbers and electricians) only undertake part of a more complex and multi-trade product. Consequently, statutory warranties linked to their individual licenses are insufficient in providing blanket coverage for the overall product. This is not to say that the license and/or warranty should be removed but more so should be situated within the broader context of a QA/QC system that provides holistic compliance and warranty requirements. The onus should be on the provider of the holistic product and not individuals in its supply or compliance chain. Even so, there is ample scope for strategically involving licensed tradespeople where necessary for quality assurance and control (QA/QC), while allowing less qualified workers to perform routine tasks under supervision. Automation is also concluded as presenting a significant opportunity to perform repetitive tasks, drawing on models from industries such as automotive manufacturing, which can be implemented as part of a QA/QC framework but should not be impeded by overly prescriptive licensing requirements.
- Consumer protection was another critical area of concern that, as said, crossed over with trade licensing and the warranty debate above. It was apparent that there was a general perception that consumer protection should be improved for all forms of construction. Even so, a conclusion from the perspectives raised during the workshop was that large and complex prefabricated products gradually change the (arguably) intended balance of responsibility and accountability of statutory warranties. For instance, in historical terms, onsite installation has notionally dominated the above trade licensing responsibility and associated statutory warranties. For instance, in statutory terms, products tend to attract shorter warranties whilst installation (building works) attract longer warranties. However, off-site construction potentially reverses this ratio insofar as they can be perceived as very large and complex ‘products’ that require very little on-site installation work. Because of this, it is concluded that risk/responsibility/statutory warranties should be re-apportioned according to the scale of the off-site product. As said above, the onus should be on the provider of the holistic product and not individuals in its supply or compliance chain.
- A separate measure for consumer protection was around durability and reliability of construction including options for run-off insurance, enhancing certification processes for long-term performance, standardising warranties, and holding manufacturers accountable for the durability of their products. Whilst durability and reliability are highly important issues, they are yet to be dealt with in the NCC. It is a complex issue that is therefore considered to be beyond the scope of this study.

The above conclusions aim to offer a pathway towards overcoming the current challenges, ensuring that off-site construction becomes a reliable and scalable part of Australia’s construction landscape. They will also play a pivotal role in building trust in off-site construction.

Table 8 Summary of the key challenges, and solutions provided by participants

Challenges	Difficulty in achieving national consistency and managing fragmented regulations
	Self-certification by licensees is insufficient compared to overarching QA/QC systems, as individual trade licenses do not cover complex, multi-trade products.
	Varying state and territorial licensing requirements across Australia
	Concern over reduced involvement of licensed trades in off-site construction
	Current product warranties may not be sufficient to protect consumers from hidden or long-term defects

	Loss of real-time design adjustments in off-site construction compared to traditional on-site methods.
	Underperformance and lack of acceptance of certification schemes like CodeMark.
	Off-site assemblies introduce multiple points of interaction that increase the risk of failure.
Solutions	Compliance for off-site production should be managed through neutral third-party certification of production processes (e.g., New Zealand’s BuiltReady scheme and ICC’s 1200 Standards). These models could be adapted for broader use in Australia.
	Develop a voluntary certification scheme, like BuiltReady, with mandatory acceptance and a unified national approach.
	Support industry transitions and de-risk compliance for off-site construction with structured certification processes.
	Establish a clear chain of responsibility and accountability across the entire construction project to strengthen consumer protection
	Utilise manufacturing-like production techniques to ensure repeatability and reliability in achieving compliance
	Implement digital and physical prototyping to identify and address issues early in the design process
	Use CAD/CAM production methods to demonstrate detailed plans for compliance and proactively design-out potential problems.
	Ensure trade licenses and warranties are part of a holistic QA/QC system, placing responsibility on the overall product provider for full compliance and coverage.
	Develop a government-administered certification framework for external validity, ensuring consistent uptake across all States and Territories.
	Explore adapting ‘CodeMark Plus’ as a compliance option to streamline certification through third-party assessments.
	Integrate automation into QA/QC frameworks for repetitive tasks, drawing insights from automotive manufacturing, without restrictive licensing requirements.
	Reallocate risk, responsibility, and statutory warranties based on the scale of the off-site product.
	Improve the reliability and durability of modular components and reconsider product certification timeframes.

CHAPTER 13 - FEEDBACK LOOP

Feedback on the project was undertaken via a number of targeted methods, which were thought to provide the best potential in promulgating the research findings to those best positioned to act on regulatory reform. This included government (federal and state), peak industry bodies and selected groups of industry practitioners. Feedback was provided both during and at the completion of the project. At times this was necessitated where for instance, regulatory reform was running in parallel with the execution of this project. Specifics are listed below:

- Multiple stages of feedback and continuous co-work with the Australian Building Codes Board concerning the content, delivery, scope and findings from Workshops 1 and 3.
- Multiple stages of feedback co-work with the Victorian Building Authority concerning content, delivery, scope and findings from Workshops 2. (Note: VBA are a Stakeholder in the project)
- Industry conference presentation
  - Timber Construct Conference 2023 and 2024: it is the primary annual industry conference dealing with prefabricated construction in the timber industry with approximately 230-250 attendees each year.
  - Presentation and panel discussion at the Building 4.0 CRC annual conference; It is an annual industry focused conference specifically on modern methods of construction and with approximately 200 attendees.
- Meetings and feedback with the MBA concerning their product traceability work and in addition, initial joint exploration concerning ways of streamlining performance solutions
- Multiple stages of feedback to the New South Wales Building Commissioner's office concerning proposed legislative and regulatory change for Prefabricated Construction.
- Feedback with peak industry bodies including PrefabAus, HIA, AIBS, and MBA (Note: MBA Victoria are Stakeholders in the project).
- Meetings and feedback with individual project stakeholders (refer to above and Appendices for details of respective organisations).
- Input and detailed feedback to the Australian Building Codes Board concerning the scope development and content of their now published handbook 'Prefabricated, Modular and Off-site Construction' i.e. NCC compliance pathways for these forms of construction.

CHAPTER 14 - OVERALL CONCLUSION AND RECOMMENDATIONS

The complexities within Australia's construction regulatory system underscore the need for reform to support the wider adoption of Off-site Construction (OC). Fragmented and inconsistent regulatory systems impede the uptake of OC[226]. Care must be taken not to force rigid solutions that impede innovation and advancement. Specific conclusions from this project are listed below.

1. **Delays and uncertainty caused by lack of clarity in compliance (both in approval and during construction) hinder the benefits of OC in Australia.** Regulation and standards play a crucial role in reducing risks and ensuring repeatable processes. In Australia, such standards are under-developed, including administrative and certification standards that could foster OC.
2. **Categorisation of various forms of OC potentially assists compliance standardisation.** This aims to simplify and streamline compliance pathways for common forms of OC products and assemblies, including standard templates and patterns. The UK Government categorisation system offers a good model for further development. Conversion to suit the Australian supply chain would be a useful adaptation for local uptake.
3. **Critical Analysis of NCC compliance pathways include:**
   a. **DtS solutions provide the fastest, lowest cost, lowest risk, and simplest option for OC**. DtS solutions have the compliance benefit of reflecting standard construction, convenient specification and well-known inspection regimes. However, at the current point in time, such solutions are under-represented for the specific needs of off-site assemblies. Here, the NCC primarily deals with the performance of individually constructed elements/components but once these are joined together into more complex assemblies, new compliance issues potentially arise. In practice, this is analogous to a 'patchwork quilt' of DtS solutions. DtS patches are like modules added together to constitute the overall assembly solution (the overall quilt). Even so, there is a high likelihood of gaps existing between DtS patches in the 'quilt'. Performance solutions become the default compliance option for filling these gaps, but unfortunately, these are problematic for OC.
   b. **Performance solutions are overly common for OC assemblies but immediately make compliance harder, more costly and slower to deliver (even if disproportionately constituting only a minor gap in the abovementioned 'quilt' analogy).** Compliance requirements for performance solutions may be fragmented and inconsistently applied across jurisdictions and across those in the compliance chain. Unlike DtS solutions, which are amortised over many thousands of projects, performance solutions are expensively developed within the context of a specific and individual project.
   c. **Existing product compliance Schemes such as CodeMark and WaterMark aim to provide automatic compliance**. Even so, perceptions expressed during the research indicate that Codemark is seen as under-performing. WaterMark certification was perceived as having limitations and potentially allowing lower quality output to pass through unchecked. More frequent testing and renewal intervals may be useful in preventing this problem. In general, new development around Codemark is recommended to support OC (refer to following conclusions).
4. **Suggested improvements to NCC compliance pathways mainly involve simplifying and standardising OC compliance processes.** Mitigation of compliance risk and its impact on time and cost, are key issues. Three initiatives are suggested:
   a. **Gapless DtS Solutions offer a streamlined and low risk compliance pathway for common OC products/assemblies.** This builds on the DtS 'patchwork quilt' analogy. It focuses on developing DtS solutions for gaps currently filled using performance solutions. Identification of the gap could be guided by the following conclusions in this report e.g. treatment of physical interfaces. The net result could lead to the

[226] *As exemplified by the US*

development of standard compliance patterns/templates for targeted products/assemblies that may be guided by the previously mentioned OC categorisation scheme. Even so, the development of such DtS solutions may involve long lead times under existing developmental and administrative processes in which case, the gapless approach only maybe a mid-term option unless timeliness can be improved to keep pace with arising needs. Options, such as the 'Robust details' case study (refer Chapter 2, Case Study 3) could assist insofar as exemplifying web portal access for individual DtS construction details where there is potential for such an approach to bypass the same details needing to wait for inclusion in irregularly and slowly released technical standards; time taken to review/reference such solutions in the NCC is another part of the timeliness issue.

b. **Performance solutions still remain necessary in novel and project specific applications (not dealt with by DtS solutions).** Reducing project time, cost and risk reduction becomes important. To address this, it is proposed that utilisation of 'similars' from past projects could be re-used (according to situational fit) on a current project. The aim would be to reduce rework in presenting evidence for compliance on the current project. A web database with a predictable data structure for sorting and grouping 'similars' is considered to be a useful starting point for further development. Once in use, highly populated groupings could also be used to identify gaps that need to be filled in addressing 'Gapless DtS solutions' (refer to previous item).

c. **Consideration should be given to the future development of a (nominally named) CodeMark Plus scheme, specifically suited to OC products**. This would aim to address solutions not efficiently covered by the above suggestions. This could include highly repetitive, highly integrated and/or innovative approaches to OC. Where used, Codemark Plus would aim to provide automatic compliance and in addition, improve on any perceived shortcomings in the existing scheme.

5. **There is a need for consistency, clarity and guidance in State Regulatory Frameworks to assist the uptake of OC.** This is a multi-faceted issue, as follows:
   a. Building surveyors/certifiers' roles and responsibilities vary across States leading to inconsistency that negatively impacts potential economies of scale from OC.
   b. Compliance checking tends to be geared towards traditional on-site processes. Certifiers/surveyors need statutory guidance about what they should do where mandatory onsite inspection becomes redundant because that same work is alternatively being constructed off-site. Confusion and duplication result but should be avoided. Any reforms should structure an integrated understanding of the relationship between on-site and off-site compliance processes.
   c. Each State has its own contractor/trade licensing arrangements where self-certification of work may be possible, but these arrangements are not necessarily mindful or well suited to the needs of OC certification. Alternative approaches are suggested elsewhere in these conclusions.
6. **Recommendations from the BCR report have been analysed and, in some instances, developed further through the lens of OC.** Interpretation of this is summarised earlier in this report (refer to **Error! Reference source not found.**). This also acts as a cross-referencing point for connecting BCR recommendations to further content development in this report.
7. **New South Wales is the most advanced State in attempting to deal with the regulatory reform for off-site construction.** Position papers foreshadow the direction of the Government's proposed Building Bill which among other things, aims to create a unified framework for off-site construction. It is concluded to be a step in the right direction that other States should also consider. Even so, the proposed approach causes a degree of fragmentation within OC by only focusing on 3D volumetric construction and excluding other options such as advanced 2D panels (that may contain integrated insulation, windows, linings, claddings and services). Inconsistency is the primary concern. Further, certification of compliance for off-site assemblies remains unclear. No detail is provided about how or by whom this will be implemented. Consequently, clarification about what happens when mandatory inspection becomes redundant where OC replaces it, remains unclear.
8. **Compliance around Fire Safety is likely the single largest compliance issue for OC.** Fire safety performance solutions are common and may have many statutory steps, leading to cost and timeliness problems. Inconsistency and variability in the outcome of solutions appear common and reduce reliability and certainty for property owners, developers and clients. Unexpected performance solutions also occur during construction, thus disrupting intended construction timelines. Perceived risks potentially mean that the

commercial viability of OC may be quickly eroded. A number of solutions posed elsewhere in these conclusions aim to assist this problem.

9. **Physical interfaces in OC represent risk for compliance problems.** This is often because such interfaces are relatively undefined (missing) in technical standards. Relevant interfaces include between different construction elements within an OC assembly; between OC assemblies being joined together on-site; between OC assemblies being joined to in situ construction on-site. Lack of solutions in such instances cause variable standpoints regarding compliance or non-compliance. Perceived risk among those in the approval chain likely impacts on this situation. As previously discussed, DtS Solutions addressing such gaps would be useful. Other solution-based conclusions also serve to address this problem.
10. **The studied wet area pod producers provide an example of OC on the large and repetitious scale, using manufacturing techniques.** They have well-developed prototyping and QA/QC systems, which enable the ability to design out quality problems as distinct from waiting for problems to occur and then rectify them. Even so, regulatory challenges exist. NCC compliance focuses on the pod as a finished product while State regulation (as used in Victoria), emphasises process compliance. For instance, the latter focuses on plumbing installation where trade-licensees self-certify installation work, but this is complicated/fragmented where pod-related work happens off-site and installation into the building, happens on-site. As a consequence, separate plumbers are involved with unclear responsibilities for compliance-related risks and statutory warranties. There is a degree of division between Commonwealth and State regulatory approaches, causing clashes and confusion in interpreting compliance requirements. Alternative treatment of OC certification and trade licensing are proposed under separate conclusions, that follow.
11. **Third party certification is considered the best approach for checking production process compliance, for many categories of OC.** On a given project, this would mean that a building certifier/surveyor would aim to seek a certificate of compliance from the OC fabricator/manufacturer rather than formally inspecting the fabrication process themselves[227]. Third-party assessment (via a CAB or similar) would assess and audit the compliance of the fabricator/manufacturer's production processes. QA/QC systems, common in manufacturing for reliable production, should be integral in serving as a foundation for the validity of the certification. Licensed tradespeople who currently self-certify their work could potentially be intermeshed as a part of such systems but should not lead or impede the system. The approach to certification that must also accommodate a degree of project-to-project variation as perfectly repeatable in production, is likely unachievable in practice. Clear 'batten change' boundaries are also required along the compliance chain (e.g. design to off-site to on-site compliance). Dependencies between these linkages may create intermeshed responsibilities. For example, a pod manufacturer may need to audit on-site handling and installation that has been undertaken according to agreed methods for their compliance certification to remain valid. In developing the above, consideration should be given to existing administrative frameworks such as New Zealand's BuiltReady Scheme and facets of the International Codes Council's 1200 series of Standards, which provide structure and context for OC-related quality management issues.
12. **Statutory consumer protection should be reviewed for construction and in doing so, attention given to the treatment of OC.** To some extent, this is already in process with the previously mentioned NSW Government initiatives but in general terms, OC potentially represents a gap in existing statutory warranty frameworks e.g. it is often less than an entire building but more than a component-sized product. Appropriate scaling of warranties is necessary. Also, some warranties are linked to self-certified work by trade licensees but in the case of OC (which involves more complex products), a more holistic and less fragmented approach seems appropriate. It is concluded that the responsibility and accountability should lie with the holistic product provider. Definitions for such products may be assisted by the previously recommended OC categorisation scheme.
13. **Selected technologies can potentially provide solutions to certain previously raised compliance and inspection issues, as follows:**
    a. **Greater emphasis is required on detailed design to provide proof of concept in terms of compliance; digital and/or physical prototyping offers a useful means of achieving the required**

[227] Note: subject to further development, onsite inspectors could still potentially undertake system-based inspection or auditing of OC.

outcome. Unforeseen design problems are common in construction but are difficult to rectify once OC has gone into production. Prototyping has been observed in a positive way on this project were used to test integrity, performance, practicality and interface challenges. It serves to reduce project risks, improve construction quality, and provide greater clarity around compliance. Further investigation should consider levels of implementation and if there is sufficient benefit in incorporating prototyping pathways to assist demonstration of compliance. This should also include feasibility of execution without adversely impacting other initiatives to streamline compliance processes.

b. **Future adoption of image recognition technologies (smart cameras) can assist QC inspection of off-site construction processes.** This is particularly relevant for inspection where progressive OC becomes hidden/sealed during ongoing production processes. Smart camera technology can potentially be located at each production station. According to the level of technology used, it enables real-time defect detection, dimensional measurement, verification of complex assemblies, pattern consistency recognition and traceability of components used. Relevant data (e.g. pictures) can be provided to building certifiers/surveyors as proof of compliant construction. These technologies are currently used in advanced manufacturing but thus far, are relatively unused in construction.

c. **Chain of compliance and Digital product traceability systems are useful for underpinning the validity of product compliance.** This is particularly useful where many different sub-products are used in OC assemblies, a complex supply chain is involved, and where sub-products are often hidden from view in the final assembly. Establishing a chain of custody allows stakeholders to track materials and components throughout their lifecycle, ensuring transparency and accountability. Digital traceability systems enable verification of compliance with regulatory standards at every production stage, mitigating risks associated with poor-quality products from overseas. The proposed national traceability system by the National Building Products Coalition, with unique identifiers, would enhance transparency and accountability for OC spanning from design, to manufacture, to installation. It could serve to strengthen confidence in the compliance of off-site construction.

A closing observation from this study concerns the apparent tension between product versus process perceptions of compliance. For instance, the NCC typically deals with product compliance. State government inspection regimes typically deal with process (installation) compliance. The arising dilemma is which lens, or what hybrid, is best applied to OC. For instance, OC can be conceived as an oversized product or in contrast, an extension of onsite processes. As separate jurisdictions are involved for each perspective, reform should aim for a streamlined system with clear accountability, so as not to overburden the intended economies of OC. A key part of this is ensuring OC is reliable and scalable but achieves trust in both compliance chain and among end consumers as well.

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