Interface problems with volumetric prefabrication

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Modern Methods of Construction can assist the construction industry to achieve higher levels of production and a higher quality of product. They are being promoted by the UK government and are seen by some as a panacea to the ills of the construction industry. Prefabrication does however need to be integrated with more traditional methods of construction and this interface is often problematic. The aim of this work is to identify these interfaces and to facilitate an understanding of how problems arise. The research included interviews with team members from a key prefabrication provider and selective questionnaires from contractors managing (and not managing) projects using elements of prefabrication. A lack of understanding between prefabrication specialists and those providing more traditionally built infrastructure was found to create problematic working relationships and good communication was found to be a key factor in successful projects. The various types of interface are mapped and then set against the parties involved and their timing within the project.

Keywords: prefabrication, communication, interfaces.

INTRODUCTION

This aim of this research is to model the characteristics of interface problems between volumetric prefabrication and traditional construction. The research comprises case studies, interviews and questionnaires leading to the identification of a timeline of common interface problems. The research was carried out in the UK and its validity must be considered within the emerging prefabrication market.

Modern Methods of Construction (MMC) is a term used to describe technical improvements in prefabrication, encompassing a range of on and off-site construction methods (Parliamentary Office of Science and Technology 2003). It is moreover a term used by the Housing Corporation to embrace a variety of approaches including off-site manufacturing (OSM). Falling under this heading are volumetric construction, panellised construction, hybrid systems, sub-assemblies and components. (BRE 2003)

The current severe skills shortage coupled with the short timescale demanded by clients means that demand for new construction is unlikely to be met by conventional construction techniques. It would seem that the market for pre-fabricated accommodation could increase dramatically over the coming years if manufacturers are able to overcome the barriers. (McAllister *et al,* 2000, ODPM Jan 2006)
The Egan Report, Rethinking Construction (Egan 1998) provided impetus for the UK construction industry to consider the way in which it operated and specifically the

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opportunities that existed for improving the process and delivery of a higher value product. This raised the level of interest in prefabrication techniques and studies are underway to assess its potential.

IDENTIFICATION OF INTERFACES

To develop an understanding of interfaces between volumetric prefabrication and traditional construction a series of interviews were arranged. The bulk of interviews were with a selected modular prefabrication company. Interviewees chosen had a range of roles and responsibilities within the same company and were found to see the interfaces differently. Their roles can be categorised as: Project Management, Construction Management, Manufacturing Management, Marketing and Promotion and Logistics

A common list of interfaces was first established from initial pilot interviews. This list of interfaces was then given to each respondent with space for other interfaces to be added.

Number	Process	Number	Process
1	Acoustic Testing	34	Modular specifications
2	Ancillaries	35	Module Tolerances
3	Arrival of modules on site	36	Offer to supply
4	Authority To Manufacture	37	Operations and maintenance manual
5	Bathroom pods delivery and installation	38	Outline General Arrangement drawings
6	Budgetary quotation	39	Planning applications
7	Communication	40	Pre delivery checks
8	Defect report completion on installed modules	41	Pre Start Meetings
9	Demand schedule / call offs	42	Preliminary demand schedule
10	Design / Project meetings	43	Progress meetings
11	Detailed Architect Module layout drawings	44	Project Management Involvement
12	Door deliveries and installation on and off site	45	Remedials
13	Electrics installation	46	Roof structure details
14	Engineering change notes	47	Scheme elevations
15	Erection schedule	48	Scheme plans
16	Final Handover	49	Shipping Call Off's
17	Final health and safety file	50	Shroud
18	Finished modules on site	51	Site levels surveys
19	Fire stopping	52	Site Managers
20	Fixings schedule	53	Site Requisitions
21	Floor layouts	54	Site Returns
22	Foundation details	55	Standard reference drawings
23	Frozen General Arrangement drawings	56	Technical queries
24	Frozen quotation	57	Testing
25	Getting hold of materials	58	The Crane
26	Handover documents to re-programme doors	59	The Team
27	HSB Drawings	60	Timing and Programming
28	Initial health and safety file	61	Transport
29	Initial inquiry	62	Variations to the contract
30	Installation	63	Weather proofing
31	Lifting Equipment	64	Weekly delivery report
32	Management of lifting frames	65	Window delivery & installn. on & off site
33	Manufacturing supply risks	66	Window drawings and schedules

Table 1 List of common interfaces

These added interfaces were included in the subsequent list of interfaces for later interviewees. The list given in table 1 shows the final list of common interfaces:

These interfaces were mapped against the different respondents and it was noted whether the interfaces were internal to the organisation or whether they were interfaces with external organisations (but within the project organisation). The interviews demonstrated that there is limited overlapping of common interfaces between the four specialisms taking part in the interview process. This seeming lack of common understanding between the various disciplines is in itself significant.

COMMUNICATION INTERFACES ESTABLISHED FROM INTERVIEWS

Communication interface problems were frequently mentioned in the interviews – with the source being interference in the communication process. This was identified by Dainty *et al* (2006) and shown within the Linear Process diagram shown here as figure 1.

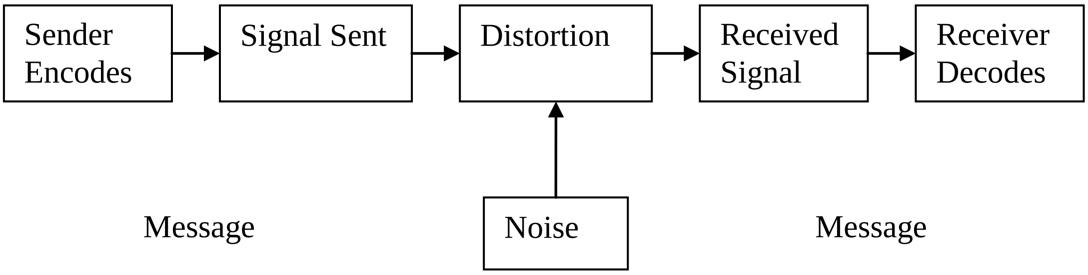

Figure 1 - A Model of the Communication Process, Dainty et al.,2006

If a message, at the start of the process, is distorted due to noise (i.e. a distraction) the received signal is decoded so arrives as something different from the message sent at the start of the process.

Dainty *et al*., (2006) identified that *effective communication is the key to achieving coordinated results, managing change, motivating employees and understanding the needs of the workforce*. Thus improved communication is as vital to the prefabrication sector as to as they are in the industry as a whole.

Table 2. shows the interview responses to each individual interface both internally and externally highlighting the problems from each area from the modular supplier:
This chart shows all responses from the in-depth interviews for all interface issues both communicational and physical, as can be seen from the chart there are a wide range of interfaces for which a frequent breakdown has been established. The chart shows that there are many internal interface issues, which may highlight that the interviewees are concerned with their internal environment

Those shaded more lightly show the links between the interfaces and external parties; those shaded darker indicate that the interface occurs within the internal environment of the business. Using the example of Acoustic testing the Client, Principal Contractor and Acoustic Testers are all involved within the process.

The information gathered from the interviews and questionnaires was used to establish a set of interface issues relating to the timing, communication, organisational structure, the internal and external environment and parties involved within the prefabrication process as a whole. .

Interface problems identified involving interaction with external parties

(Numbers indicate cumulative occurrence)	Client	Prinpl Contr-actor	Installer	Arch.	Struct. Eng.	Other Sub-Contractors
Acoustic Testing	1	1				1 Testers
Ancillaries	2	2	1	1		
Arrival of modules on site		3	2			2 Transport
ATM's	3	4	3			
Bathroom pods delivery and installation	4	5				3 Bathroom Suppliers
Budgetary quotation				2	1	
Communication						
Defect report completion on installed modules		6				4 Remedial Works
Demand schedule / call offs	5	7	4			5 Material Suppliers
Design / Project meetings						
Detailed Architect Module layout dwigs	6			3	2	
Door deliveries & install. on & off site	7	8				
Electrics installation		9				6 Electricians
Engineering change notes						
Erection schedule		10	5			7 Scaffolders
Final Handover	8	11				
Final health and safety file						
Finished modules on site		12				8 Cladders
Fire stopping	9	13				
Fixings schedule	10	14				9 Suppliers
Floor layouts	11			4		
Foundation details		15			3	10 Cladders
Frozen GA drawings	12	16	6	5		
Frozen quotation	13			6		
Getting hold of materials						
Handover docs to re-programme doors		17				
HSB Drawings						
Initial health and safety file						
Initial inquiry	14			7		
Installation	15	18	7			
Lifting Equipment	16	19	8			
Management of lifting frames						
Modular specifications	17	20	9	8		
Module Tolerances		21				11 Cladders
Offer to supply	18					
Operations and maint.manual						
Outline GA drawings	19					
Planning applications	20	22	10	9	4	12 All
Pre delivery checks		23	11			

Preliminary demand schedule						
Pre Start Meetings	21	24	12		5	
Project Management Involvement						
Progress meetings						
Remedials						
Roof structure details	22	25		10	6	
Scheme elevations	23	26	13			
Scheme plans						
Shipping Call Off's	24	27	14			
Shroud	25	28	15			
Site levels surveys	26	29	16			13 Surveyors
Site Managers						
Site Requisitions		30				14 Material Suppliers
Site Returns		31				15 Transport
Standard reference drawings		32	17			
Testing						
Technical queries	27	33	18			
The Crane	28	34	19			16 Crane Suppliers
The Team	29	35	20	11	7	17 All
Timing and Programming						
Transport	30	36	21			18 Transport
UMS supply risks						
Variations to the contract	31					
Weather proofing	32	37				
Weekly delivery report	33	38	22			
Window delivery and installation on and off site		39		12		19 Window Fitters & Suppliers
Window drawings and schedules	34	40		13		20 Window Suppliers
NUMBER OF "EXTERNAL INTERFACES" IN WHICH PROBLEM HAS BEEN ENCOUNTERED (PERCENTAGE)	34 (52%)	40 (60%)	22 (33%)	13 (20%)	7 (11%)	20 (30%)
External Effect (& on Whom)						
Internal Effect						

Table 2 – mapping interface versus respondents internal/external view

The percentages indicate the frequency of engagement in the problematic interfaces. The principal contractor is therefore involved with 60% of the problematic interfaces, the Client with 52% the installer with 33%, other contractors such as window and transport suppliers with 30%, the Architect 20% and finally the Structural Engineer with11%.

Based on the findings from the interviews a questionnaire was then devised to issue to selected commercial contractors and house developers in order to gain an insight into whether the prefabricator's perception of problems correlated with those of contractors managing the construction project. Fifteen questionnaires were circulated to selected Commercial Contractors and House Developers of which 8 responses were returned:
Open ended and closed questions were used and a series of rating scales provided to determine frequency and severity of interface problems.

The open ended questions enabled more qualitative responses to be provided by the contractors; "offsite production took the burden of repetitive works off the critical path" and "the system was relatively costly, but the speed helped to reduce prelims and allowed other trades to commence early in dry conditions".

Some negative aspects established from the respondents were that "it is difficult for trades up to DPC if they have not had previous experience with areas such as accuracy of bases, design detailing also needs considerable special attention, long lead in times for prefabricated components and designs have to be done a long way in advance with some designs completed late causing complications to the construction". From this it is clear that design is (potentially) a key negative factor with the use of prefabrication. The need for early design input and for knowledge and expertise of designing for prefabrication is essential. Attitudes of respondents were however generally positive with few negative points.

Answers to the questionnaire were formatted within a matrix to include the frequency rating of the problematic interface and the severity rating of the specific interface. This matrix (table 3) shows the frequency and severity rating of the respondent's experiences with the interfaces. There are many over lapping interfaces where more than one respondent answered the same frequency or severity rating. From this it is clear that there are few very high frequency ratings and very few high severity ratings, suggesting that pre-fabrication, is viewed positively by the responding contractors.

Ref	Interface	Problem Frequency Rating				Severity Rating				IF PARTICULAR PROBLEM OCCURS PLEASE STATE HERE
		1	2	3	4	1	2	3	4	
1	Arrival of prefabricated modules on site	2	1 3			1 2		3		
2	Quotations from the prefabrication company	1	2 3			1	2	3		
3	Poor Communication	1	2	3		1	2		3	
4	Design / Project meetings			1 2 3				1 2 3		Difficult when prefabrication company is far away
5	Detailed Architect Module layout drawings		2 3	1			2	1 3		Designers need specialist knowledge
6	Deliveries of prefabricated components to site		2 3	1			1 2	3		Some upper floor panels arrived before ground floor
7	Erection schedule		1 2 3			1	2 3			
8	Final Hand over of prefabricated components		1	23			1	2 3		Clear scope of works required, who provides what
9	Health and safety files for the prefabricated components	1 3	2			1	2 3			
10	Movement of finished prefabricated components on site		2 3				2	3		
11	Fire stopping between prefabricated components and traditional construction			1 2 3			1 3	2		Careful attention / detailing required
12	Fixings schedules for the prefabricated components	1	3	2		1		2 3		Normally clear and concise
13	General arrangement drawings from the prefabrication company	1	2 3			1	2 3			Normally clear and concise
14	Hand over documents for the prefabricated components	3	1 2				1 2	3		More difficult if other parties become inv
15	Installation of prefabricated components	1 3	2			1 3	2			
16	Lifting Equipment for the prefabricated components	1 3		2		1	3	2		Quite easy
17	Modular specifications	1 3	2			1	2	3		
18	Tolerances for the prefabricated components	3	2	1		3	2	1		Can be very difficult

19	Offer to supply form the prefabricated company	3	2				2 3			
20	Operations and maintenance manuals for the prefabricated components	1	2 3			1 3	2			
21	Planning applications for the prefabricated components	1 3	2			1 3	2			No great problems but restrictions on design freedom
22	Involvement from the prefabrication company	1	2 3			1	2	3		
23	Remedials on the prefabricated components	1	2	3		1	2 3			
24	Reference drawings for the prefabricated components	1 3	2			1	2	3		
25	Testing of the prefabricated components	1	2	3		1	2	3		
26	Technical queries for the prefabricated components		2 3	1			2 3	1		Designers need to fully understand the system
27	The Crane usage for the prefabricated components	1 3	2			1 3	2			
28	Timing and Programming for the prefabricated components	1	2 3			1	2	3		
29	Transport for the prefabricated components	1 3	2			1 3	2			
30	Supply risks of the prefabricated components	1 3	2			1 3	2			
31	Variations to the contract from the prefabricated components	3	1 2			1 3	2			
32	Weather proofing of the prefabricated components	3	1 2			1 3	2			

Table 3 - Frequency & Severity ratings of interface problems

Table 4 gives a summary of these findings in terms of the frequency they occur, their severity, and the number of contractors who identified each level.

	Problematic Frequency					**Severity Rating**			
	1	**2**	**3**	**4**		**1**	**2**	**3**	**4**
Total Answers (1+2+3+4 = 100%)	35%	**47%**	18%	0%		34%	**40%**	25%	1%
1 Respondent	46%	34%	53%	0%		44%	53%	61%	100%
2 Respondents	54%	59%	12%	0%		56%	47%	26%	0%
3 Respondents	0%	7%	35%	0%		0%	0%	*13%*	0%
Total Respondents (1+2+3+4 = 100%)	100%	100%	100%	0%		100%	100%	100%	100%

Table 4 – Frequency and severity rating

A problematic frequency and severity-rating of 2 was the most popular choice followed in popularity by rating of 1, which means that the frequency and severity is low or infrequent for the majority of interface problems. A rating of 4 is not identified for any respondent in terms of frequency and only 1% for severity rating.

The findings from the questionnaires show that there clearly are problematic interfaces between modular and traditional construction although these interfaces carry different weightings of severity and frequency. The most frequent score was 2 which represent “occasional frequency” and “medium severity” ratings. These ratings are relatively low which suggests that problems are manageable and could with care be reduced to have less impact on the project.

CONCLUSIONS

This paper set out to investigate how modern methods of construction (MMC) interface with the traditional aspect of construction. The aim was “to model the characteristics of interface problems between volumetric and traditional construction”. From the interviews the following key issues were identified:

- types of problematic interface,
- lack communication within prefabrication companies concerning interfaces and
- internal and external organisational interface problems for the prefabrication company.

From the questionnaires key points established included: severity scales for each interface problem, generally positive views on working with prefabrication except where lack of experience, the importance of design detailing and advance detailing and lead in times for the prefabricated components.

The results from these questionnaires and interviews enabled the development of an interface model incorporating, parties effected, frequency of occurrence and severity involved.

This will facilitate development of a potential solution to avoid problematic interfaces occurring. It is intended that a process time mapping model in order to incorporate aspects of timing, parties, predecessors to each interface and finally the severity ratings as calculated from the questionnaires. There is great scope for further research in this field. It is hoped that this research project can be continued to enable the participation of a wider sample of prefabrication companies and contractors using this model as a basic framework.

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