RESEARCH ARTICLE

Barriers to adopting modern methods of construction in the UK

M. Williamson, A. Ganah* and G.A. John

University of Central Lancashire, School of Engineering, United Kingdom

Abstract

The purpose of this paper is to present the research findings that investigated the uptake of Modern Methods of Construction (MMC) within the construction sector in the UK, and to understand the barriers and challenges preventing the widespread use of MMC within the industry. MMC is not new, which was introduced on a commercial scale after the WWII, although recent reasons for the uptake are due to the population increase, government inability to meet the high housing demand, and transference of high risk venture by the government to the private sector. The findings from this research undertaken is that MMC are now of better quality as opposed to its first usage and that quality is assured because of the better processes and technologies that are now available. However, the findings also highlighted the continued negative public perception of MMC, which will need to be erased and a positive perception generated by the government for a win-win situation for all stakeholders to be realised.

Keywords

Modern methods; Modular; Construction; Barriers; Adoption

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1. Introduction

Modern Methods of Construction (MMC) has no universally accepted definition but can be recognised as collective term, used to describe a number of unconventional and unfamiliar innovative construction methods. The main purpose of introducing MMC is to improve products and processes in terms of business efficiency, quality, customer satisfaction, environmental performance, sustainability and the delivery of the final product on time and within the constraints of the project environment. High quality MMC requires better processes in the performance and delivery of the product [1].

History has shown that MMC struggled with negative press and as such has been affected by the way it is utilized to increase output and improve

profit margins. Some large companies who specialize in MMC innovations are prospering because of their solutions to diminishing trade skills and the need to adapt for current demand. However, many large to medium construction companies are using MMC but not to their full potential. The primary question on this matter is if numerous consultants are advising construction companies to use a standardized approach toward construction methods with particular focus on pre-manufacture [2], why are we not utilising this guidance and developing strategies to improve our industry?

In key Construction Industry reports [2, 3, 4], there is a persistent push for the use of MMC to improve the process and minimize risks on projects. Currently, MMC is seen as a method to improve efficiency, buildability, and considerably decrease

* Corresponding author
Email: aganah@uclan.ac.uk

overall works programme. Many companies see MMC as a tool to increase housing output, however there are many emerging commercial solutions to large scale residential, healthcare and educational projects that some companies are yet to try as knowledge and inexperience with methodologies are still seen as a risk due to unfamiliar techniques.

The research undertaken consists of a literature review, which mapped out the evolution of MMC, barriers, benefits and innovation of modern methods of construction. The key findings of the literature review were used in shaping the primary research. The primary research involves the case study review of key demonstration projects, as well as questionnaire survey conducted within the industries of major stakeholders. The survey was analysed, and the final section of the work is a discussion on our findings, when all the research efforts are considered holistically.

2. MMC systems overview

The current trend of MMC development and its impact on the construction industry from the literature review are discussed under following headings: Volumetric (Modular) Construction and Semi Volumetric (Pod) Construction.

➤ *Volumetric / Modular Construction*

Modular Construction is sometimes referred to as three-dimensional building under factory conditions, the entire building would be manufactured off- site under controlled conditions. It can also be defined as "units that enclose usable space, but do not themselves constitute the whole building" [5].

Modular Construction entails; factory production of pre-engineered building units, these are then delivered to site and assembled to form the structure. This method normally has structural properties and can act as a delivered JIT (Just In Time) solution.

➤ *Volumetric / Modular construction enablers*

- Overall program reduction
- Repetitive building techniques
- Good price certainty
- Weather has little effect to planned activities

- Re-usability, (future relocation)
- Mechanical and Electrical (M & E) is plug and play philosophy mitigating commissioning processes.

Usually around 90% of total construction is off-site and carried out under factory conditions, this leads to better quality, building performance and eliminates the snagging procedure, making the entire procedure efficient.

The main body of site work is assembly, and this is carried out in an accelerated manner compared to conventional methods due to the standardised processes and repetitive nature of modular or volumetric construction.

➤ *Volumetric barriers*

- Early collaboration for design purposes
- Design freeze, from a certain stage any changes after this time prove costly
- Accurate foundations usually 5mm tolerance of line and level
- Logistical constraints on
- There are a variety of manufactured materials used to create

➤ *Material Variations include*

- Light gauge steel framing
- Timber
- Concrete
- Hybrid composites [6: p. 48]

➤ *Semi Volumetric / Pod Construction*

Semi volumetric construction would usually consist of non-structural enclosable spaces such as bathroom pods, kitchen pods or pre-finished plantrooms. These are used typically on student accommodation and commercial hotel schemes due to the repetitive nature of the bathrooms / service riser co-ordination.

Bathroom Pods would usually be delivered in clusters of ten, due to the size and maneuverability of these prefinished modules, it is common practice to have these delivered and positioned before the structures envelope is progressed. Depending on the project, they can be positioned by means of crane or fork lift [5].

➤ *Semi Volumetric / Pod enablers*

- A good ideology for hotels and student accommodation.
- Pre-manufactured Plant rooms can save multiple trade congestion during the commission / execution phase of the project
- Mitigates the M & E sequencing constraints during construction
- Consistent quality
- High level of customer satisfaction [9, p. 13]

➤ *Semi Volumetric / Pod barriers*

- Some pods need housing into floor to create level access, this can prove difficult to accommodate in some scenario's
- Substantial repetition is required to ensure pods are cost competitive with conventional methods of construction
- Design freeze, from a certain stage any changes after this time prove costly
- Some sequence of works will need to be planned differently and carried out in advance of normal timescales (for example fire Compartmentation)

As it can be seen from the above MMC literature, recent innovation in materials and construction technology has improved the quality of construction in comparison to traditional approach that was previously not envisaged. This has been highlighted in the recent case study in the next section.

2.1. *Illustrative case study: Kingston hospital*

The client had an urgent need for a surgical block consisting of an extra 132 beds, planning permission was sought and received but only for five-year duration, The Trust knew that to achieve the project within this timescale, prefabrication would need to be considered.

Kingston NHS Trust went out for competitive tender in September 1997; the project was awarded to Terrapin Prospex LTD for a capital value of £3.4 Million pound. The trust worked directly with Terrapin to reduce overall construction period to 18 weeks (without increasing original tender price). All tenders received from Principal contractors had

scheduled the construction programme at 36 weeks; the request from The HNS Trust was an overall reduction in time based construction operations by 50%. The project was to consist of a three-storey complex, with the use of "pre-engineered modular design" [7, p. 86]. Accommodation was specified as "Five bed and single-bed bays, each with an ensuite bathroom. There are two assisted use toilets and bathrooms on each floor. Each bed is served with medical gases and a nurse call system. The block had to provide all facilities one would expect in a normal hospital" [7, p. 86].

This new hospital project used the Terrapin Matrix system, which is a hot rolled steel frame with light steel secondary members. The modular elements comprise of bathroom pods (i.e. different types of bathroom units) and plant rooms. The modular unit elevation also demonstrates the flexibility of the modular system to accommodate a variety of wall finishes, cladding and architectural features [8]. All of these techniques are further reviewed in "Off-site Fabrication" [5].

The Project commenced on the 14th of April 1998 and was handed over to the hospital on the 4th September 1998 with an overall construction period of 20 weeks. The hospital was opened to patients a week later on the 10th September 1998. End users had only three issues with the scheme post completion, all related to design issues, not functionality of the modular bathroom pods. Terrapin had met their commitment and both parties were happy with the completed scheme.

2.2. *Advantages in utilising modular/ volumetric construction at Kingston hospital*

Some of the lessons that came out from the case study highlighted above contain important advantages of using the MMC approach. Close and early collaboration between client and contractor resulted in a good planning and flexibility during design stages. Both parties were committed to the success of the project. Terrapin saved on preliminaries and overhead forecasts for the initial 36-week programme. The NHS Trust received the building for the initial Tender price and also had early possession due to their involvement with up-

front planning and co-ordination of logistics with the existing live buildings. Components and modules adopted the “Just In Time” delivery practice, as the site was congested, the logistics were targeted as a risk and managed well from the offset by Terrapin LTD. Reduced disruption to the occupied buildings on the hospital campus, due to the use of modular innovations also resulting in less on site activity (modules were pre-finished down to Mechanical and Electrical with minimal finishing trades needed). The advantages of the use of MMC were evident in the success of this particular scheme.

The Construction industry has been directed to use MMC to improve and de-risk projects. Currently MMC is seen as a method to improve efficiency, buildability, and considerably decrease overall works programme. Many companies see MMC as a tool to increase housing output, however there are many emerging commercial solutions to large scale residential, healthcare and educational projects that some companies are yet to trial as knowledge and inexperience with methodologies are still seen as a risk due to unfamiliar techniques. In the next section a primary survey is conducted with stakeholders to negate or reinforce some of the findings in the writing within this section.

3. Research methods

For the purpose of this study, a mixed research methodology was used. The research design was in two stages. The first targeted, 3-SMEs, and a quantitative questionnaire was sent to the three Small and Medium Enterprises (SMEs) who are specialist in MMC. This was based on the literature review information about MMC systems and experiences. The second stage was to send questionnaire out to the wider construction organisations. The questionnaire was distributed to the target audience, which would have two weeks to complete and return the survey via the online internet tool adopted. The survey consisted of ten questions and concentrated on MMC methodologies and current usage of systems/processes. The sampling method for the quantitative study is a quota sampling [10]. The

survey was distributed as widely as possible within the selected organisations.

This data was collated by the internet survey tool and analysed after the deadline date. This study was aimed to have over 30% responses for the questionnaire, of which will make inferences about large populations using relatively small samples of collected statistics. All responses will be industry based and within a small to medium organisation.

Secondly, qualitative interviews were undertaken. The semi-structured interview was designed to ascertain different attitudes from construction professionals towards types of MMC not used before. The interview’s questions were trying to extract relevant information and experiences about MMC and using the opinions and experiences of the interviewees to formulate data provided enablers or barriers for MMC. All interviewees were asked specifically because of their use of conventional and modern construction methods.

There are no closely defined rules for the sample size in qualitative research in the literature. Sampling in this study was rather purposefully than randomly selected, as using initially small numbers of samples, seeking for richness of data on the subject of ‘MMC’ with the aim to study in-depth and in detail the experiences of the experts in traditional modern methods of construction. Sampling keeps going until the point of recognition that no new data are forthcoming. Information redundancy is then comparable to data saturation and the research continues to the point that no new information is heard of the interviews that are conducted [11].

The semi-structured interviews were conducted and the employed interview technique was face-to-face, this gave participants enough time to process the question and answer to the best of their knowledge; also some opinions were likely to be very helpful to the aims of this study.

The interviews were conducted on live projects where the construction professionals were working. A total of eight people have been asked to undertake an interview, of which seven had accepted. It has been assured that all personnel undertaking the

interview have had a least ten years construction management/procurement experience in both modern and conventional methods of construction. The semi-structured interviews undertaken for this study have been analysed with only manual content analysis. There were six main questions/issues in the semi-structured interviews. The manual content analysis approach was adopted for analysing the collected data and this approach allowed the researchers to objectively study the collected data and relate the findings to the aims and objectives of the study.

3.1. Questionnaire survey

➤ Respondent profile data collection

This is important as this demonstrates to the audience that the collected information has been received from. As can be seen from Table 1 the majority of respondents were Principal Contractor based 70%. For the purpose of this study that is beneficial as principal contractors control what type of construction method is procured and implemented.

The second question of Section 2 of the questionnaire survey was designed to capture the current position of the respondent, if position does not relate directly to construction, this would make evident the respondents input would need removing from the questionnaire to keep data at a constant. 'Site Manager' were highest proportion of respondents (38%), followed by "Project Manager" (27%). This is a good set of information as site managers and project managers are more likely to be involved with both conventional and modern methods of construction. Also, among the respondents, 19% were "Quantity Surveyor", 8% for each were 'Architect' and 'Managing Director'.

Table 1. Respondents Characteristics

Role	%
Principal Contractor	70%
Sub-contractor	14%
Supplier	3%
Consultant / Architect	8%
Other	5%

3.2. Main findings of the questionnaire survey

➤ Respondents' experience with MMC

One of the questions in the questionnaire was designed to extract overall experience with MMC, including types of MMC currently being used and types previously adopted. The majority (57%) of the respondents to the questionnaire survey have extensive experience while the rest (43%) of the respondents stated that they have limited experience in MMC. This highlights a good overall experience from the respondents; this is as good as could be expected. Despite the respondents being from a range of backgrounds they have all been a part of MMC in one of the following disciplines; design, procurement or execution of at least one MMC system. Although this does not directly answer any of the aims or objectives of the questionnaire survey it demonstrates that the correct audience have been chosen for the purpose of this study.

➤ Current forms of MMC being utilised

The participants in the questionnaire survey were asked about current forms of MMC being utilised, and if possible to ascertain what types are now becoming standard procedure within the construction Industry (See Table 2). The main findings from responses are as follows:

- Curtain walling scored the highest weighted average with 74%. This establishes that most companies would utilise this form of MMC.
- Composite panels recorded the second highest weighted average, these form part of the envelope, hence the reason for MMC. It was assumed this was high because of the time / cost optimisation opportunity concerning installation speed and quality of finish.
- What was interesting from the results, the volumetric/semi volumetric solutions were a quite low weighted average.

Table 2 Current forms of MMC

Use	Frequency	Never	Rarely	Sometimes	Often	Always
Volumetric / 3D units		23%	23%	41%	4%	9%
Semi Volumetric / Bathroom Pods		20%	8%	44%	24%	4%
Open Panels		19%	0%	67%	14%	0%
Closed Panels		19%	0%	71%	10%	0%
Composite Panels		8%	0%	32%	56%	4%
Structural Insulated Panels (SIPS)		20%	16%	32%	32%	0%
Curtain Walling		16%	0%	16%	48%	20%
Tunnel Form (in situ formwork)		33%	25%	33%	9%	0%
Floor Cassettes		32%	28%	32%	8%	0%
Pre-fabricated Foundation		37%	46%	17%	0%	0%
Pre-fabricated Dormers		39%	39%	17%	5%	0%
Timber I Beams		22%	13%	43%	22%	0%
Metal Web Joists		13%	17%	37%	33%	0%
Prefabricated Lift Core		32%	20%	40%	8%	0%
Pre-finished Roof Structure		37%	37%	21%	5%	0%
Wiring Looms		32%	40%	16%	8%	4%
Kitchen Pods		40%	24%	28%	4%	4%
Pre-finished Plant Rooms		44%	40%	8%	8%	0%
Modular M7E Distribution (horizontal or vertical)		44%	20%	24%	8%	4%
Concrete Panels		20%	24%	40%	16%	0%
Pre-fab Plumbing		28%	40%	20%	8%	4%

- The average “Always used” percentage was 2%, it was found that this was quite alarming that the industry could not find or adopt workable solutions and continue to implement them within their organizations. When considering the type and availability of MMC methodologies, it was expected that a much higher percentage of respondents would have regularly used MMC.
- The lowest weighted percentage was “prefabricated foundations” with only 17% of the respondents opting for “sometimes used”. Again, this was unexpected, and it has been assumed that the commercial ratio between conventional & modern approaches must be far apart.

The general overview is that, MMC is a good solution to the skills shortage however, one

respondent goes as far to imply “It has potential, but it will never be realized”. The main issues raised from the respondents are:

- Upfront design timescale
- Commercial competitiveness (against conventional methods)
- Education of project managers in Procurement (and the associated risks)
- Upfront costs are difficult to report to senior managers (often opting for Conventional)
- Change management becomes an issue with MMC as once designed calculations need to be re-run and this leaves principal contractors at a disadvantage with their clients (interchangeability during construction)

3.3. Interviews

Interviews were conducted with experts in MMC to gain further insight into their experiences in construction projects using MMC and what effect it has on capital cost, timescale delivery and quality of the finished product. The interviews also gauged their knowledge of and opinions on MMC and their usage pattern of MMC based on comparative analyses of conventional and modern methods, these interviews encompassed small sample of people from which a large amount of data was captured.

The construction industry professionals were selected for this research study based on their experience with both conventional and modern methods of construction (See Table 3). These individuals and their positions were targeted because of the range of experiences in dealing with procurement, execution and management of live construction projects within a small to medium enterprise.

The interview discussed:

- issues related to the specific MMC schemes have been the interviewee been involved with and whether there was more

opportunity available than conventional methods.

- why MMC was utilised for the developments.
- the implications of MMC on cost and quality of the projects
- their opinions on clients' adoption of MMC as the method of construction restricts the choice of fixtures and fittings.
- whether the current supply chain can cope with MMC demand and early collaboration constraints.

The analysis of the interviews highlighted the industry's issues with being client driven, if there was more scope for MMC at the front end of the project and increased design time, it was found that project efficiency and quality increased and there in some cases could be a good commercial opportunity. The main issues with MMC were the early collaboration and extended design interfacing. However, if more time is allowed for this in the tendering stage, it can be realised that a better quality of finished product and a good working relationship can be built between client and principle contractor.

Table 3. Interviewees profile

Interviewee Code	Job Title	Construction Experience	Project Type	MMC Experience
Int 1	Operations Manager	12 Years	Retail, Infrastructure, Commercial & Residential	Pods, panellised systems & trialled volumetric solutions
Int 2	Design Manager	32 Years	Retail, Commercial & Residential	Semi-volumetric pods
Int 3	Commercial Manager	24 Years	Retail, Commercial & Residential	Precast concrete & preformed lift shafts
Int 4	Site Manager	30 Years	Retail, Commercial & Residential	Pre-finished roofing – roof components & precast concrete foundations
Int 5	Project QS	15 Years	Retail, Commercial & Residential	Precast manufacturing, Pods and precast façade panels
Int 6	Ops Manager	25 years	Retail, Commercial & Residential	Volumetric solutions
Int 7	Site Engineer	10 Years	Retail, Infrastructure, Commercial & Residential	Precast and volumetric solutions

4. Discussion

From this study, it is clear that the construction industry should continue to promote the implementation of MMC. Whilst wholesale changes are not yet manifesting throughout the construction sector, there will come a time in the near future when there might not be a choice because of the skills shortage. It has been shown that MMC can be successful on numerous schemes and through every sector within Construction (Retail, Commercial and Residential), however, a standardized system of work needs to be generated to allow companies that are less familiar with MMC to fully recognize all benefits. Principal contractors and government would be invited to incentivise MMC for the benefit of the industry. This needs to be implemented alongside MMC training of trades and management. The usual constraints of time, cost, quality and health and safety all have better records of efficiency and end product when managed correctly however correct training needs to be filtered to companies and personnel that are not accustomed to the MMC process. The easiest way for this to be implemented is through framework agreements and partnering of the supply chain. Early collaboration is vital if MMC is to work efficiently.

This study has established that MMC has a mixture of positives and negatives; this is mostly affected by the type of scheme and the client's preference of building. This study has found that whilst MMC is seen as relatively well-established process within the industry, a combination of commercial competitiveness against conventional methods & developers or clients build specification is making their implementation difficult. Interestingly all the interviewees shared the same views with regards to the future of MMC "within the next five years I expect to see a large increase in the use and implementation of MMC systems of work because of the UK skills shortage crisis" (Int 6). Also, the interviewees shared the same thoughts on the skills crisis and that it would deepen following the 'Brexit' and triggering Article 50.

The study has found that whilst time, cost and quality are the determining factors when procuring

and construction any scheme, that when using MMC there is the best balance between the three. A relatively high percentage of respondents said they used MMC because of programme savings and increased quality concerns, again this further promotes MMC and is good positive based evidence that if planned correctly, the benefits from MMC are recognized by all.

The findings can be correlated with the literature review as there is an ignorance toward MMC as proven from respondent analysis "Methods are Unfamiliar to management and workforce" in some instances. This was also reviewed in Dimarakis [12] where it was found a lack of research and development within companies is holding back the progression of MMC systems and implementation. In measurement against the 5:4:7 targets set in Egan [3]. It is not believed that any targets have been fully achieved with exception to a reduction in accidents. This is further demonstrated in the survey findings as accidents gained the highest weighted responses. It is difficult to measure current progress against these targets as some respondents skipped this question and this is a limitation of this study.

In years to come, the Farmer Review will be regarded as an impetus for change within the construction industry and if the government is to adopt the recommendations and strive to mandate the use of MMC as advised in Farmer [2], large opportunities for the supply chain and main contracting could be available, and this is also a view shared in KPMG [13]. The results that have been realised from the questionnaire survey have found that, both recommendations 3 and 8 from the Farmer Report are favourable within the industry and should be concentrated on in the near future.

Overall, the literature review found a positive feedback, however the survey analysis has found a mixed reaction from the majority of construction professional's responses. Current MMC usage was less than expected and again this is down to knowledge sharing throughout the industry and familiarisation of techniques and procedures. There are however good sources of knowledge sharing, for example Build-off site are an organisation that

collectively promote and offer guidance on MMC and innovative construction techniques. This demonstrates that MMC guidance and knowledge can be sought if there is enough design and procurement time.

Design timescale is the biggest barrier in the implementation of MMC, as early design freeze was mentioned by numerous respondents as a contributing factor against using MMC. This is also found in HCA [14] as some schemes in DFM competition suffered expense because of early design freeze, as found in the literature review.

5. Conclusion

The first wave of MMC struggled from negative reports, due too reasons such as the reliability of product, poor workmanship, and durability was lacking and not quality assured. Since then construction firms have learnt from the past. The new types of MMC are quality assured, but barriers are that the design time of projects are not frozen early enough to allow for lead manufacturing time of such products. Such problems can be overcome through better procurement routes for example on PFI projects. Although the results have shown some positive attitudes toward MMC, there is still much progress to be made if the standard principles are to be adopted throughout the industry. It was expected from most construction professionals that there would be basic awareness of the Egan & Farmer reports, however, the results proved that only a relatively small population are aware. Wider dissemination of the recommendations within such reports is required. Without awareness of the recommendations found in both of these reports it is difficult to see how the principal contractors can be implementing and benchmarking best practice, while endeavoring to innovate new solutions.

In conclusion, from the findings presented, it is quite clear that MMC has still not developed to the position that Egan [3] had advised, also Mark Farmers report was not recognized by many of the respondents so a true conclusion to the subject matter can only be extrapolated from the results gathered. Within the construction sector, the deciding factor has and always will be cost driven,

until the MMC supply chain can make MMC more cost efficient, SME's that are the largest building stakeholders/practitioners, not considering clients, will most likely to opt for methodologies that are familiar to procure and build. Once solutions to MMC barriers and challenges are addressed the future is bright as MMC will become cheaper, and there is a market out there for it to be used and replicated especially in developing countries where quality is a big issue.

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