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# The potential role of Modern Methods of Construction in addressing systemic supply issues

Evidence review

Dr Sarah Payne (University of Sheffield), Dr Bilge Serin (University of Glasgow)

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# About the authors

Dr Sarah Payne is Co-Investigator with the UK Collaborative Centre for Housing Evidence and a Lecturer in Real Estate in the Department of Urban Studies and Planning at the University of Sheffield.

Dr Bilge Serin is Co-Investigator with the UK Collaborative Centre for Housing Evidence and a Lecturer in Global Urbanism in the School of Social and Political Sciences at the University of Glasgow.

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# Contents

Executive summary.....	Page 5
1. Introduction.....	Page 7
1.1 Background.....	Page 7
1.2 Project aim and objectives.....	Page 9
1.3 Defining MMC.....	Page 9
2. Methodology.....	Page 11
2.1 Characteristics of the evidence base.....	Page 14
3. Regulatory practices.....	Page 17
3.1 Regulation as driver, facilitator, and promotor.....	Page 17
3.2 Confusing regulation and slow processes.....	Page 21
4. Business models.....	Page 23
4.1 Bias towards tradition and business culture inertia.....	Page 23
4.2 Hybrid strategies, the wider system, and a new paradigm of quality.....	Page 26
5. Consumer practices.....	Page 29
5.1 Adverse public impression.....	Page 29
5.2 The characteristics of the consumer.....	Page 30
5.3 Standardisation vs. customisation.....	Page 31

6. Conclusion.....	Page 33
6.1 Competing defintions.....	Page 33
6.2 The state versus market misconception.....	Page 34
6.3 Not a quick fix.....	Page 35
6.4 Its not just about standardisation.....	Page 36
6.5 The hangover of prefabrication.....	Page 37
6.6 Can MMC address systemic supply issues? .....	Page 37
References.....	Page 39
Appendicies .....	Page 41
Appendix A: Review guidance .....	Page 41
Appendix B: Inclusion and exclusion criteria .....	Page 45
Appendix C: Data extraction sheet .....	Page 47
Appendix D: Quality appraisal check.....	Page 48

# Executive summary

The past few decades have seen an increasing policy and business interest in modern methods of construction (MMC) across countries, coupled with a growth in the emerging technologies facilitating contemporary MMC practices. However, modern methods of construction are not a new phenomenon. In the past, serious quality issues ultimately led to the abandonment of this form of development and the stigma associated with failed past practices has made prefabricated housing largely unattractive to construction industries around the world as well as to end users. Nonetheless, contemporary modern methods of construction that typify industry practice in the early 21st century have been shown to bring about numerous benefits for the development industry, such as offering better building quality and high-quality control, improvement of the speed of construction and a reduction in environmental impacts to name but a few (Zhang et al., 2018).

At the same time, MMC has been hailed as a policy solution for addressing systemic housing supply problems. Systemic supply problems, while institutionally complex, are caused to varying degrees by inter alia restrictions in land supply, planning constraints, access to finance, skills and materials shortages and more controversially the speed of development. In this regard, modern methods of construction represent a faster and more efficient form of housing construction, which can increase build out rates and have the potential to address deficiencies in the design value of new housing (White et al., 2020) as well as contributing to increased social housing (Welsh Government, 2020).

Despite numerous policy and development benefits, the uptake of MMC remains low and slower than it could be (Pan et al., 2012). In looking to the existing evidence to understand why this is the case, it becomes clear that much of the academic evidence on modern methods of construction is technical and based largely within the domains of engineering and construction management. Evidence on the technical barriers to MMC and their associated solutions is equally extensive, with research seeking to overcome engineering and materials-based issues constraining this form of construction.

In this report, we suggest this narrow technical focus neglects aspects of the wider development process we think are equally important to consider if MMC is to gain wider industry legitimacy. Indeed, the paucity of research on MMC business models, regulatory practices and consumer preferences in particular, belies the significant contribution these important aspects of housing delivery play in supporting or constraining the use of modern construction methods and by extension, housing supply more broadly.

In response, this research sets out to examine the existing international evidence on modern methods of construction but from a framing of what we refer to as modern methods of development. This framing shifts the focus away from construction - which is but one aspect of the development process - to a broader institutional perspective capturing the complexities of housebuilder business strategy, regulatory protocols and predilections of the end user. Thus, our overall aim is to evaluate the potential role of modern methods of construction in addressing systemic supply issues. To achieve this, we undertake a systematic review of the international evidence, covering business models, regulatory practices and consumer preferences as core aspects of understanding what drives the adoption of MMC.

We find that regulation can be a driver, facilitator and promoter, yet confusing regulations and slow processes also hinder MMC uptake. We also find a bias towards tradition and business culture inertia within the business models of housebuilders, but with some evidence of hybrid strategies and a new paradigm of quality emerging within the industry. Finally, our review reveals an adverse public impression of MMC, where the characteristics of the consumer play an important role in driving interest but design concerns exist around the balance between standardisation and customisation.

Our findings raise some notable implications. Regarding regulatory practices, we find that state leadership is crucial in promoting and incentivising MMC as a mainstream form of housing provision. Regulation should include both increasing the quality and quantity of housing supply rather than simply promoting MMC as a booster for increasing the number of new build houses. When it comes to business models, the evidence reveals that MMC requires unique processes that are often considered risky due to project complexity and a fragmented supply chain. These issues indicate that the take up of MMC practices - and modular housing in particular - by the currently dominant producers may be unlikely and may help explain why MMC has not become an industry norm, remaining the preserve of 'disruptors' and specialist SMEs. Finally, much needs to be done to address the prevailing perceptual hangover of prefabrication as low quality and substandard. If MMC, and modular housing in particular, are to gain institutional traction and become more normalised forms of housing delivery, consumer perceptions about quality must be addressed. We would also argue that definitional clarity - in both academia and practice - is needed to overcome the perception bias of MMC as poor quality and to educate interested parties on the multiple benefits that modern construction methods in all versions bring.

We conclude our report with a suggested re-framing away from MMC and towards modern methods of development (MMD), which we hope will reframe policy and industry debates away from a narrow focus on construction to a broader consideration of how the key components of residential development can enable or constrain MMC uptake. A key drawback for the debates around MMC is the fact that it is seen as a problem of construction methods. Our review on the other hand shows that wider adoption of MMC requires a comprehensive look at the whole development process. This requires a change in perception and we argue that the scope for modernisation will remain limited until sufficient focus is placed on the wider development context. We suggest this change in perception would also help to better address systemic supply issues rather than seeing MMC simply as a quick fix that can boost the construction speed of housing units in the short term.

In conclusion, our report reveals importance nuances in the debates around the practice of modern methods of construction that we hope will be helpful to policymakers and industry leaders alike. For policy makers, the key question is whether MMC is integral to meeting housing supply numbers or whether its value is simply in supporting other policy objectives. Either way, the policy discourse should be clear, consistent and certain. If MMC is seen as a means of simply speeding up housing delivery, this comes with a potential 'perception cost' and with it, reputational harm for the manufacturer / developer should quality and design value emerge as issues during the development process and in after sales.

# 1. Introduction

## 1.1 Background

The past few decades have seen an increasing policy and business interest in modern methods of construction (MMC) across countries, coupled with a growth in the emerging technologies facilitating contemporary MMC practices. However, modern methods of construction are not a new phenomenon. There have been many attempts across different housing markets and through different tenures to implement large scale industrialised building systems, conventionally known as prefabricated houses. In the past, serious quality issues ultimately led to the abandonment of this form of development and the stigma associated with failed past practices has made prefabricated housing unattractive to construction industries around the world as well as to end users (Leabue and Vinals, 2003; Hall and Viden, 2005; Ouroussoff, 2009 cited in Nadim and Goulding 2011, p.83).

Nonetheless, contemporary modern methods of construction that typify industry practice in the early 21st century do bring about numerous benefits for the development industry, one of which is better building quality. Evidence from Zhang et al's (2018) review of the literature on prefabricated housing in Hong Kong - applicable to other housing systems - suggests the following development benefits:

1. better building quality and high-quality control
2. improvement of the speed of construction and improved quality control
3. reduction of the overall cost of construction
4. reduction of the construction waste
5. reduction of the environmental impacts
6. improvement of working condition and health and safety of the workers
7. decreased labour
8. lower maintenance and repairs
9. reduction of the environmental impacts to residents around construction sites; and
10. decrease in disputes during construction (p.71)

In addition to these multiple development benefits, MMC has also been hailed as a policy solution for addressing systemic housing supply problems, which are a feature of many market-led housing systems around the globe. Systemic supply problems, while institutionally complex, are caused to varying degrees by inter alia restrictions in land supply, planning constraints, access to finance, skills and materials shortages and more controversially the speed of development. In this regard, modern methods of construction represent a faster and more efficient form of housing construction, which can increase build out rates and have the potential to address deficiencies in the design value of new housing (White et al., 2020) as well as contributing to increased social housing (Welsh Government, 2020).

Despite numerous policy and development benefits, the uptake of MMC in the UK housebuilding industry in particular remains low (Pan et al., 2008) and slower than it could be (Pan et al., 2012). In looking to the existing evidence to understand why this is the case, it becomes clear that much of the academic evidence on modern methods of construction is technical and based largely within the domains of engineering and construction management. A historical, cost-driven approach predominates, focused largely on the performance measurement of offsite technologies, whilst the benefits of other MMC aspects such as time, quality, health and safety, and sustainability are more hidden and not as fully realized by the construction industry (Blismas et al., 2006; Pan et al., 2008). Evidence on the technical barriers to MMC and their associated solutions is equally extensive, with research seeking to overcome engineering and materials-based issues constraining this form of construction.

Looking to practice, significant recent work has been undertaken by the construction industry itself as a means of enhancing the uptake of modern methods of construction (e.g., HBF, 2004, RICS, 2018, NHBC Foundation, 2018). This work is ostensibly driven by the industry's desire for enhanced resource efficiency and economic productivity, as well as addressing persistent skills, labour and materials shortages made worse by the global financial crisis. This work has also been driven to some extent by national government policy ambitions on housing supply (MHCLG, 2017) and the industrial strategy (HM Government, 2018). The resulting policy and practice discourse around MMC - like that of the existing academic literature - is one that favours technical fixes, material and process efficiencies and economic productivity. This, we argue, has led to a narrow focus on technological and cost barriers and solutions predominating the conversation around modern methods of construction.

In this report, we suggest this narrow technical focus neglects aspects of the wider development process we think are equally important to consider if MMC is to gain wider industry legitimacy. Indeed, the paucity of research on MMC business models, regulatory practices and consumer preferences in particular, belies the significant contribution these important aspects of housing delivery play in supporting or constraining the use of modern construction methods and by extension, housing supply more broadly. These are particularly acute issues since, in the UK at least, housebuilding is often decoupled from contracting, instead focusing on land acquisition in response to stiff market competition and the function of land use planning as a regulator of location, type and quantity of new housing. This renders the competitive edge obtainable from technological innovation less important or noticeable (Pan and Goodier, 2012), with the larger housebuilders focusing on '...eliciting profits from the development of land and the management of finance during this process rather than the actual construction process itself (Ball 1996; Barlow et al. 2003; Venables et al. 2004; Meikle 2008)' (Pan et al., 2012, p.1331). This suggests that MMC may have different impacts on potential production rates (a technological issue) and build-out rates (a market/planning issue).

Whilst the business model in off-site construction research is a relatively new unit of analysis, we argue it is an important one since it '...emphasizes a systemic perspective on take-up of off-site construction in housebuilding businesses; encompasses organizational activities; and seeks to explain both value creation and capture in the process of housing delivery' (Pan and Goodier 2012, p.91). Indeed, modern methods of construction, like any new process or technology, involves change, which often attracts resistance from UK housebuilders (Gibb, 1999).



## 1.2 Project aim and objectives

In response to the issues identified above, this research sets out to examine the existing international evidence on modern methods of construction but from a framing of what we refer to as modern methods of development. This framing shifts the focus away from construction - which is but one aspect of the development process - to a broader institutional perspective capturing the complexities of housebuilder business strategy, regulatory protocols and predilections of the end user.

As such, our overall aim is to evaluate the potential role of modern methods of construction in addressing systemic supply issues.

To achieve this, our objectives consider:

1. what business models, regulatory practices and consumer preferences drive the adoption of MMC;
2. what evidence exists to explain the low uptake of MMC in residential development practice; and,
3. what policy and market processes might enhance the adoption of MMC in the UK housing system.

## 1.3 Defining MMC

Our evidence review reveals that multiple terms are used within the academic literature to define MMC or particular MMC processes and applications. These terms include: industrialised building (Zhang et al., 2014); offsite production (Nadim and Goulding, 2011); offsite manufacture in construction (Blismas and Wakefield, 2009); prefabricated housing (Koklic and Vida, 2011); modern methods of construction (Lovell and Smith, 2010); modular integrated construction (Wuni et al., 2020); off site construction (Pan et al., 2008, Pan and Goodier, 2012); off site modern methods of construction (Pan et al., 2007); platform-based approaches (Halman et al., 2008); off site manufacturing (Elnaas et al., 2014); and, pre-fabricated building systems (El-Abidi et al., 2019).

Interestingly, the utilisation of a given term in individual studies appears to be far from random. Lovell and Smith (2010) for example avoid using the term prefabrication and prefer to use modern methods of construction, suggesting this is largely '... in an effort to dissociate contemporary factory-produced housing from its historical technical problems' (p.465). Wuni et al., (2020) highlight the complicated use of similar - but not the same - terms in the literature:

*'... models of MiC [modular integrated construction] are promoted in Australia, Canada, USA, the UK, Singapore, Sweden, South Korea, China, and Malaysia... as off-site manufacture, modular construction, prework, off-site production, prefabricated prefinished volumetric construction, industrialized housing construction, and industrialized building systems.' (p.64).*

The situation in practice is equally complex, with multiple terms and definitions used in the grey literature to characterise what is known colloquially as modern methods of construction, but for which no standard industry definition exists. The UK government, as part of its wider effort to promote the use of MMC, commissioned Mark Farmer of Cast Consultancy to regularise the terminology and produce a definition framework (Cast Consultancy, 2019). A seven-category spectrum was produced, encompassing a range of approaches which span off site, near site and on-site pre-manufacturing to site-based process improvements and technology applications. Category One defines a systemised approach based on volumetric construction, involving the production of 3D units in controlled factory settings that can be brought to site for final installation i.e. modular homes. At the other end of the spectrum - Category Seven - are site-based construction techniques, for example the use of drones, workface robotics, lean

construction techniques, exoskeletons, and other wearables. Volumetric podded assemblies such as whole bathrooms or kitchens feature in Category Five, whilst pre-manufactured components such as floor slabs and staircases feature on Category Three.

Perceptually, this means volume housebuilders can utilise some aspects of MMC in their traditional brick and block masonry houses, such as pre-assembled timber roof structures or staircases (Category 3). This compares with specialist developers focused on fully volumetric homes that are configurable (Category 1). This is important to note and could go some way to addressing or even reversing some of the negative perceptions and assumptions end users may have of MMC which are falsely synonymised with just prefabrication. Whether the term 'prefab' remains synonymous with modular or volumetric housing remains to be seen.

In this evidence review, we adopt the term modern methods of construction as we think this catch all term best represents the varying technical and philosophical intentions underpinning the approach. We reflect on the implications of such competing definitions on the longer-term efficacy of modern methods of construction in the discussion.

## 2. Methodology

This research employed a systematic evidence review methodology that has been produced in accordance with literature mapping exercises (Soaita et al., 2020) by researchers at the UK Collaborative Centre for Housing Evidence (CaCHE) (see Serin, 2018a, 2018b, Soaita, 2018a, 2018b). A review guidance document was produced to establish a protocol for completing the systematic evidence review and ensure it was robust and transparent. The key components of the review guidance document include: brief information about the review (e.g. its scope, research aim, questions and objectives); the review process steps (steps 1-5); sources to be reviewed (e.g. academic indices and journals); keywords and queries to be run on the indices and/or selected journals; inclusion and exclusion criteria to be applied when selecting sources; quality appraisal criteria for assessing the of sources; and, a work plan.

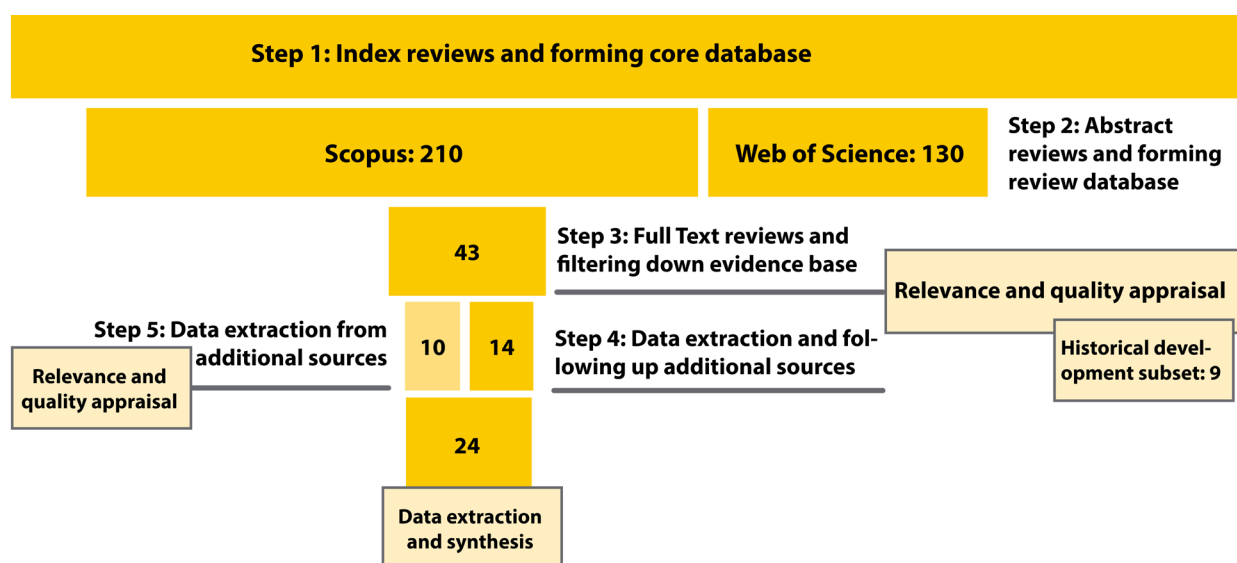
The following strategic decision points shaped the review approach:

- The review focused on scholarly publications (academic journal articles and indexed book chapters) and excluded international grey literature (e.g., policy documents, reports, briefs) to account for any language bias that may have skewed the distribution of evidence among countries and led to an overly dominant country perspective. A preliminary search showed much of the grey literature to be published in the native language of the respective country. We did consult grey literature from the UK to contextualise our findings.
- Scopus and Web of Science were used as the main search media, since these indices cover most published academic material (Serin, 2018a).
- Inclusion and exclusion criteria were developed to easily filter out irrelevant publications. Thematic criteria were set to include evidence on the specific sub-topics of the review's focus - regulatory practices, business models and consumer preferences - and exclude studies exclusively focused on technical and design aspects. No specific time frame criteria for publication were set, so to explore the publication trajectory of the literature. Similarly, no geographical limit criteria were set.
- Keywords and queries were decided in accordance with the research aim and objectives and piloted to ensure they addressed definitional ambiguity and yielded relevant results in manageable numbers from the selected indices.
- Data extraction categories were developed to enable the extraction of relevant findings from the reviewed publications. These categories were selected based on the research aim and objectives.
- Quality appraisal criteria were developed in line with a previous CaCHE evidence reviews (for example, see Payne et al., 2019), which had shown to work successfully. These criteria, in the form of a checklist, provided the reviewers with a matrix for assessing the quality of each publication (high, medium or low) against a three-stage criteria (see Appendix A for further detail).
- A set of outputs and a workplan were agreed by the research team.

Step 1 of the review involved running the keyword queries (on title, abstract, stated keywords of journal articles and indexed book chapters) on the selected indices. These queries resulted in 340 returns (See Table 1 for the details). These returns, which included journal articles and indexed edited book chapters, formed the core database.

In Step 2, the abstracts of these returns were reviewed according to the inclusion-exclusion criteria. Irrelevant publications were then excluded and a review database with the remaining publications was created. The purpose of this round of inclusion-exclusion was to identify studies that were likely to engage with the socio-regulatory aspects of MMC and filter out any technical or engineering-based studies (see Appendix B for the full inclusion-exclusion criteria). The publications for which it was not possible to identify whether they engaged with socio-regulatory aspects were retained for full-text review in step 3.

Figure 1: Review steps and filtering process of the systematic evidence review



In Step 3, full-texts of the publications in the database were reviewed according to the inclusion-exclusion criteria, data extraction categories, and quality appraisal checklist (see Appendices B, C and D for details). This resulted in some publications being excluded and no data extracted from them. The research quality of papers was assessed by examining transparency and rigour in line with the quality appraisal checklist, specifically determining:

- whether the aims, objectives, rationale and context of the study in each paper were clearly reported;
- whether the methodology was transparent;
- whether the research design was rigorous given the aims and objectives and methods;
- and, whether the findings were clearly linked to the purpose of study.

After this initial quality appraisal, an additional set of assessment criteria was used for quantitative, qualitative and mixed method research to undertake a deeper assessment. In this, each publication was given an overall mark for its quality as either high, medium, low or poor. The publications that received a poor mark were then excluded.

Step 4 involved data extraction, which was applied only on those papers that passed the quality appraisal and relevance assessments of Step 3. When assessing the relevance of publications to the scope of the evidence review, their engagement was categorised as either major, through a key section, peripheral or minor. Although some papers were not directly engaged with all topics the review aimed to cover, they were still included based on providing evidence on particular subtopics of the aim. In this instance, only the relevant sections were utilised when extracting data. The data extraction sheets indicated which subtopic - business models, regulatory practices, consumer preferences, any other - the studies were engaged with, to evaluate the engagement of the evidence base overall

within these subtopics. During the review of the full-text of the publications, references that were potentially relevant to the review were followed-up. Additionally, papers that the research team identified through their familiarity with the literature as being relevant were also included in the review. In Step 5, we reviewed these additional publications and conducted the data extraction as in Step 4.

Table 1 and Table 2 show the number of returns in the initial reviews and the number of publications reviewed. Figure 2 shows the geographical distribution of the studies according to the case studies they conducted. A full list of the publications reviewed can be found in the bibliography marked with a star (\*). Once all steps were completed, a synthesis of the identified evidence was produced based on the data extracted over the review and this report is produced as a result of that review.

Table 1: Summary of the review scope and the search medium

Search medium	Number of returns and reviewed publications	Notes
Scopus	210	This is the total number of returns indexed by Scopus after removing duplicates. The abstracts were reviewed and irrelevant articles were filtered out according to the inclusion-exclusion criteria.
Web of Science	130	This is the total number of returns indexed by Web of Science after removing duplicates. The abstracts were reviewed and irrelevant articles were filtered out according to the inclusion-exclusion criteria.
Total number of publications	340	This is the total number of publications reviewed. Table 2 summarises the filtering phases and the final number of the publications of which full texts were reviewed and included in the evidence review.

Table 2: Summary of the review phases and final review database

Review phase	Reviewed publications	Notes
First phase review database	43	This group of articles are those remaining after the first step filtering process, applying the inclusion-exclusion criteria on the abstracts of the returns.
Second phase review database	14	This group of articles are those remaining after the second step filtering process, applying the inclusion-exclusion criteria on the full text of the selected publications after first step filtering.
Follow up and additional articles	10	This group of articles were identified by following up the references of the articles read and by the researchers via their subject familiarity.
Final review database	24	This is the number of articles in the final database and included in the evidence review. These publications are marked with a star (*) in the bibliography.

## 2.1 Characteristics of the evidence base

The 24 articles compiled after the filtering processes described in the previous section comprise the evidence base of this report<sup>1</sup>. This section sets out the overall characteristics of the evidence base regarding its geographical distribution and publication timeframe, as well as the disciplines that the studies engaged with and the theories adopted.

### Geographical Distribution

The evidence base is observed to be geographically diverse, accommodating studies based on MMC practices from every continent except for South America and Antarctica. However, the distribution of studies among countries or continents is far from equal. A degree of clustering<sup>2</sup> around three countries - the UK, Hong Kong and Australia - was observed. Most of the studies (n=21) are based on one single country, using that country as its case study. Only three studies exploring comparisons or undertaking a crosscutting evaluation of MMC practices in more than one country were identified (See Figure 2 for details).

### Time Frame

The evidence review did not implement any time limit when reviewing the indices or during the filtering down to studies of interest. However, the 24 studies included in the review were all published in the 2000s. This may be a result of increasing policy and business interest in MMC practices across countries during this period, as well as emerging technologies facilitating contemporary MMC practices. An analysis of the distribution of these studies across the years of the 2000s did not yield any meaningful results. More than 60% of the studies were published in the last decade, while the rest were published in the early 2000s (Figure 3). Again, this distribution is not conclusive when taking into consideration the relatively small number of studies inspected in the review, as well as the changing nature of publication practices over time. As such, any conclusions regarding the increase in the number of studies in the last decade should take into consideration the relatively increasing number of publications over that decade. With this in mind, we have not sought to interpret the increasing number of the studies in the last decade, apart from acknowledging a growing policy and business interest in MMC owing to the availability of contemporary tools and technologies that may facilitate MMC practice. Among the nine papers discussing the historical development and practice of MMC - included to capture historical changes regarding MMC practices - those published in the pre-2000s include studies from the 1980s and 1990s<sup>3</sup>. Studies published in the 2000s covered debates and practices from the pre-2000 period.

1 In addition to these 24 studies, we identified nine papers during the review stage that focused on the historical development of MMC. As these studies acknowledged the progressive nature of MMC techniques and models, we excluded them from the evidence.

2 If three or more papers published on MMC practice in a country is observed, this is considered as forming a cluster.

3 We acknowledge there is a potential technological redundancy issue about the coverage that will be in the older papers, particularly where 1980s publications may look at work done in the 1970s or early 1980s and where the technology for construction was very different. However, our focus in consulting this dated evidence was to establish historical trends in order to contextualise the more recent evidence.

Figure 2: Geographical distribution of the studies included in the evidence base

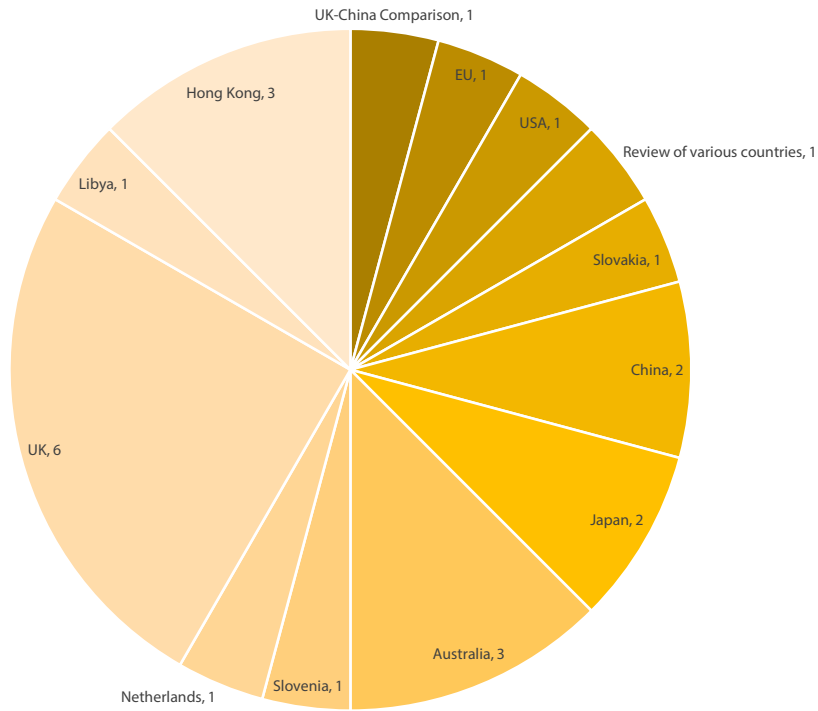
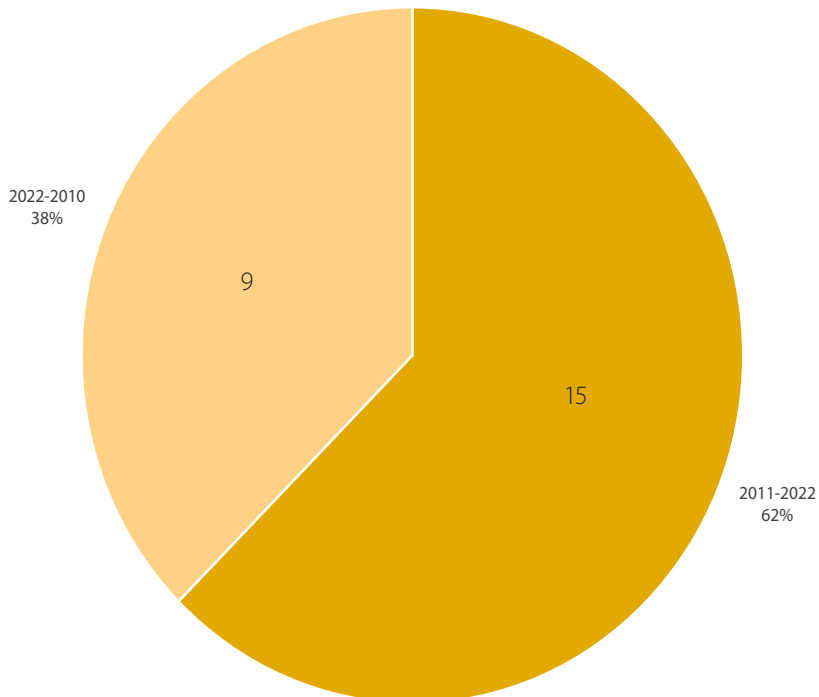


Figure 3: Temporal distribution of the studies included in the evidence base



## Disciplines

The reviewed studies crosscut various disciplines and disciplinary boundaries, including urban studies, housing studies, geography, public policy, management, consumer studies, construction management, and civil engineering. This is an expected result, with the scope of this evidence review focusing on what we refer to as the socio-regulatory aspects of MMC practice. While the reviewed studies demonstrate a diverse engagement with disciplines, this was not the case for their theoretical engagements or tendencies. Indeed, most of the studies were observed to be atheoretical.

Most papers included in this evidence review had significant engagement with the scope of the review - 19 out of the 24 were evaluated as having a major engagement with the scope and specific subtopics. However, a small number of papers were included that only demonstrated engagement through a key section (n=2), or peripherally (n=3). These studies still provided some relevant data to the scope of the evidence review despite it not being their major focus.

The evidence base demonstrated a fairly well distributed engagement with the specific subtopics of business models, regulatory practices and consumer behaviour. Out of the 24 studies included in this review, 15 studies engaged with business models, 10 studies covered regulatory practices, and 10 studies engaged with the topic of consumer behaviour. Some studies engaged with multiple subtopics throughout the paper. These studies were therefore not classified according to the subtopics they covered one by one but were identified by their engagement with the areas of interest of this review.

Whilst our report reveals important nuances in the debates around the practice of modern methods of construction, we must consider a number of limitations that we think add caution to our findings. First, the research is based on a small number of academic studies that are clustered around the post-2010 time frame and which are published in English. We consider this small number of academic articles the result of a lack of academic interest in the topic, whilst also being affected by the selection criteria we adopted. Nonetheless, we are confident that we have identified the key sources for the topic. Second, we did not look at grey literature or industry reports published in other languages. By excluding grey literature, there is a possibility that we have missed out some important evidence. However, language constraints mean we were unable to consider this evidence. We also wished to avoid any language bias that may have skewed the distribution of evidence among countries and led to an overly dominant country perspective. Third, we did not cover the literature that evaluates the main barriers and opportunities of MMC, since this focused too much on construction technologies and methods. However, we would recommend our review being read in conjunction with those studies for readers who are looking for a more specific discussion on these aspects of MMC practice.



# 3. Regulatory practices

## 3.1 Regulation as driver, facilitator, and promoter

The evidence review revealed that regulatory practices play a key role in promoting or limiting the use of MMC in construction industries. Looking to the Chinese literature, China is a country where state support has been a common feature in transitioning from state-run to free market industries. The approach is often characterised by early government industry protection and control, followed by support and finally replacement by the open market (Zhang et al., 2014). Whilst modular housing construction - known in China as industrialised building or industrialised housing - remains fledgling in the Chinese context (Zhang and Skitmore, 2012), recent research reveals some interesting insights into these dynamics. According to Zhang and Skitmore (2012), industrialised building technology has been introduced 'with a high priority to help survive the challenging housing market ahead' since 'the housing industry is still in an extensive development stage' (p.144). To support this, two policy interventions took place. The first was a list of industrialised housing (IH) standards that provided technical support for IH practices. Secondly, a preliminary IH building materials and standardized production system was established (Zhang and Skitmore, 2012).

In their study, Zhang et al., (2014) examined a series of 'critical' factors affecting the take up of industrialised building (IB), with the purpose of helping business professionals and local government find ways of overcoming the major barriers to IB in practice. The six critical factors identified in their research, ranked by importance, were:

1. Higher initial cost
2. Lack of skilled labour
3. Manufacturing capability, involvement issues and product quality issues
4. Lack of supply chain
5. Lack of codes and standards
6. Lack of government incentive, direction and promotion.

Whilst these findings show that regulatory practices - 'lack of codes and standards' and 'lack of government incentive, direction and promotion' - were not considered as significant a hindrance as the harder constraints of cost, labour, materials and supply chain, they did nonetheless remain an important factor in challenging industrialised residential building practice in China. Zhang et al., (2014) note that the lack of industry peremptory norms - with the exception of pilots who have set up their own standards - makes it difficult to find any national uniform codes and standards. This, the authors argue '...not only leads to the duplication of design and the repetition of construction waste, but also hinders the further development of prefabricated components in the factory, construction mechanisation and assembly' (p.182).

Similar but more far-reaching issues are found in the perceived 'lack of government incentive, direction and promotion' issue. Indeed, Zhang et al., (2014) argue there is a perception that government - as mentor, supervisor and facilitator - should develop a reasonable policy to drive industrialised building into a healthy state. Their research revealed an insufficiency of proactive incentive policies, regulatory mechanisms and efficient government supervision systems in generating enthusiasm for the development of industrialised building. Importantly, the authors suggest this lack of government promotion has caused some consumer misconceptions concerning 'housing industrialisation', which they argue is particularly problematic given the problems associated with China's prefabricated housing programme of the 1980's, '...where quality problems left customers with a negative impression that industrialised building means quality is not guaranteed' (p.182).

Ultimately, Zhang et al., (2014) suggest that without an official legal system or strong government support, many Chinese developers and contractors will hesitate to take a lead in furthering the progress of industrialised residential building. This was also concluded by Zhang and Skitmore (2012), whose study on industrialised housing in China based on a literature review and survey, found a need for 'formulating policies to encourage industrialized housing in China and for well-planned R&D themes to be implemented simultaneously with industry practices in the near future' (p.143). However, the authors state this does not mean that there have been no efforts to achieve this in the context of China already - the Trans-century Housing Industrialization Policy programme on China in 1996 'started the developing objectives and the overall guidelines for housing industrialization in China (Nie, 1999)' (Zhang and Skitmore, 2012, p.145). Further, 'Measures of Beijing on the Reward for IH Residential Projects' was issued in 2010 which indicated 'IH would be allocated to 3% of all construction work - proactively encouraging the rapid development of IH in future' (Zhang and Skitmore, 2012, p.145).

Whilst regulatory constraints may be a lesser hinderance in China than the harder issues of cost, labour, materials and supply chain, Zhang et al., (2014) nonetheless argue for a 'paternal government approach' in overcoming the major barriers to industrialised residential building in practice. Specifically, the authors argue for subsidies or incentives to support necessary investment '...until production levels reach the point where economies of scale due to mass production result in viable market prices of components and parts' (p. 182); and for government support in reskilling the labour force, increasing manufacturing capability and providing codes and standards where issues of quality are involved. The authors expect that the housing industry would then provide the enterprise necessary for the creation of the necessary supply chains.

These above sentiments are supported by research in the UK context by Elnaas et al., (2014) which found that UK housebuilders identified lack of existing codes and standards; old regulations that did not cover all offsite aspects; and no legal framework to support offsite manufacturing as moderate constraints to the use of offsite manufacturing in UK housebuilding.

Research from Libya (Amtered El-Abidi et al., 2019) provides an historical perspective on how inadequacies in the role of governments caused failure in the prefabrication construction industry and ultimately, the market provision of prefabricated housing. Their research explored the current situation of prefabricated building systems in Libya and its potential to address Libyan housing conditions. Most of the interviewees reported that the Libyan government had not played a major role in the development of the construction industry. This conflicts with the expected role of the Libyan government as having a major role in endorsing and strengthening '... institutional arrangements in accordance with the systematic planning and execution of national strategies and policies that will affect the construction industry. Accordingly, the overriding factor to the developmental transformation of the sector is the commitment of the government at all levels' (p. 8295).

Amtered El-Abidi et al's (2019) research indicated that the lack of progress of the construction industry can be attributed to the absence of measurable targets for programs aimed to enhance overall industry performance with prefabricated technologies, which they refer to as 'government neglect of the construction industry' (p.8295). Their research goes on to suggest that a private sector strategy may be needed to improve the current status of the industry and enhance its performance. The authors argue if the success of public policies are to be realised, they should be done through an integrated and systematic approach '... by which the usefulness of alternative policies can be evaluated on the basis of the private sector's response and foreseeable changes in the industry's environment' (ibid.). Ultimately, the experts Amtered El-Abidi et al., (2019) interviewed generally agreed that the government plays a critical role in the promotion and development of prefabricated buildings and is considered a major driver in embracing such a technology.

Research from the UK, undertaken by Lovell and Smith (2010), provides interesting reflections on the role of UK government policy in relation to prefabrication. In their research, the authors examined the UK construction industry's 'lock-in' to masonry house building, which involved interviews with a range of market actors, including UK government, housebuilders and consultants. Regarding the role of government, the authors argue there is a need for a state wishing to effect change to conceive of markets and intervene in them using more subtle approaches than those typically employed by policy makers. Lovell and Smith (2010) use the example of the introduction of the 2004 social housing policy to illustrate, which whilst requiring one quarter of new publicly funded social housing to adopt prefabrication in England and Wales '... has in retrospect been rather a blunt tool to encourage up- take in light of the lock-in of masonry construction' (p.465). Prefabrication has essentially been 'locked out', with evidence of a hands-off approach by government in its implementation of the target suggested by the authors. Despite this, the authors do suggest the UK government can be praised for its appreciation of the cultural aspects of markets, where they have attempted to change the discourse about factory-based housing technologies, avoiding use of the term 'prefabrication' in favour of 'modern methods of construction'. The authors suggest this is largely '... in an effort to dissociate contemporary factory-produced housing from its historical technical problems' (p.465).

Lovell and Smith's (2010) research emphasise what they refer to as the cultural and institutional issues as hampering uptake of prefabrication. They warn that government intervention is '... unlikely to succeed without tackling the more fundamental (and even less obviously political) aspects of market framing, for instance the politics of calculation, that is determining what is inside and outside of project accounts. There is also a need to recognise the sociality and materiality – the complexity and interconnectedness – of markets; how costs, prices and values are constituted through a hybrid combination of economics, social, political, cultural, technical and institutional factors' (pp.465-466). Indeed, the authors go on to suggest that one reason politicians have '... hitherto favoured prefabrication to rather little avail is that interventions have been based on a partial understanding of how markets change' (p.467). They suggest a better understanding of the complexity of how markets work and deterring thoughts of a 'quick fix', '... may at least provide governments with a sense of the size and subtlety of the challenge they seek to address' (p.467).

From the Hong Kong perspective, Chiang et al., (2006)'s study looks at the issue of competitiveness and MMC uptake by construction companies tendering for Housing Authority projects. The study reveals the complexity of the market-regulatory incentive relationship and provides insight into how the market operates, stating 'Recently, the government has started to promote prefabrication as a general principle to improve buildability, to increase quality and efficiency as well as to reduce construction wastes. However, an analysis of public tender results between 1988 and 2002 shows that the market appears to be less competitive in this housing sector than the other institutional building sector' (p.482). The authors emphasize the importance of mandatory regulations requiring MMC by the Authority as a means of expanding its use in the Hong Kong construction industry, stating 'Contractors might not have chosen prefabrication, if it had not been mandatory, and might not have taken the opportunity to drive costs and consequently tender prices down in the long run' (p.485). The study, however, reveals a drawback of this regulatory approach that is 'during this 15-year period, between 38% and 74% of the total annual public housing contracts, by value, were undertaken by only three contractors' (p.482). According to the authors, a limited number of companies operating in the MMC space of the construction industry raises concerns that 'the prefabrication requirement might have raised the market entry barriers, and probably construction costs' (ibid.). Therefore, regulations that are intended

to encourage the use of MMC may actually be creating unintended barriers for firms other than the dominant three companies to enter the competition space for MMC tenders.

In contrast, Li et al., (2016), in their study based on a SWOT analysis for prefabricated housing production in Hong Kong, argue that policies encouraging the use of prefabrication in housing production have facilitated innovation in both public and private companies operating in housing sector, stating 'In general, the early adoption of prefabricated units in public housing projects and the HKHA [Hong Kong Housing Authority] 's extensive experience in applying prefabrication technology have significant influence, and subsequently inspired prefabrication innovations in the private sector, including the use of precast staircases, façades, beams, slabs, and volumetric bathrooms. Innovations in the private sector have also affected those in the public sector with the use of precast structural walls and lost form panels (permanent formwork). Extensive experience has enabled innovations in the Hong Kong prefabrication sector to continue to thrive and be rewarding' (pp.77-78).

In the Japanese context, evidence shows how MMC housing has been encouraged by the government extensively and integrated into mainstream housing policy. In the 1980s and 1990s, government policies designed to encourage homeownership, housing quality and increase the number of available housing units also promoted the use of MMC in the Japanese construction industry. These policies '... included promotion of prefabrication in the five-year housing plan beginning in 1971 and funding for the collaboration of ninety firms in the century house project, among other things' (Patchell, 2002, p.288). As a result, this extensive state intervention 'provided capitalists with both a potential mass market and substantial guidance on how to capture it' (ibid.). Government support for MMC also included founding new bodies - The Ministry of Construction and the Ministry of International Trade and Industry founded an association called the Japan Prefabricated Construction Suppliers and Manufacturers Association (JPC SMA). The aim of this association was 'to support research and training, undertake promotion activities (e.g., managing model-home sites), and foster information exchange and collaboration on standards' (Patchell, 2002, p.288). According to Patchell (2002), the '... promotion of collaboration was most significant, because the establishment of industry standards for quality fostered public trust in the industry and in individual builders' (p.288). Policymakers also used competitions as a way to promote MMC in Japan. To illustrate, in the 1970s, 'the government proposed a nation-wide competition called the "House 55" project to encourage housing manufacturers to improve the quality of their products and to demonstrate to the public that industrialized housing need not be of low-quality (Sackett, 1986)' (Noguchi, 2003, p.355). However, Noguchi (2003) also emphasizes that the perception for prefabricated homes in Japan in the 1960s and 1970s was associated with low quality due to simple mass production techniques and monotonous design schemes. The foundation of the Japanese Prefabricated Construction Suppliers and Manufacturers Association (JPA) was actually to improve this image. We discuss how this reputation has changed over the years in Japan and prefabricated homes have become associated with quality home image in the following sections.

A related policy tool which is used to promote MMC is that of demonstration projects or pilots. Moore and Higgins (2016)'s study of a demonstration project (the Nicholson) in Melbourne, Australia demonstrate the mixed perceptions about MMC across the stakeholders. The project was a modular construction development facilitated by the Victorian state government. While some stakeholders evaluated the project as 'an attractive proposition for developers and consumers' (Moore and Higgins, 2016, p.14), others disagreed with this proposition. The main challenges that stakeholders identified were about the cost of the development and its financing. However, they also argued that the demonstration project was useful for the banks to understand the process of an MMC development, which is different than financing a traditional development due to the different steps followed (e.g. off site production of the parts). The Moore and Higgins (2016) study shows that demonstration projects can act as a policy tool to promote wider use of MMC, with the authors stating 'Overall though, considering that the Nicholson was an early Australian example of large-scale modular construction, many of the stakeholders thought it had influenced the wider building industry. It was a well-known example in the building industry and had provided a platform for further innovation in modular construction and the financing mechanisms to support it. Developers in particular seemed to be moving closer to accepting modular construction approaches, with many having looked at the costs and trialled the inclusion of modular elements such as bathrooms within new developments' (Moore and Higgins, 2016, p.14).

## 3.2 Confusing regulation and slow processes

In the UK context, research by Pan et al., (2007) on the perspectives of housebuilders on the use of offsite technologies found that the slow process of obtaining planning permission and changing building regulations inhibited the use of offsite MMC in 25% of respondents. This measures against other barriers such as higher capital cost (68%), difficulty to achieve economies of scale (43%), complex interfacing between systems (29%), and inability to freeze the design early on (29%) (pg. 187). Specifically, their research revealed that many of the potential benefits from the use of offsite MMC were not realized due to planning process delays. Recommendations and implementation strategies suggested by housebuilders, as part of their research on how to address these issues, revolved around making the planning system more flexible and market responsive; establishing dialogues between housebuilders and local authorities; housebuilders keeping compliance with enhanced building regulations; and, designers not sacrificing design flexibility when specifying the use of offsite MMC. These findings were corroborated in later work published by Pan et al., (2008) in which the nature of the planning system was considered the 5th most significant barrier to the use of offsite MMC among the top 100 housebuilders (p.61). Extra costs for obtaining certificates for new systems were also claimed to be negative to offsite practices (p.62).

In the Dutch context, research by Halman et al., (2008) examined the opportunities, limitations, and external restraints on the implementation of what they termed platform-based approaches in the Dutch housebuilding industry. Their research involved interviews with a range of stakeholders in residential development, including architects, construction firms, suppliers and municipalities. A number of important insights on the nature of regulatory practices were revealed. To start, there was a consensus among the respondents that the regulations and procedures set by the national government '... were far too complex, extensive and time-consuming with a need to allow greater flexibility in the process' (p.790). Some respondents recommended the issuing of preliminary permits during the design phase of a project, which could be checked at a later date when greater certainty exists about the final design. It was argued such would '...avoid unnecessary delays and enable rapid construction once a design decision is confirmed' (ibid). Changing current land policy and increasing the amount of land available were also considered as having potential to encourage platform-driven housebuilding.

Further, Halman et al's (2008) research also found that municipalities perceived their own role mainly as being a promoter and a regulator and they did not anticipate any major changes regarding the current system of regulations - it was argued urban plans provided sufficient space for the realisation of customer-focused projects and it was not seen as necessary to change procedures. Ultimately, Halman et al's (2008) research indicated that municipalities perceived their position as one of encouraging the development of the platform-based approach, with the actors in the market having to make it happen. It was suggested that subsidising projects and offering information would enable municipalities to fulfil the role as promoters of customer-focused projects. In this regard, the authors suggest that '...the exchange of knowledge between municipalities and the building industry will become more important and, in order to promote consumer-oriented building, land policy will have to change' (p.794). With regard to the expected roles of the different actors, the results of Halman et al's (2008) research showed that most of the discussion that still exists concerns the role to be played by local authorities. Indeed, while most of the interviewed municipality representatives saw no reason to change regulations and procedures, the other actors stressed that changing land policy to reduce the scarcity and the price of land plots is essential if platform-based approaches are to be successfully implemented in the Netherlands. This, the authors suggest, requires national and local governments to adopt a less restrictive land policy.

From a European legislation perspective, research by Nadim and Goulding (2011) on offsite production (OSP) revealed that OSP needed to '... comply with numerous regulations, e.g., "safety, thermal insulation, energy reduction, and ecological prescriptions", etc' (p.86). This myriad of regulatory controls were perceived by their respondents '...to be "conflicting" in some cases; the augmentation of which could consequently hinder improvements and stifle innovation' (ibid.).

In the Australian context, Blismas and Wakefield's (2009) study on the construction industry and the use of offsite manufacturing products (OSM) found there were similar regulatory challenges in Australia as with the UK and US. The authors argue these regulatory challenges arise from the fragmented regulatory framework across Australia, stating 'The regulatory constraints are multi-faceted ranging from qualifications, codes and local regulations. Legislation and qualifications are unclear for pre-casters (as opposed to concreters). Codes for varieties of OSM products are inadequate which creates uncertainty and extra work. Likewise, inconsistency between local and shire legislation and interpretations can create difficulties when using OSM' (p.81). For the authors, these constraints are expected given the limited use of OSM in this context. However, they recommend that regulatory change is needed to increase the use of OSM. In other words, an increase in the use of OSM should be accompanied by changing regulation designed to overcome fragmentation, uncertainty, obscurity and inconsistency.

Also from Australia, Steinhardt and Manley's (2016) study about beliefs and perceptions of MMC in the Australian construction industry show how government tenders are being designed can have an impact on the implementation of MMC within construction industry. They state 'Government housing tenders were criticised by interviewees for their short-sighted criteria that limited opportunities for prefabrication firms. They perceived that tenders favoured firms that produced traditional housing, had existing government relationships, and could produce high volumes of relatively low-cost builds using established methods.' (Steinhardt and Manley, 2016, p.37).

The Steinhardt and Manley (2016) study also touches upon a widely side-lined regulatory aspect about the adoption of MMC: financing and lack of regulatory initiatives to promote financing of MMC. This is a key issue for risk takers contemplating such changes allied to the certainty of demand. Findings from their study show there is 'a lack of support from the financial sector for prefabricated housing' (Steinhardt and Manley, 2016, p.37), which means companies adopting MMC had to 'internally finance entire projects until manufacturing was complete, rendering large-scale projects prohibitively expensive for all but the most successful firms' (ibid.). Their findings also reflect on policy failures to promote banks to finance MMC projects, revealing 'Respondents pointed to a lack of political will for regulatory authorities to compel banks to change ("Why would they?"). The high profitability of Australia's major lenders in the traditional housing market was also seen as a major deterrent to expanding their interests. This remains a central roadblock to reform, particularly given the existing power imbalance between banks and most prefabricated innovators' (Steinhardt and Manley, 2016, p.37).

Research from Hong Kong reveals planning and regulations to be among the major hinderances to MMC, but to a lesser extent than that described in the other contexts above. Zhang's (2018) research focused on the Hong Kong's building industry and explored the hindrances to using prefabrication. According to Zhang's (2018) analysis based on the literature, 'planning and regulations' were among the major hinderances together with 'cost and time aspects, lack of experience in the construction industry, the drawbacks of prefabrication and transportation issues, ...negative perception and management problems' (p.72). The study also conducted a survey and interviews and identified six major hinderances: (1) Inflexible for design change, (2) lack of storage space on site, (3) long lead-in time, (4) long design time, (5) high initial cost, and (6) high total cost (p.75). Policy issues, such as the lack of incentives and promotion were less considered as hindrances to using prefabrication compared to the six major challenges.



## 4. Business models

Despite there being a growing literature on business models in the business and management field, such knowledge in housebuilding and construction is comparatively underdeveloped, with a significant lack of research into UK practices in particular (Pan and Goodier, 2012). The authors argue that there is need for developing a specific definition of business models in the context of off-site construction and for developing a stronger knowledge base of their relationships and interrelationships. This, Pan and Goodier (2012) suggest, includes aspects relating to process, activities, risks, finance, strategy, organizational form, and firm structure.

Wuni et al's (2020) research reveals insight into the complexity of the challenge of builders and developers in adopting MMC business models and the unique processes that are involved in this alternative form of construction. The authors examined the literature on the risks associated with what they termed modular integrated construction. Their review revealed the industry to be resistant to modular integrated construction [MiC] as it was considered 'a risky approach owing to a perceived increased complexity in project delivery' (p.69). This is supported by Li et al., (2016), who suggest such risk and complexity in the business model impacts on industry's uptake: 'For example, the implementation of MiC [modular integrated construction] requires modular design, manufacturing, transportation, storage, and jobsite installation. These distinct stages of the supply chain of MiC are currently fragmented but substantially interdependent, resulting in manifold uncertainties which could compromise the successful implementation of MiC projects' (p.64).

Moreover, given the modular nature of MMC, modular parts are not easily replaceable from alternative suppliers for any given MMC project should this be necessary, which raises question beyond business models to supply chains and vertical integration. When examining business models, it is therefore important to recognise issues and problems stemming from the whole supply chain, with Shahtaheri et al., (2017) arguing that 'optimal configuration of the entire supply chain is required to minimize extreme uncertainties, disruptions, and disturbances during the construction process' (Shahtaheri et al., 2017, cited in Wuni et al., 2020, p.70).

Pan et al's (2012) study on off-site construction in the UK confirms the risks associated with this unique supply chain model, stating 'greater commitment to specific supply chains will inevitably reduce the house builder's flexibility with its supply chain strategy and introduce risks associated with planning and market changes. This suggests off-site integration as a dichotomy, which is really attributable to the general perception that most U.K. private house builders largely elicit profit from land development rather than construction processes' (p.1339).

### 4.1 Bias towards tradition and business culture inertia

In the UK context, research by Pan et al., (2007) presents one of the first in-depth investigations of UK housebuilder perspectives on the use of what they term offsite modern methods of construction. Whilst their research touched upon a range of issues, including regulatory practices and consumer preferences, it revealed some insight into how housebuilders perceived conventional and MMC-based business models. Indeed, whilst their results show that the housebuilders surveyed were generally satisfied with their own in-house traditional construction methods, with 82% satisfied/very satisfied, at the same time a significant number of housebuilders were not satisfied with the performance of offsite MMC, both within their own organizations (31%) and in the overall industry (47%). Many respondents had a neutral view on the question (41% and 44% respectively). Further, their research found 64% of housebuilders indicated the industry needs to increase the take-up of offsite MMC applications, with 21% not sure and 15% believing that no increase was necessary. Housebuilders did not generally see great potential for complete modular buildings.

The findings of Pan et al's (2007) study show that UK housebuilders are substantially more satisfied with the application of traditional construction methods than of offsite MMC, which the authors suggest illustrates the inertia within major housebuilders against the uptake of offsite MMC. The authors are keen to point out that their findings do not necessarily suggest UK housebuilders do not believe that there are considerable potential benefits from using offsite MMC. Rather, they suggest '... the current low level of satisfaction with offsite MMC application may be largely attributable to the low level of application of such technologies (see Pan et al., 2006) with builders, not surprisingly, being supportive of their preferred work methods' (p.189). Their research also revealed evidence of a critical lack of knowledge within UK housebuilders on the use and benefits of offsite MMC. This, the authors go on to argue, may support the view '...that construction companies are typically risk averse and do not include many innovators or early-adopters (Moore, 2002; Rogers, 2003), preferring to allow others to take the risk of developing new products before they adopt them for themselves' (p.189).

In a later and complimentary piece of work, Pan et al., (2008) reported on the utilisation of offsite construction methods by the UK's leading housebuilders, based on a questionnaire and a series of interviews. Their research showed the overall application of offsite-MMC as being generally low. Whilst offsite-MMC was taken on board by some housebuilders, many did not integrate it into their company long-term strategy, but rather utilized offsite technologies on an ad hoc basis for their projects (p.61). The housebuilders surveyed did not generally see great potential for complete modular buildings. The authors argue that most UK housebuilders were aware of the principle of integrating offsite-MMC early on but, in practice, adhered to conventional procurement methods (p.63).

Pan et al's (2008) study also revealed UK housebuilders assessed the potential for offsite-MMC against a wide range of factors including technical requirements, cost, time, site integration and logistical concerns, customer choice options, sales impacts, mortgage issues, and site constraints (p.61). Factors such as sustainability, restricted sites, government promotion, company strategy and clients' influences were of less importance in driving adoption. Interestingly, UK housebuilders did not regard issues such as current organization mechanisms and land acquisition processes in housebuilding business, or the risk-averse culture and fragmented nature of the industry, as significant barriers inhibiting the use of offsite-MMC. However, a number of firms did suggest a lack of previous experience with using offsite as preventing them from a wider take-up. In a later study, Pan et al., (2012) argued that despite various guidelines produced for off-site production in construction, 'it is still unclear how off-site production can be integrated into the house-building business processes at the organizational level and what relevant strategies are needed for optimizing the use of such technologies' (p.1332).

Nadim and Goulding (2011) undertook research to elicit construction industry perceptions and views in four different EU Countries - Germany, The Netherlands, Sweden, and the UK - regarding implementation of, and problems with offsite production (OSP). Their interview-based approach aimed to capture stakeholders' views regarding the traditional construction industry and the shift towards OSP and the introduction of 'openness' to the system. They sought the views from a wide range of professions, comprising suppliers/manufacturers, media communication, contractors, designers, developers, IT firms representing CAD operators and software developers, public administration, research institutions, and end-users. Several findings related to business model factors within the OSM context, covering practical and cultural issues.

First, from a practical perspective, respondents noted that any introduction of new models for working such as 'partnerships/alliances' would by default require the integration of different phases/processes to leverage synergy (p.92). However, Nadim and Goulding (2011) note that this integration is somewhat challenging for OSP practices when employing the current business model. Further, respondents noted that the approach of 'just-in-time' also need to be appreciated by the industry to '...reduce the cost of storage, as well as reduce the risk of theft and damage of material' (p.92).



Second, regarding cultural issues, respondents attributed resistance of the construction industry towards OSP to 'protectionism and conservatism' inherent within industry culture, as well as fear of 'lost identity' and 'change in role descriptors' (p.93). Notably, respondents perceived OSP as 'architecture off the shelf', which they thought would diminish individuality, uniqueness, and creativity. In addition, respondents acknowledged the current culture of 'late design changes and modifications requests' and the perceived bias towards the traditional way of building as also inhibiting take up (p.93). The latter was attributed by the authors to another cultural barrier concerning organizations' lack of planning capabilities, '... as according to the respondents, the current approach is to order only few days before the products are needed on site, which make it difficult to plan production and storage' (ibid.). The overarching view of respondents was that radical change was not possible and that 'evolution' rather than 'revolution' was advised.

Additional cultural factors inhibiting OSP uptake identified by respondents of Nadim and Goulding's (2011) study revolved around what the authors referred to as 'softer' issues, which were perceived to be as important, if not more important than technical features of the system. For example, this included 'soft issues of people with respect to the different roles', and 'training and education needs such as how legal issues and the market would be affected by the new system' (p.93). This was perceived by respondents '...to require new knowledge and understanding outside "one's expertise/ speciality", to encapsulate such issues as purchasing, production methods, labour market conditions, management, transferable skills such as teamwork and communication skills' (ibid.).

Similarly, in their study on the Australian construction industry and the use of offsite manufacturing products (OSM), Blismas and Wakefield (2009) also stressed 'negative cultural perceptions of OSM products' (Blismas and Wakefield, 2009, p.79) in the industry as a key constraint for its wider use, stating "'The whole industry is conservative" is how an industry practitioner has described construction, manifested as resistance to change by contractors, suppliers and professions' (ibid). The authors relate this negative perception with the extensive use of prefabricated housing in social housing projects constructed in the post war period as well the 60s and 70s. They argue that this resulted in 'giving OSM a reputation for producing only "low-cost" products' (Blismas and Wakefield, 2009, p.79).

In later research, Steinhardt and Manley (2016) studied the beliefs and perceptions of MMC in the Australia construction industry. This study was based on 14 interviews that explored housebuilders experiences in adopting prefabrication, 'with a particular focus on how the current views of the industry have affected their actions' (p.28). The study revealed, and confirmed other evidence, the stigma around MMC adoption in the industry, finding that 'perceptions of prefabrication as low-quality, cheap and ugly permeated the industry' (Steinhardt and Manley, 2016, p.34). The study also confirmed that the industry was being conservative adopting MMC in construction processes, which made its adoption even harder, revealing 'Lack of clear support from the architectural and building design sub-industries continued to manifest in difficulties tying prefabrication's standardisation to mainstream design sensibilities. The inertia of traditional trade resistance to both factory-based or panellised forms of prefabrication was also commonly acknowledged' (ibid). The authors argue that this overall creates an almost completely unsupportive industry infrastructure, which hinders the adoption of MMC. Even the early-adopter firms report that 'promised long-term benefits could not be realised without the support of the wider industry during the lengthy development process' (Steinhardt and Manley, 2016, p.35).

From a Chinese context, Zhang and Skitmore's (2012) study on industrialised housing (IH) in China also identified the problems of shifting 'from 'traditional and on-site construction' to 'innovative and industrialized housing'" (p.146), revealing that issues around business culture inertia and a bias towards traditions tend to transcend markets and contexts. According to the authors, 'housing developers in China are reluctant to switch technologies, perhaps because of their lack of familiarity and experience of industrialized approaches in buildings' (Zhang and Skitmore, 2012, p.144). This reluctance results in the fact that 'only few research institutes and housing developers in China focus on IH, and few buildings have been constructed with these industrialized methods' (ibid.) at the time the study was conducted. However, the authors acknowledged that 'a preliminary IH building materials and standardized production system has been established' (Zhang and Skitmore, 2012, p.144) in China.

Zhang et al., (2018), in their study on the Hong Kong's building industry, where they explore the hindrance to using prefabrication in this country, also identifies this business inertia apparent within in private sector: 'The use of prefabrication has become very popular in Hong Kong public housing projects owing to the focused effort of the Housing Authority in the last three decades. However, the application of prefabrication in the private sector is still challenging. In the private sector, most developers have been more hesitant to use prefabrication owing to the slightly higher cost of prefabrication when compared with conventional construction methods.' (p.71).

## 4.2 Hybrid strategies, the wider system, and a new paradigm of quality

Work by Lovell and Smith (2010) on the UK construction industry examined the industry's 'lock-in' to masonry house building, which at the time of research and publication they argued endured '... despite recognised shortcomings, even in the wake of government policies encouraging factory-based prefabricated alternatives' (p.457). Their data included 25 intensive interviews conducted in 2003 with UK government, housebuilders and consultants about the introduction of prefabrication as an element of social housing policy; and a postal survey of private sector UK housebuilders, conducted in 2004 and aimed at Technical Directors, which documented housebuilders' experiences of, and attitudes towards, prefabrication. Whilst the focus of Lovell and Smith's (2010) publication was largely theoretical - masonry house building as a socio-technical assemblage and the forces for inertia against the impulse for change in methods of housing construction - they did provide some pertinent reflections on business models based on their empirical research worth including in this review.

The crux of Lovell and Smith's (2010) reflections are around the concept of 'agencement' which they argue '...captures a sense of how whole systems (of housing construction) change, either incrementally through a process of ongoing 'jostling', or more radically as completely different modes of construction (for example) are forced together' (p.463). They suggest it is an apposite way to account for why masonry building 'enacted, re-formatted and made to prevail'. The authors make an important distinction between assemblage (as a description of what markets are or consist of in particular places and times) and agencement (as an active property or quality of markets - the quality by which they change, or remain the same), focusing attention towards masonry lock-in as an active process. Thus, the distinction is between a masonry assemblage and a prefabrication assemblage and agencements are '... made up of a continual jostling not just within, but also between, assemblages; and this jostling is a messy, unpredictable process'. (p. 463). The authors go on to note that the outcome of the jostling between masonry and pre- fabrication '... has been notable for the extent to which, despite significant differences in masonry and prefabrication assemblages, the initial adoption of prefabrication by UK housing producers has resulted in a hybrid strategy blurring the boundaries of the two assemblages. In other words, housing producers have used prefabrication in conjunction with masonry (ibid.).

With specific relevance to business models, Lovell and Smith (2010) go on to argue that the hybrid strategy of jostling between masonry and prefabrication can cause difficulties in relation to other technical construction issues suggesting that '... because masonry homes are craft-based (i.e. individuals build the houses with inevitable minor discrepancies), it is difficult to mix masonry construction with other more precisely engineered, high-technology construction methods, such as prefabrication' (p.464). Further, the authors make comment on another hybrid strategy adopted by UK housebuilders, which is to counteract negative public associations between prefabrication and poor quality low income housing by building prefabricated houses with a brick outer layer so they resemble masonry-built homes. The authors argue in this use of masonry cladding '... we see an attempt by prefabrication housing producers to respond to masonry lock-in by a strategy of alignment rather than distinction. In other words, prefabricated homes are being built which closely resemble those produced by masonry methods, whereas an alternative strategy would be to use the technological capabilities of prefabricated homes to build dwellings with a very different appearance,

and, whilst this approach has been taken in some prefabricated housing developments (see Greenwich Millennium Village, 2003; Hyde Housing Association, 2004) it is not the industry norm' (ibid).

The effect of such 'masonry lock in', highlighted by Lovell and Smith (2010), is that the institutions set up to support housing construction in the UK revolve around masonry products and techniques: planners, insurers, contractors, surveyors, and mortgage lenders all act in ways which create masonry lock-in. The authors research goes a long way to elucidate the complexities of '... creating change in a sector where one assemblage is locked-in, because opportunities for change hinge on the actions, beliefs and preferences of multiple organisations and things' (p.462).

Pan et al., (2008) also make comment on the importance of considering the wider context of housing supply within debates about MMC. In their research on UK housebuilders' strategies for increasing their use of offsite-MMC, they comment: '... it is worth noting that the main strategy used by housebuilders was to involve those directly involved in project delivery process (e.g. designers, manufacturers and suppliers). However, stakeholders who are indirectly involved (e.g. the public, mortgage lenders, insurers, planning authorities, and building control) were seldom mentioned. This suggests that housebuilders had developed substantial strategies within their direct supply chain, but neglected the great potential in the wider context of housing supply for using offsite-MMC' (p.66). They go on to argue this situation must be improved since an organization's strategy should be driven '... by an assessment of external opportunities and threats, and involve mediation between external forces for change and internal forces for stability (Tushman and Moore, 1988)' (p.66). The authors recommend a pan-industry mechanism to disseminate good practice as being crucial to the increased uptake of offsite-MMC in the future. They also argue that more attention be paid in future academic research to dealing with stakeholders who are not directly involved in project delivery.

From a European perspective, Nadim and Goulding's (2011) respondents perceived OSP as a manufacturing process requiring capital to set up and provide continuity, requiring a '... "consistent and predictable market"; and furthermore, require a paradigm shift away from a "supply market" to a "demand market"' (p.95). This contrasts with conventional construction methods as being traditionally low capital intensive.

Japan presents an interesting example for how branding techniques by housing manufacturers are being used to improve the image of MMC buildings, away from low quality housing and towards high quality homes (Noguchi, 2003): 'Japanese housing manufacturers have married their production methods to specially developed marketing techniques to skillfully satisfy local housing demands. In the past, manufacturers encountered many difficulties including strict building codes, building officials, local unions, banks and, in particular, consumers' prejudices that limited the popularity of industrialized housing. Manufacturers have seemingly overcome these difficulties by developing their own 'quality-oriented' production approach that focuses solely on responding to consumer demand for housing quality, while housing affordability has been less of a consideration.' (pp.353-354).

According to Noguchi (2003), prefabricated housing companies in Japan have improved the quality of their products over the years while also actively using marketing strategies and branding techniques to improve the image of the prefabricated housing. The prefabricated housing industry in Japan was dominated by large housing manufacturers. In fact, 'the ten largest housing manufacturers produced an estimated 97.2% of all new prefabricated detached homes' (p.356). These large companies were able to fund R&D developments, marketing campaigns as well as offering long warranty periods: 'housing manufacturers usually offer a ten-year warranty and post-purchase services, such as free regular check-ups, to maintain the quality of their products for long-term use. Such systems of quality certification enhance levels of customer satisfaction (CS) by reducing the risks that normally concern potential homebuyers both before and after the purchase of a prefabricated house (Mishima, 1996)' (p.357). The key issue for these marketing campaigns was that 'manufacturers emphasize that they have been producing 'better-quality' homes for about the same price as conventional homes' (p.358). As part of a 'cost performance marketing strategy', the companies are not aiming to market these houses based on affordability, although their production costs are drastically reduced: 'today's tendency among Japanese housing manufacturers is to compete to improve the quality of their products rather than to reduce the selling price (Sekisui Chemical, 1998a)' (ibid).

One key aspect of this 'quality-oriented approach' is mass customisation: 'In effect, manufacturers mass-customize their industrialized homes by mass producing housing 'components' (as opposed to entire housing 'models'), and the combination of these components enables buyers to customize their new homes in response to their individual housing demands' (Noguchi, 2003, p.363). This approach is based on the repetitive use of mass-produced housing components and effectively cuts the cost compared to custom made ones while presenting an array of choices for the users. Noguchi (2003) asserts, through this approach, that 'in practice, manufacturers maintain high selling prices by adopting cost-performance marketing strategies that allow them to provide a variety of 'standard equipment' that considerably increases product quality without, at the same time, increasing users' 'economic' choices' (ibid).

# 5. Consumer practices

## 5.1 Adverse public impression

Work in the UK context by Pan et al., (2008) on housebuilders utilisation of offsite-MMC found that issues of purchasers' perceptions were claimed negative to offsite practices. Lovell and Smith (2010) suggest this is because prefabrication has been typically used in the social housing sector in the past. This historic link, they go on to argue, is problematic due to '... a number of highly publicised problems with prefabricated social housing in the past, such as the Ronan Point tower block collapse in the late 1960s (Ross, 2002)' (p.462). The authors put this down to 'systemic failure' - if a defect is found, then it will be common to all dwellings built using that particular technology - and that negative consumer and industry attitudes about prefabricated housing based on this historical experience are a continuing influence perceptions. Lovell and Smith (2010) go on to state that in the UK, mortgage lenders have been reluctant to lend money on contemporary prefabricated homes<sup>4</sup>. In effect '... historical social and institutional issues have been carried forward with the prefabrication technology even as, as proponents of 'modern' pre-fabrication would claim, concerns about systemic failure are now unfounded' (p.464).

In the Chinese context, Zhang et al., (2014) found that lack of government promotion had caused some consumer misconceptions concerning housing industrialisation. The authors suggest that without adequate promotion and incentives provided by the Chinese government, it appears the public perception of construction methods including offsite production remains defensive. This is a particular acute issue given China's 1980s prefabricated housing programme suffered from many quality problems that left customers with the negative impression that '... industrialised housing means that quality is not guaranteed' (p.182). The authors argue the current Chinese government's lack of promotion has not yet changed this adverse public impression.

In the UK context, research by Pan et al., (2007) on the perspectives of housebuilders on the use of offsite technologies found that changing people's perceptions was an important factor in overcoming barriers to enhanced uptake. Even though housebuilders revealed that attitudinal barriers due to historical failures (11%) and client scepticism (4%) were relatively minor barriers when compared to higher capital costs (68%) or difficulties in achieve economies of scale (43%), they were deemed important to address for increasing uptake. Indeed, housebuilders suggested 'changing people's perceptions' as one of 6 core recommendations, the others being improving procurement; providing better cost data; tackling planning and building regulations; encouraging political leavers; and, providing guidance on the use of offsite MMC (p.189). Housebuilders suggested a series of implementation strategies to address how to change people's perceptions that included: test and demonstrate that offsite MMC can deliver as good or better performance than traditional methods; provide a UK central site with practical offsite MMC examples; develop a consistent and objective approach to the use of offsite techniques amongst institutes (ibid.). The broader point emerging from Pan et al's (2007) research was that enhanced MMC uptake requires commitments from the whole supply chain covering housebuilders, designers, manufacturers and suppliers, institutions and the government.

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<sup>4</sup> Whist modular construction is gaining popularity in recent years, it's commonly accepted that the mortgage industry hasn't caught up. Some lenders remain reticent to lend on such non-standard construction.

## 5.2 The characteristics of the consumer

Koklic and Vida (2011) undertook research on consumer strategic decision with recent owners and potential buyers of prefabricated houses in Slovenia. Their research was smaller in scale than other studies included in this review but was deemed to be conceptually strong, methodologically well deployed and offering some worthy insights to be included in the review. Koklic and Vida (2011) sought to understanding the processes of prefabricated house purchase in Slovenia to help consumers make informed, responsible buying decisions. Their findings revealed a person's self-concept, identity, and extended self to be important during home buying process, with the house as a product that is closely related to the homeowner's self-concept. Respondents viewed the house as a part of their personality or their extended self and most wanted a custom-made house to reflect their lifestyles, with household members intimately familiar with their desires and lifestyles, which lead to their house design preferences.

Koklic and Vida's (2011) research further revealed that the buying process of a prefabricated house was influenced by both internal and external factors, with external factors namely being:

- other people's opinions and time pressure as part of the socio-cultural environment
- marketing communications in the housing market
- sellers' (manufacturers') behaviour representing the companies' marketing efforts, mainly from the first moment purchasers contacted the seller
- recommendations provided by friends or other homeowners with experiences and information about the prefabricated house

In terms of internal factors that mostly influence the decision-making process, Koklic and Vida (2011) found these include an individual's motivation, involvement, personality, self-confidence, knowledge, affect and prior experience (p.639). The authors go on to state that '... the notion that a custom-made house requires high involvement and strong motivation has been confirmed in our empirical work and was reflected in an intensive search for information about various producers/sellers in the housing market. Our participants actively engaged in information gathering, mostly because they perceived their existing knowledge as insufficient' (ibid.).

When it came to commonly used criterion for choosing a home, Koklic and Vida (2011) found that the house being custom-made was the most important, followed by company behaviour, namely how the representatives of the house producer communicated with the potential buyers (p.639). A sense of feeling confident about the company was mentioned several times by their respondents, indicating potential buyers '...needed to have trust in the company's process of production and delivery of their house' (ibid.). The authors go on to suggest that '... as house purchase is a rather risky venture - mainly due to its high price and longevity - the seller/company's reputation matters a great deal' (p.640). Finally, the authors research also suggested that house buyer consideration of a specific manufacturer/company depended on two key factors: (a) information kept in memory; and (b) the word-of-mouth recommendations.

Koklic and Vida's (2011) research provides an important perspective on consumer perception when it comes to prefabricated housing, that is one where emotionally charged internal factors are as important as external factors in the success or otherwise of this form of housing provision. Their results confirm the notion '... that cognitive and rational factors alone do not offer a sufficient explanation of consumer behaviour in the case of high-involvement products being purchased only a few times in a person's lifetime. In addition to the idiosyncratic characteristics of the customer, his or her personal situation and environmental factors, the role of feelings, experience, subconscious factors, needs and goals should be taken into account to better understand strategic consumer decision making and choice process when buying a house' (p.641).

Elsewhere, Svajlenka and Kozlovská's (2018) study explored MMC in the context of Slovakia, but for the wooden structures. This is an extensively underexplored area since MMC is predominantly associated with precast concrete. The authors analysed the buildings regarding sustainability parameters and users' perception for the quality of MMC-produced wooden buildings. They found out that for both sustainability and quality, the users were satisfied with these buildings. In contrast, Jeong et al's (2013) study on customer relationship management in the US manufactured housing market reports that 'manufactured homeowners continue to report slightly lower satisfaction levels than conventional site-built homeowners' (Jeong et al., 2013, p.26) according to the American Housing Survey.

## 5.3 Standardisation vs. customisation

Debates around the customisation of MMC homes are concerned mainly with mass customisation, which in this context, is about "creating variety and customization through flexibility and quick responsiveness" within the requirements of developing processes for low-cost volume production of goods and services (Pine 1993, 44)' (Patchell, 2002, p.289). As discussed in the previous section, such a strategy has been successfully implemented by prefabricated housing companies in Japan extensively (Noguchi, 2003). Indeed, in the Japanese context, Noguchi (2003) reported that 'In a 1999 JPA survey studying consumer preferences in the purchase of prefabricated homes, the perceived high quality of prefabricated housing was the most significant factor attracting potential homebuyers' (p.357). However, in other contexts, challenges have arisen about the balance between customisation and standardisation with MMC practice.

Research by Nadim and Goulding (2011) on European construction firms views of what they term offsite production (OSP) revealed an interesting paradox between a potential shift towards customization in the consumer base and the tendency towards standardisation that OSP naturally entails. In respect of design concerns, respondents perceived automation as '... difficult to achieve without standardisation which would counteract flexibility (p.95). Their respondents also perceived standardisation as '... "unrealistic" if the market was striving for "individuality"; and advised that OSP would need to embrace the "soft emotional and individual" issues'... people would feel they have "influenced" the project with respect to their preferences and individuality'. (p.94). In this sense, respondents advised that 'standardisation is only welcomed in "repeatable/less distinguished buildings", and that OSP was not appropriate for "statement buildings"' (ibid). Relatedly, Nadim and Goulding's (2011) research covered aspects of design quality, where respondents were of the view that quality was starting to gain momentum over cost and in the medium-term, would be as important as the price. The impact, the authors suggest, is that OSP products would need to demonstrate better quality than traditionally build, which would require the better management of tolerances and inaccuracy.

In the United States context, Jeong et al's (2013) study on customer relationship management in the US manufactured housing practice examined manufacturers and retailers of MMC produced housing. In this practice, the customers, as future users, were given options for customisation: 'One of the important steps for customers is to select the features of the house depending on their taste and budget limitations. The interior design options include custom cabinets, walk-in closets, bathrooms with recessed tubs and whirlpools, fireplaces, and upgraded appliances (Manufactured Housing Institute (MHI), 2006). Customers can also choose from many exterior designs such as exterior siding material, hardboard awnings, and enclosures around the crawl space, patio covers, and decks (MHI, 2006)' (p.25). However, the process was not as straightforward as it may sound at first glance. The authors pointed out the issues related to 'capturing each customer's preference in an efficient way' (ibid.). In addition, customisation was limited for certain interior or exterior finishing and there was a lack of standardisation in the process of customization between manufacturers and retailers.

Further customer-related issues highlighted by Jeong et al's (2013) study revolved around customers being able to access the necessary information to make informed decisions: 'Limited visibility through the house purchasing process makes the customers unsatisfied. What houses are available where, and whose houses are built best? Which retailers are trustworthy? What financing is available? Usually, customers find it difficult to obtain information on house quality

and available options for themselves. The dealership sales process discourages shopping through high-pressure sales techniques and deposit requirements. Customers may lack the technical expertise to ascertain the quality of the construction process and materials used to construct the house' (p.26). As a result, the authors suggest 'there is an imminent need to create a customer-centric, cross-functional process solution' (ibid).

Patchell's (2002) study on the Japanese housing market also points out the importance of interaction between the customers and housebuilders regarding the customisation process to overcome the associated issues: "This customization process begins with consultation between customer and salespeople at the local office of the builder. Customers are asked about family size, lifestyle, possessions, retirement plans, income, and so on. Customization progresses through familiarization with products, tours of model homes, site inspection, CAD and virtual reality design, choice of fittings, furnishings and facilities, coordination of interior and exterior, financial advice, cost estimation, and, finally, the signing of the contract. Engineers and architects staff the sales offices to assist design and consultation. The process takes up to ten months because of the time needed for consultation and government approvals." (p.297). As the quotation reveals, this is a time-consuming process as well as being information intensive.



# 6. Conclusion

Our evidence review has revealed five key aspects about modern methods of construction. First, it is observed that the literature contains multiple, even competing, definitions for modern methods of construction. These are sometimes used interchangeably and sometimes to refer to specific aspects of MMC. Second, the review revealed that in many contexts, the state and the market worked together to facilitate the wider use of modern methods of construction, with the state rolling out the regulations that promote and facilitate the wider use of MMC and market actors delivering the MMC projects. This finding highlights the misconception around the roles of the state and market in housing supply systems as being competing, even adversarial actors. Third, our review showed that modern methods of construction can boost housing supply, however, this shouldn't be considered as a quick fix. On the contrary, a holistic and long-term approach is needed to expand MMC within conventional housing development practice. Fourth, whilst modern methods of construction are more standardised than traditional construction products, an MMC building doesn't necessarily lead to a more standardised product when compared to a mass produced one. Fifth, there is a pervasive hangover of previous low-quality prefabrication applications, but this is not a necessarily an 'end of the story' situation. We go on to unpack these aspects in turn before discussing whether MMC can address systemic supply issues, as this question dominates contemporary MMC-related debates in the UK.

## 6.1 Competing definitions

It is observed that the literature contains multiple, even competing, definitions for modern methods of construction. These are sometimes used interchangeably and sometimes to refer to specific aspects of the construction process (e.g., prefabricated housing) or particular MMC processes and applications, such as industrialised building (Zhang et al., 2014), offsite production (Nadim and Goulding, 2011) or offsite manufacture in construction (Blismas and Wakefield, 2009). The choice of term used in the studies is far from random. Lovell and Smith (2010) for example avoid using the term prefabrication and prefer to use modern methods of construction. The authors suggest this is largely '... in an effort to dissociate contemporary factory-produced housing from its historical technical problems' (p.465). Wuni et al's (2020) study demonstrates the complicated use of similar - not the same - terms in the literature:

*"Owing to these benefits, models of MiC [modular integrated construction] are promoted in Australia, Canada, USA, the UK, Singapore, Sweden, South Korea, China, and Malaysia such as off-site manufacture, modular construction, prework, off-site production, prefabricated prefinished volumetric construction, industrialized housing construction, and industrialized building systems." (p.64).*

Some of these definitions are context-dependent (e.g., the concept 'industrialised building' is used in China to refer the modern methods of construction) or sector-dependent (e.g., prefabricated housing). This multiple, interchangeable, even competing, use of terms and concepts creates challenges in understanding the extent of the application of modern methods of construction. This challenge is critical, especially when exploring applications and case studies from other contexts or specific sectors of the construction industry, such as housing or even tenure. The prevalence of multiple terms and concepts can perhaps be expected, since similar methods and applications do take place in various countries and varying sectors of any construction industry. Interestingly, it appears that, in some contexts, terms are being produced by experts to mitigate the stigma around 'prefab' (see Lovell and Smith, 2010).

Rather than trying to homogenise the vast literature around modern methods of construction, we hope this evidence review will help to mitigate this definitional challenge for researchers and practitioners by revealing these multiple definitions. For those who would like to explore MMC practices and their applications in other contexts, we hope our findings provide a helpful guide for the concepts to look for some context-specific definitions as well.

## 6.2 The state versus market misconception

Our review revealed that in many contexts where MMC practice was more prevalent, the state and the market both worked together to facilitate its wider use. This reveals a misconception around the roles of the state and market in contemporary market-led housing systems. It is often expected that the market be the key driver of innovation or indeed, a disrupter to conventional and traditional construction techniques. The studies in the evidence review showed that in countries where MMC practices were widely used (e.g., Hong Kong), governments had rolled out extensive incentives, policies and regulations to facilitate the use of MMC in housing production. These programmes paved the way for further innovation in the construction industry, not only through providing incentives to the companies to adopt MMC, but also by setting up new institutions to facilitate knowledge exchange and learning.

The Hong Kong case in particular shows how the state can facilitate expansion in the use of MMC through its role as a 'commissioner' of housing (through the Housing Authority in Hong Kong). Chiang et al's (2006) study in particular emphasizes the demand-driven push by the Housing Authority to facilitate an increased use of MMC in housing provision:

*'Contractors might not have chosen prefabrication, if it had not been mandatory, and might not have taken the opportunity to drive costs and consequently tender prices down in the long run' (p.485).*

While the review revealed that regulatory bodies may have a potentially transformative role in encouraging expansion in the use of MMC by the market, their regulatory focus may, or may not, be about both/either quality and/or quantity of new buildings.

On the other hand, the Japanese case included in this review showed how industry itself transformed the perception - and therefore the uptake - of houses produced using modern methods of construction. The state actors supported this push by rolling out policies and setting up a regulatory body for MMC, the Japan Prefabricated Construction Suppliers and Manufacturers Association (Patchell, 2002). The aim of this association was 'to support research and training, undertake promotion activities (e.g., managing model-home sites), and foster information exchange and collaboration on standards' (Patchell, 2002, p.288). According to Patchell (2002), the 'promotion of collaboration was most significant, because the establishment of industry standards for quality fostered public trust in the industry and in individual builders' (p.288).

Resonating with these multiple interventions utilised in these two contexts is Lovell and Smith's (2010) argument based on their research on the UK construction industry. The authors argue there is a need for a state wishing to effect change to conceive of markets and intervene in them using more subtle approaches than those typically employed by policy makers. All these examples demonstrate how the state and the market worked together in a complex relationship to achieve MMC goals. Therefore, the conception of the state and the market as being dichotomous is somewhat misleading in capturing the nature of this relationship. It is plausible even to suggest the state and the market could swap 'leader' and 'follower' roles, for example with the state initiating regulatory change as opposed to supporting and popularising market-led business practice change. As such, regulatory bodies, in deciding whether to pursue MMC policies, should consider which policy target(s) they are seeking to address in order to maximise clarity and certainty in the market and accurately define the intended recipients.

## 6.3 Not a quick fix

Our review revealed that using modern methods of construction can boost housing supply. However, this should not be considered as a quick fix. In the UK, which is facing a housing crisis, modern methods of construction are, from time to time, proposed as a quick solution to speed up build out rates and increase housing supply over a short period of time. However, the studies reviewed in this research show that the expansion of MMC practices require regulatory mechanisms, supply-chain considerations and in many cases, the transformation of existing business models. We discuss these in turn.

First, as was discussed in the previous section, policies, incentives, and new regulatory bodies may work to facilitate the wider use of MMC within the construction industry. However, these all require long term commitment by state actors, and therefore, policies targeting long term transformation in the construction industry. The evidence from Hong Kong (Chiang et al., 2006; Li et al., 2016) shows it takes decades long commitment by state actors to effectively facilitate MMC adoption.

Second, the studies we investigated in this review show that the implementation of modern methods of construction requires a consideration of the whole supply chain. Zhang et al., (2014) for example list the lack of supply chain as among the six major barriers to industrialised buildings. Wuni et al., (2020) also draw attention to the role of the supply chain in the effective implementation of modular integrated construction. They reveal that distinct stages of the supply chain are currently fragmented but substantially interdependent and manufactured parts for construction projects cannot easily be replaced with something else. This indicates that problems in the supply chain are therefore likely to have a bigger impact on the MMC process than a traditional construction process. Such practices undermine propositions of MMC as a quick fix for the housing shortage. This is not inconceivable when considering the significant materials shortages that affected the UK housebuilding industry after the global financial crisis (Payne, 2020).

In addition, modern methods of construction usually require large capital investment. This requirement reveals its impact in the potentially monopolistic behaviour among companies operating in sectors of the construction industry where MMC is widely used. Indeed, Pan et al's (2007) UK study indicated higher capital cost as among the major barriers to MMC applications. Noguchi (2003) argues that in Japan, the prefabricated housing industry was dominated by large housing manufacturers that were able to fund R&D developments and marketing campaigns as well as offering long warranty periods. As a result, this capital investment challenge is likely to have an impact on the supply chain by limiting the actors able to enter this market.

Third, in connection with the capital investment and supply-chain aspects, the evidence indicates that companies that adopt modern methods of construction are often required to transform their business model according to these specific construction needs. The key point of difference here is in the bespoke supply chain requirements of MMC when compared to traditional construction processes and how housing systems respond to these institutionally. Despite a growing literature on business models in the business and management field, it remains stubbornly limited for the housebuilding and construction industry, albeit for MMC as a sub sector (Pan and Goodier, 2012). Wuni et al., (2020) argue that the industry is resistant to modular integrated construction due to their need to change traditional construction practices. The industry is resistant to this change as it brings about additional costs and is considered as risky. Further, it is not likely that individual companies will achieve industry-transforming change themselves, since effective change will require the whole supply chain to be integrated in this transformation. This may limit the effectiveness of leading supply actors in acting as 'agents of change', disruptors or pioneers since they are less likely on their own to cause the strategic alignments necessary to generate large scale practice change.

To this end, Pan et al., (2012) argue that despite various guidelines produced for off-site production in construction, 'it is still unclear how off-site production can be integrated into the house-building business processes at the organizational level and what relevant strategies are needed for optimizing the use of such technologies' (p.1332).

In addition, Nadim and Goulding's (2011) study indicates that any introduction of new models for working, such as partnerships and alliances, would require the integration of different phases and / or processes to leverage synergy. There was no evidence to suggest that businesses could adopt both MMC and traditional construction as equal forms of output.

In considering these three key aspects, policies that aim to use modern methods of construction as a quick fix to boost housing supply are not realistic and may even be misleading. A holistic and long-term approach that focuses on quality over quantity can, on the other hand, potentially expand the adoption of the modern methods of construction within the wider housing system.

## 6.4 It is not just about standardisation

Since modern methods of construction involve industrialised, lean and systemised approaches, often in controlled factory settings, product and process standardisation is likely. There is a tendency to consider MMC leading to a highly standardised form of housing, which is a key design and place making critique often levied at mainstream volume developers. In contrast, the studies investigated in this review reveal that applications of modern methods of construction present an urge to diversify the look, design and character of the products delivered by these methods. Three cases, two from Japan and one from the US, particularly engage with the ways in which customisation is possible with MMC products. The strategies defined in these studies mostly refer to a '... mass-customisation' strategy that is to say 'mass producing housing 'components' (as opposed to entire housing 'models'), and the combination of these components enables buyers to customize their new homes in response to their individual housing demands' (Noguchi, 2003, p.363). Noguchi (2003) asserts, through this approach, that 'in practice, manufacturers maintain high selling prices by adopting cost-performance marketing strategies that allow them to provide a variety of 'standard equipment' that considerably increases product quality without, at the same time, increasing users' 'economic' choices' (p.363).

An important aspect to customisation in MMC products is the engagement with the future users. As indicated in the US case, future users are given options for customisation through an array of options for the interior and exterior design of the buildings (Jeong et al., 2013). Patchell's (2002) study on the Japanese housing market points to the importance of interaction between the customers and housebuilders within the customisation process but warns that it is a time-consuming and information-intensive process.

All in all, the studies show that although there is a mainstream understanding that projects based on modern methods of construction are more standardised than traditional construction products, an MMC building doesn't necessarily mean a more standardised product. However, customisation processes have their own challenges despite the positive aspects these would bring to the satisfaction of future users and overall quality of the building. Moreover, a mass customisation strategy has its limitations as it is still based on the selection of units from a palette of standardised parts of the building. Therefore, it is not a means of producing fully customisable and bespoke buildings, but rather of providing a choice from a selection of parts to future users.

## 6.5 The hangover of prefabrication

Many studies included in our review refer to the hangover of problematic and low-quality prefabrication practices (e.g., Zhang et al., 2014), especially from the post-WWII period. This they suggest has created a stigma around modern methods of construction. Contemporarily, the prevailing emphasis on quantity - that is, of MMC speeding up housing supply - also feeds into this stigma, possibly sabotaging intended policy goals of enhancing the wider use of MMC. Steinhardt and Manley's (2016) study about MMC in the Australian construction industry demonstrates this perception starkly, suggesting that 'perceptions of prefabrication as low-quality, cheap and ugly permeated the industry' (p.34).

In contrast, the Japanese case demonstrates an interesting example of how changes in the perception of the MMC buildings as low quality and monotonous were achieved. Noguchi (2003) notes that the perception for prefabricated homes in Japan in the 1960s and 1970s was associated with low quality due to simple mass production techniques and monotonous design schemes. The subsequent creation of the Japanese Prefabricated Construction Suppliers and Manufacturers Association (JPA) aimed to improve this image. Prefabricated housing companies in Japan were able to improve the quality of their products over the years while also actively using marketing strategies and branding techniques to improve the image of the prefabricated housing (Noguchi, 2003).

All in all, while there is a pervasive hangover of previous low-quality prefabrication applications, the Japanese case shows that this is not a necessarily an end of the story situation. The potential for modern methods of construction to enhance perceived quality will be a key factor in successfully responding to this hangover effect. A discourse relating modern methods of construction with quality, on the other hand, doesn't guarantee delivery of quality products. A discursive improvement without material delivery of quality buildings via MMC would potentially have an even worse impact in the future than the previous low-quality prefabrication experience. This may help explain the muted uptake of MMC within mainstream housebuilding industries across the globe.

## 6.6 Can MMC address systemic supply issues?

The aim of this evidence review was to evaluate the potential role of modern methods of construction in addressing systemic supply issues. Our focus has been on looking to international evidence that covers business models, regulatory practices and consumer preferences as core aspects of understanding what drives the adoption of MMC.

Our conceptualisation has been one of modern methods of development (MMD) that we hope will reframe policy and industry debates away from a narrow focus on construction to a broader consideration of how the key components of residential development can enable or constrain MMC uptake. A key drawback for the debates around MMC is the fact that it is seen as a problem of construction methods. Our review on the other hand shows that wider adoption of MMC requires a comprehensive look at the whole development process. This requires a change in perception and we argue that the scope for modernisation will remain limited until focus is placed on MMD and not simply MMC. In turning to our final point, whether MMC can address systemic supply issues, we argue that this change in perception - from solely construction to development - would also help to understand these systemic supply issues rather than seeing MMC as a quick fix that can boost the construction speed of housing units in the short term. We now consider the findings our three lines of enquiry - regulatory practices, business models and consumer preferences - in turn as well as reflecting on the definitional issues identified at the beginning of the report.

Regarding regulatory practices, our findings indicate that state leadership is crucial in promoting and incentivising MMC as a mainstream form of housing provision. Regulation can act as a driver, facilitator and promoter for the wider adoption of MMC for responding systemic supply issues such as the inadequate number of new builds or low-quality housing units. The regulatory practices from different countries investigated in this review showed that these could be a combination of different policy tools in action, including but not limited to, incentives, setting up new industry bodies, and rolling out MMC requirements for public housing tenders. A key aspect to note here is the fact that

regulation should include both increasing the quality and quantity of housing supply rather than promoting MMC simply as a booster for increasing the number of new build houses.

When it comes to business models, the evidence revealed that MMC requires unique processes that are involved in this alternative form of construction, which are often considered risky due to project complexity and a fragmented supply chain. Evidence from Pan et al., (2008) showed that housebuilders did not integrate MMC into their company long-term strategies, but rather utilised off site technologies on an ad hoc basis. These issues indicate that the take up of MMC practices - and modular housing in particular - by the currently dominant producers may be unlikely and may help explain why MMC has not become an industry norm, remaining the preserve of 'disruptors' and specialist SMEs.

Turning to the end user, much needs to be done to address the prevailing perceptual hangover of prefabrication as low quality and substandard. If MMC, and modular housing in particular, are to gain institutional traction and become more normalised forms of housing delivery, consumer perceptions about quality must be addressed. A few case studies included in this review show that it is possible to overcome this stigma by focusing on the quality that MMC can deliver, in addition to its potential for the faster delivery of housing. The responsibility of changing this perception and overcoming the stigma around MMC fall both to the state and the market. This will require not only discursive interventions such as branding, but also material / tangible pilot projects and showcases demonstrating the potential quality that MMC can deliver as opposed to failed poor quality examples.

Finally, we'd argue that definitional clarity - in both academia and practice - is needed to overcome the perception bias of MMC as poor quality and to educate interested parties on the multiple benefits that modern construction methods in all versions bring. One of the key issues we've faced in this review is working to an agreed definition of MMC. In the UK, the work done by Cast Consultancy (Cast Consultancy, 2019) to regularise terminology and produce a definitional framework appeared much later than most of the studies included in this review. Therefore, whilst definitional clarity is to some extent moving forward in industry and policy contexts, academia lags way behind. This we argue frustrates attempts to present a comprehensive picture of MMC research and the important role of institutional context in evaluating individual countries' approaches - successful or otherwise - to enhancing MMC adoption.

In conclusion, our report reveals importance nuances in the debates around the practice of modern methods of construction that we hope will be helpful to policymakers and industry leaders alike.

For policy makers, the key question is whether MMC is integral to meeting housing supply numbers or whether its value is simply in supporting other policy objectives. Either way, the policy discourse should be clear, consistent and certain.

If MMC is seen as a means of simply speeding up housing delivery, this comes with a potential 'perception cost' and with it, reputational harm for the manufacturer / developer should quality and design value emerge as issues during the development process and in after sales.

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# Appendices

## Appendix A: Review Guidance

### CaCHE Evidence Review Guidance: Modern Methods of Construction Project - The Potential Role of Modern Methods of Construction in Addressing Systemic Supply Issues

#### Purpose of the Review Guidance

- To facilitate a structured conversation at the start of proposed evidence review
- Ensures consistency in setting up the reviews, but enables diversity in terms of the ultimate scope of projects
- Provides evidence of the process used to set up a review, including the justification for restrictions, exclusions and limitations. This can be used to feed into the write-up of methods for reports and papers

#### Defining the Review (Step 1)

##### Review's Aim / Purpose:

A small number of UK housing providers are now utilizing construction integrated manufacturing (CIM), also known as modular construction, to deliver new homes. The potential for this form of housing provision to speed up and diversify housing delivery is of growing interest among policy makers and wider industry stakeholders (Mayoral Housing Strategy, 2018; RICS, 2018; Letwin, 2018, Farmer, 2016). Indeed, modular construction has the potential to introduce greater levels of productivity, quality, quantity, sustainability, design and diversity to the UK housing system. Despite these advantages, the level of take up and adoption into the market remains limited and the UK now lags behind the US, Germany, Sweden, Japan, France and the Netherlands in utilizing CIM technologies to deliver new homes. Much of the existing evidence on modern methods of construction is technical and materials-based, focusing on the science of construction technologies, processes and management. Very little evidence exists on examining how modern methods of construction fit into existing residential development practices or what business models and regulatory practices may enhance the uptake of modular home development. It remains unclear what challenges modern methods of development may present to a housebuilding industry built on 'brick and block' masonry construction; and, whether housebuilders have the capacity to incorporate radically new construction methods into their wider development practices.

##### Research Objectives:

Drawing on an international evidence review, the project will evaluate the potential role of modular construction in addressing systemic supply issues. The project will deliver on the following objectives:

- 1) what business models, regulatory practices and consumer preferences drive the adoption of MMC;
- 2) what evidence exists to explain the low uptake of MMC in residential development practice; and,
- 3) what policy and market processes might enhance the adoption of MMC in the UK housing system.

Keywords and Search Queries:		
<p>First Chunk (to be repeated): (“offsite construction” OR “off-site construction” OR “offsite production” OR “off-site production” OR “offsite manufacturing” OR “off-site manufacturing” OR prefabrication OR prefabricated OR prefab OR “pre-fab” OR “pre-fabricated” OR modular OR modularization OR “modern methods of construction” OR MMC OR volumetric OR “industrialized building system”) AND (housing OR home OR house OR housebuilding))</p> <p>Business Models - Query 1: (First Chunk) AND (“business model” OR “business strategy” OR “business strategies” OR behaviour OR transition OR investment)</p> <p>Regulatory Practices - Query 2: (First Chunk) AND (policy OR planning OR regulation OR “regulatory practices” OR policies)</p> <p>Consumer Behaviour - Query 3: (First Chunk) AND (demand OR preference OR consumer OR sale OR experience OR occupant OR occupancy OR resident)</p>		
Agreeing on the Search Strategy (Step 2)	Criteria/ approach	Justification
<p>Conduct a scan to “get a feel of the literature”</p> <p>Completed by Bilge Serin and Sarah Payne.</p>	General search.	To familiarise the research team with the recent literature.
<p>Search Medium: Where to look?</p> <p>First: Index search using Scopus and Web of Science.</p> <p>Second: Follow-up/snowballing references on the reviewed sources.</p>	<p>Broad.</p> <p>Follow-up/snowballing</p>	<p>To reach evidence beyond the circles of the research group.</p> <p>To reach the primary sources and possible further evidence.</p>
<p>Type of the Sources</p> <p>Included sources: What to review?</p> <ul style="list-style-type: none"> <li>Peer reviewed journal articles</li> <li>Book chapters</li> </ul> <p>Excluded sources: What NOT to review</p> <ul style="list-style-type: none"> <li>PhD thesis and dissertations</li> <li>Conference papers</li> <li>Books</li> <li>Grey literature (e.g., non-peer reviewed academic papers, reports, policy briefs, working papers)</li> </ul>	Inclusive	To produce an exhaustive but focused evidence review (scholarly sources only).

<b>Creating a Core Database (Step 3)</b>	<b>Criteria/ approach</b>	<b>Justification</b>
<p>Collate the sources into a core database</p> <p>Tool/Software: Endnote</p> <p>The two-phase-method:</p> <p>First: Downloading and recording the sources with their abstracts and keywords, merging the query results into a main database compiled by using Endnote, and eliminating overlapping results.</p> <p>Second: Reviewing the titles (firstly) and abstracts (secondly) of the sources in the database in order to exclude unrelated sources according to the first-round inclusion-exclusion criteria (below).</p>	Focused, but comprehensive	To narrow down to the related sources and create a comprehensive but focused database for the following step.
<b>Reviewing the Evidence (Step 4)</b>	<b>Criteria/ approach</b>	<b>Justification</b>
<p>Review the full-texts of the sources contained in the database in order to exclude unrelated sources, according to the second-round inclusion exclusion criteria (below).</p> <p>Tool/Software: Endnote/Microsoft Word.</p>	Systematic and informed.	To review existing evidence according to the agreed inclusion-exclusion terms.
<b>Quality Appraisal (Step 5)</b>	<b>Criteria/ approach</b>	<b>Justification</b>
<p>The publications to be assessed according to Quality Appraisal Checklist and the ones below the threshold to be excluded.</p>	Systematic and informed.	To systematically evaluate the quality of the studies and exclude the ones below the threshold.
<b>Data extraction (Step 5)</b>	<b>Criteria/ approach</b>	<b>Justification</b>
<p>What to extract from the full text.</p> <p>Provided below as data extraction categories (inclusion-exclusion criteria).</p>	Systematic and informed.	To systematically extract existing evidence according to the agreed inclusion-exclusion terms.

<b>Synthesizing the Evidence (Step 6)</b>	<b>Criteria/ approach</b>	<b>Justification</b>
<p>Revisit the aim, research questions and the scope of review and revising accordingly, synthesizing the evidence.</p> <p>Undertake the following tasks:</p> <ul style="list-style-type: none"> <li>• Review, compare and contrast data.</li> <li>• Examine data on relevant outcomes as well as supporting and contradictory.</li> <li>• Evidence of original program theories.</li> <li>• Use evidence to modify and refine previously developed program mechanisms and theories.</li> <li>• Identify gaps, disputes, discussion points, major criticism areas and consensus (if any).</li> </ul>	<p>Systematic and critical.</p>	<p>To bring together identified and filtered evidence in a meaningful way.</p>
<p>Written output:</p> <ul style="list-style-type: none"> <li>• CaCHE evidence review report</li> <li>• Conference presentation</li> <li>• Seminar/Workshop/Event with invited speakers</li> <li>• Published article</li> </ul>		
<b>Work Plan – Timeline</b>		
<ul style="list-style-type: none"> <li>• Refer to the Gantt chart.</li> </ul>		

## Appendix B: Inclusion and exclusion criteria

First round inclusion/ exclusion criteria	Criteria / approach	Justification
To be applied on the initial database which is compiled by title/abstract/ keyword queries on the search mediums (indexes, journals, etc).	Focused, but comprehensive.	The aim of this round is narrowing down to the related sources and creating a comprehensive but focused database for the following step.
Publication date range:	No limit.	
Language:	English.	
Country/geographical focus:	Not limited with particular countries/regions.	
Thematic fit/relevance:	Sources directly engaging with modern methods of construction <ul style="list-style-type: none"> <li>• Business models</li> <li>• Regulatory practices</li> <li>• Consumer behaviour</li> </ul> without excluding any scale, intervention or detail	
Second round inclusion/ exclusion criteria	Criteria / approach	Justification
To be applied on the full-text the sources in the main database.	Systematic and informed.	The aim of this phase is to review existing evidence according to the agreed inclusion-exclusion terms.
Publication date range:	Same as in the first round.	
Country/geographical focus:	Same as in the first round.	
Thematic fit/relevance:	Include: <p>Sources directly engaging with modern methods of construction</p> <ul style="list-style-type: none"> <li>• Business models</li> <li>• Regulatory practices</li> <li>• Consumer behaviour</li> </ul> without excluding any scale, intervention or detail <p>Exclude:</p> <ul style="list-style-type: none"> <li>• Sources exclusively about technical aspects of MMC such as new technologies enabling MMC production and deployment.</li> <li>• Sources about exclusively about architectural design, design aspects and methodologies leading to MMC production, use and deployment.</li> </ul>	

Participants characteristics:	No exclusion based on participant characteristics.
Research setting:	No exclusion based on research setting.
Methods:	No exclusion based on research methods.
Validity thresholds and/or relevance for exclusions and/or weighting:	Quality Appraisal Checklist to be applied (see overleaf).

## Appendix C: Data extraction sheet

The publication: (e.g., Albatici, R., et al. (2016) A decision making tool for a comprehensive evaluation of building retrofitting actions at the regional scale, Sustainability (Basel, Switzerland) 8(10), p. 990-990.)

1. Research aim of the paper
2. What is the scope of the paper regarding:
  - (a) the extent of the paper's engagement with MMC:  major  key section  minor/peripheral  
*(please tick here your assessment and record the details in findings section)*
  - (b) focus on:  Business models  Regulatory practices  Consumer behaviour  
*(please tick here your assessment and record the details in findings section)*
3. What methods are used (and how rigorously are these deployed)?
4. What theoretical standpoint is taken by the authors, implicitly or explicitly?
5. Whose views does the paper reflect, again implicitly or explicitly?
6. What are the key findings and research results regarding:
  - Business models
  - Regulatory practices
  - Consumer behaviour
7. What policy/planning/industry/ recommendations does the paper suggest?
8. What particular research gaps are identified or further research suggested?
9. Limitations of the reviewed research
10. Significant quotes (in addition to quotations in above sections)
11. References to follow up

## Appendix D: Quality appraisal check

<b>Quality Appraisal Checklist</b>	<b>High</b>	<b>Med.</b>	<b>Low</b>	<b>Poor</b>
<b>Quality Appraisal Stage 1 – Research Quality in General</b>				
1.1 Transparency				
• Clear statement of aims and objectives				
• Clear statement rationale for why study was undertaken				
• Clear and adequate description of the context				
• Transparent methodology: Explicit about methods used, including benefits and limitations and sampling including sample size and sample selection				
1.2 Rigour				
• Thorough and appropriate approach applied to key research methods				
• Appropriate research design given aims/objectives (including questions, data collection methods and data analysis methods)				
• Appropriate sample selection and sampling methods				
• Findings clearly linked to purpose of study				
<b>Quality Appraisal Stage 2 – Research Quality according to methodology</b>				
2.1 Quantitative				
• The research measures what it says it measures				
• Measures of concepts are consistent				
2.2 Qualitative				
• The research observes or identifies what it says it does				
• The research appears to be dependable				
2.3 Mixed Methods				
• Quantitative analysis has been applied adequately				
• Qualitative analysis has been applied adequately				
• The quantitative and qualitative parts are well integrated				
<b>Quality Appraisal Stage 3 – Overall rating</b>				
High/Medium/Low/Poor				
If it is poor, write a couple of sentences on your assessment and exclude:				