A COMPARISON OF MODERN METHODS OF BATHROOM CONSTRUCTION: A PROJECT CASE STUDY

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Volumetric modules are often employed as an efficient and effective means of constructing highly serviced areas in buildings such as bathroom, kitchens and structures to house mechanical plant and equipment. Recent developments in structurally integrated volumetric pod concepts have seen a shift towards small format modules with the ability to be configured to provide alternative architectural solutions as part of a product family architecture. However, without careful consideration of the procurement strategy for such products, cost variation can arise from additional labour and materials required to make good and mend the results of design and construction process decisions that may not have been undertaken in concurrence. Using the unique case of a city centre project constructed using volumetric bathroom pods and a series of pre-engineered component kits (supplied by the pod manufacturer) an unusual financial comparison of two modern methods of bathroom construction is presented. The data emanating from the unit of study includes manufacturers production cost data and site based sub-contractors labour and material costs and considers the context of the construction in terms of new-build and building refurbishment. This is then used to provide an economic comparison of the use of volumetric pods and simpler pre-engineered component kits. Significant cost variation has occurred and the benefits of using off-site manufactured bathroom pods have been eroded due to specific procurement decisions and the complexity of the interface procedure with other trades and on-site constructed building elements. Using this method of comparison, those considering implementing modern methods of construction for bathroom and washroom facilities are provided with procurement strategy guidance in obtaining improved control over labour and material costs through using the modern methods of construction presented.

Keywords: Buildability, innovation, prefabrication, standardisation, cost.

INTRODUCTION

The benefits of off-site construction are well documented (Johnsson and Sardén 2008; Blismas et al 2006; Gibb and Isack 2003; Finnmore 1989; Herbert 1978). However, guidance is available (Buildoffsite 2008; Ross et al 2006; Ritchie 2002) but generally it is limited in relation to practical production (manufacturing), technical design guidance and site-level installation guidance. Recent house building industry interviews and questionnaire survey research concluded that guidance on the decision making process and practical applications should help increase the take-up of offsite modern methods of construction (Pan et al 2007).

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The case study presented examines the site based application of two modern methods of offsite construction applied to the construction of high specification bathrooms for the construction of a prestigious city centre hotel development. The two methods under consideration are (1) bathroom pods and (2) a pre-finished 'kit' of parts to be assembled on site. The project incorporated the refurbishment of an existing building combined with a new build element. The client required a high specification of finishes and fittings and it was deemed that an offsite manufactured solution would provide assurance in relation to the programme, quality and cost of the construction.

THE PROJECT

The project is a £28 million design and build four-star hotel. The building consists of a new build and refurbishment of existing structure in the heart of the Edinburgh's old town. The hotel has 6 structural levels with 135 rooms and consists of a conference room, private dinning space, breakout space, hotel restaurant (with kitchen and beer cellar) and staff areas/offices. In addition, the premise has two retail units, one unit for a bank, and underground car park (existing).

POD AND KIT DESIGN CONCEPT

A bathroom accounts for approximately a quarter of the floor area within a typical hotel room, and has the highest level of required facilities and services for such a space. Furthermore, bathrooms account for approximately 6-10% of the capital cost of a hotel (Meyer, 2008) and require at least four different trades for traditional construction. For these reasons hotel chains have in the past opted for the use of bathroom pods and kits in order reduce costs, increase health and safety and decrease project timescale as well as increase standardization and quality of finishes.

The pods have several different types, the majority being standard. This is due to the unusual shape of the building which did not lend itself well to general pod construction and the client requirements for disability discrimination act (DDA) compliant and luxurious pods (for the suites). Figure 1 shows an extract from an architectural general arrangement drawing showing interior finishes. Both standard pods and DDA compliant pods are shown with their service riser's access points also shown.

Pre-engineered kits are a form of 'flat-pack' system. All materials required to complete the bathroom arrive together and are assembled on site. These may include panels of laminate and/or tiling with pre-cut seams that lock together similar to 'click and lock' flooring. Toilets and sinks are generally installed into pre-drilled connection points with the supporting structure fitted behind the pre-finished panel. Pre-engineered kit systems have a mixture of the benefits and disadvantages of both traditional and off site construction (OSC). Where quality is normally of a factory finish, construction is generally not as straight forward. Kits rely on the workmanship of the fitter rather than factory assembly. However, bathroom kits do have several benefits over traditionally constructed bathrooms, such as:

- reduction in personnel on site
- reduction in construction programme
- reduction in waste
- reduction in snagging

To maintain control over site operations and responsibility for delivery and control of quality, the use of the bathroom kits was considered with a similar strategy to the pod procurement. This approach involved a single contractor taking on the responsibility

of the construction of the bathroom 'kits'. The selected contractor was responsible for building the structural frame, installing the services (mechanical and electrical), installation of all sanitary ware making the connections to the main service risers, the tiling and the installation of the pre-finished panels and all other finishes. Upon completion of the 'kits' the bathrooms were locked and secured in a similar manner to the bathroom pods until the final commissioning phase of the project. This approach provided improved control over quality and avoided the problems caused by multiple package sub-contractors coming in and out of the bathrooms with no single sub-contractor taking ownership and ultimate responsibility (apart from the main contractor). This process avoided the common "wisnae me" attitude which trade sub-contractors often take on such works.

Additionally, refurbishment is similar to traditional construction and the kits can be disassembled and removed. As more innovative and sophisticated pre-engineered kit systems for bathrooms come out onto the market, fitting of the kits may become less workmanship based and more of a ‘click and lock’ system.

Figure 1: Typical arrangement for standard pod configuration. (Courtesy: Graven Images)

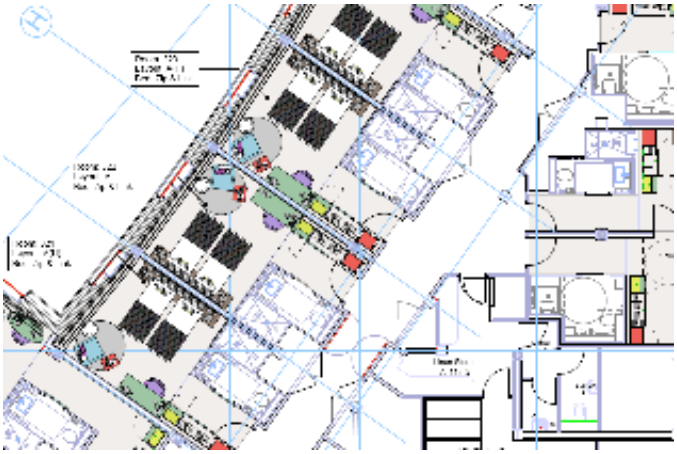

Figure 2 shows an in-situ view of the bathroom pods in their final position. Note that the sliding glass door has not yet been installed. The glass sliding doors were installed on site following the final installation and services connections for the pod. The lack of a secure door to prevent unauthorised access led to issues surrounding control of operative access to the pods during the decoration and final installation works outside the pod and during the floor installation. It is normal practice to use the door as a means of securing the pod prior to final commissioning and practical completion and handover.

Figure 2: In-situ view of pod without glass sliding door (Courtesy: Sir Robert McAlpine)

Figure 3 shows the mechanical and electrical service access points behind the pods. Each service riser allowed access to the SVP's, hot and cold supply manifold, lighting and electrical distribution hub with control systems. A modular wiring system was adopted to improve site installation of the complex electrical installation for lighting and the AV equipment. The position of a primary structural column created a number of restrictive access issued for the installation operatives. It is essential that this type of structural clash is considered at an early stage in order to minimise disruption and unnecessary delays during construction.

Figure 3: Mechanical and electrical services riser. (Courtesy: Sir Robert McAlpine)

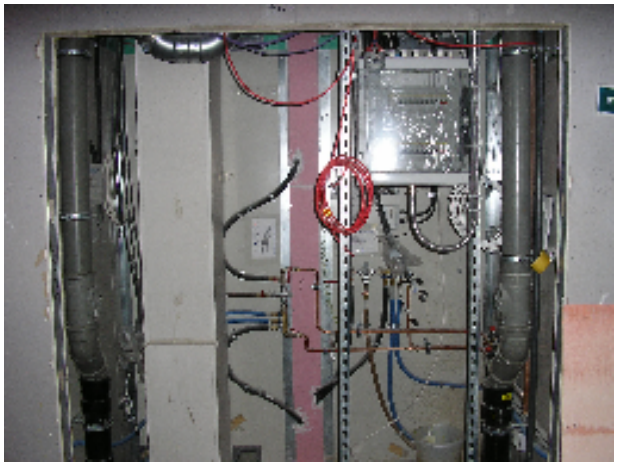

Figure 4 shows the pre-engineers bathroom 'kits' being installed. Each panel was delivered as a pre-finished element complete with the provision of pre-drilled holes for the connection of the various fixtures required. An integrated plumbing system was and modular wiring system was specified. These kits were required to interface with traditional construction materials and processes.

Figure 4: Pre-finished 'kit' panels being installed on site. (Courtesy: Sir Robert McAlpine)

PROCUREMENT

In financial terms, hotel bathrooms have a high level of capital costs associated with them due to the mechanical, electrical and architectural specification for finishes, fixtures and fittings. Any efficiency of design, manufacture and installation can result in a notable reduction in the overall out-turn cost of the project. In addition, to the overall incorporated capital costs, traditionally built bathrooms require an intensive level of management and logistical planning. Unlike other spaces within a hotel,

bathrooms require a significantly higher level of trade interaction when compared to others elements of the building.

Many of the trades involved will require more than one visit and separate snagging works. Snagging can be particularly challenging for site management in both the interface co-ordination of the trades and when undertaken snagging and defect correction works. The standardisation of sanitary ware, fixtures and fittings are a possible means of reducing the overall capital costs through the careful modelling of standardised platforms with mass-customised configuration options to create the bespoke aesthetic designs required by the interior designers.

In order to maintain control and responsibility for the delivery and quality of the bathrooms which could not be constructed using pods, they were procured in a similar manner to the pods but delivered to site as a 'kit of parts'. This procurement strategy involved a single sub-contractor undertaking the construction of the 'kit of parts'. The sub-contractor was responsible for the construction of the frame structure, the mechanical and electrical services, sanitary ware, and connections to service risers, tiling, finishes and any other fixtures required. Upon completion of the work, the bathroom doors were locked and secured until the final commissioning phase of the project.

This approach provided the main contractor with greater control over quality standards and avoided the problems associated with multiple package contractors requiring access to the bathrooms with no single line of responsibility. The bathroom pod construction required a floor less system to be incorporated into the design solution. The floor area outside was manufactured using a 1.6mm galvanised steel sheet to provide the protection required during delivery and final installation. The installation procedure required the pods to be manoeuvred using load moving skates.

Scope of design package for bathroom pods included:

- Design of bathroom pods.
- Manufacture of pods - including services tails for later connection by others.
- Delivery of pods to site.
- Unpacking, commissioning and testing.
- Manoeuvring of pods to final 'on-site' position.
- O&M manuals.
- As-built drawings.

Scope package exclusions included:

- Doors to pods - sliding glass doors fitted on-site.
- Under floor heating mat (cable spur allowed for)
- Fixing of floor tiles in non-shower areas (tiles provided by others).
- Off-loading and final connection of services.
- Provision of buffer storage yard.
- Provision of off-loading and re-loading delivery to site from buffer yard.

The decision to place the order with the Italian manufacturer was based upon their willingness to provide a high specification pod and the pre-engineered kits for the non-pod bathrooms (building refurbishment). During early technical discussions, the project design team referred to their previous experiences with bathroom pod manufacturers in relation to limitations on the number of variants and minimum

orders. Manufacturers that allow higher quantity of variations and lower quantity for minimum orders generally are seen as more competitive. The lack of flexibility within the UK market has provided opportunity for less restrictive markets in the EU, and this was the case for this particular project. Furthermore, the majority of the UK manufacturers considered did not believe they could achieve the level of specification required for this particular project.

The contractual arrangement for the pods and kits was based on a material order. Unlike a sub-contractor order, payments where based on invoices for materials and therefore, leaving no held retention. There were no collateral warranties provided, but rather product warranties provided by the manufacturer. If issues arose with the pods or kits (kits are questionable) then the manufacturer must repair or remedy. The installation contractors were restricted to what they could repair due to the risk of invalidating the product warranty.

INTERFACE WITH TRADITIONAL CONSTRUCTION

It is rare that modular construction techniques do not interface with more traditional methods of construction. This alone often gives rise to interface and tolerance issues that could, if not considered at the early design stages, led to lost productive time on site and contribute to additional costs. The pods are lifted clear of the pallets and pushed into final position using 'scoots' - a form of lifting skate. This requires the minimum headroom clearance to avoid clash with the existing structure. The pods were designed and constructed with ‘thin floors’ and therefore arrived on site without floor finishes. The structural and loading issues regarding the existing foundations necessitated the pods be manufactured without a rigid floor. Additionally, the 'thin floor' construction of the concrete floor slabs made it impossible for a recess to be constructed within the concrete for the pods to be inserted into. Without the recess the pods would sit to high off the main floor slab and would require the floor finishes within the room to be substantially higher. This consequently would result in further loads on the structural elements and a reduction in the overall room height. The use of a thin floor within the pods required them to be bolted down into position, under floor heating mat and tiling was installed traditionally on site.

As part of design and space saving exercise the designers decided to use sliding doors instead of normal left or right opening doors. In order for the sliding doors to remind undamaged and for the pods to be positioned correctly, the doors were installed after the positioning of the pods. Unfortunately the lack of doors left the pods prone to vandalism and theft which did occur an a few occasions. In order to prevent any further vandalism, temporary doors from 18 mm plywood was screwed onto the openings.

The unusual shape of the new building did not lend itself well to pod construction resulting in site logistical issues. Therefore, three access points were left opened in external cladding. The pods where craned into the openings and pushed along on the corridors on ‘scoots’, then placed in position. Unfortunately due the pods size and shape it was impossible to construct any partitions facing the corridors or install any door frames, as the pods would not fit otherwise. Although a buffer storage facility was provided, the installation programme was achieved and the requirement for storage off-site prior to installation was not actually required. However, it would be advisable to maintain this contingency to prevent the storage of bathroom pods on site.

FINANCIAL AND ECONOMIC APPRAISAL

Table 1 provides a summary of the costs associated with the manufacture, supply, installation and remedial works required to the pods and bathroom 'kits' employed on the project. The majority of the cost is, as expected, associated with the manufacture and delivery of the pods and the 'kits' to the site. Despite the use of offsite construction methods the main contractor also made contingency provision for spare parts, waste and unattributable damage. Despite the use of offsite construction techniques and processes, the interface requirements with traditional construction materials and processes led to damage that had to be repaired on site. The congested and compact nature of the site made site management and security particularly challenging.

The offloading and temporary storage of the pods at the off location storage yard led to significant cost being attributed to the labour required for these procedures. Significant labour cost was also required for the installation of the bathroom 'kits'. The process of kit installation requires a trained joiner and plumber to undertake the mechanical and installation of the pre-engineered panels. The hire of the 'scoots' (load lifting skates), temporary joinery for security (due to the glass sliding doors being fitted to the pods following installation) and site cranage for the high level hotel suites made up the remainder of the costs for the project.

Table 1: Financial summary of bathroom pod and 'kit's supply and installation.

Total supply cost of all Pods and kits	£	1,250,147.91
Allowance for spares/waste/unattributable damage	£	18,310.00
Labour - Offloading and installation of Pods	£	35,000.00
Installation of Kits	£	29,952.00
Temporary doors/ironmongery	£	536.71
Hire of scoots for moving Pods / Protection	£	8,418.76
Additional protection for site conditions	£	1,404.20
Allowance for concrete to shower base	£	200.00
James Jack invoices for Level 6 suite pod cranage	£	2,184.00
Total	**£**	**1,346,153.58**

Table 2 provides a cost breakdown for the manufacturing, delivery to site, final positioning, installation, protection and installation of the tiling to the bathroom pods. Unlike traditional bathroom pods, the pod design for this project required a thin floor construction with the final installation of the heated floor and tiles being undertaken on site. The section relating to the pod floors covers the various activities and materials that were required to undertake and complete this work. Importantly, there were a number of unforeseen items relating to the remedial works and cleaning. It is essential when using pods to consider the security of the pods from the outset and ensure that they are locked and secured to prevent unauthorised access of use. Furthermore, the design must ensure that only external work must be undertaken on site to further eliminate the need to open and work inside the pods following site installation.

The installation and positioning costs are influenced by the co-ordination and management of site based activities. It is essential that planning and integration with traditional construction materials and processes are considered from the outset to keep these costs to a minimum. As previously explained, the pods required work to be undertaken in relation to the installation of the under floor heating and the tiled surface. The unforeseen costs were the result of alterations in relation to plumbing

fittings being non-compliant with UK Building Regulations. It is critical when engaging non-UK bathroom pod manufacturers to ensure that the design is being produced in accordance with the UK Building Regulations and design standards.

Table 2: Summary of pod cost data (standard pods only)

Information Source	Description	Qty	Unit		Rate		Total
	Cost of manfacturing and delivery of pods						
Invoiced	Prototype	1	nr	£	8,275.91	£	8,275.91
	Standard Pods	88	nr	£	8,295.00	£	729,960.00
	Total (excluding prototype)	88					
	Replacement and Additional Items						
	Positioning and installation of pods						
Invoice/estimate	Cranage	88	nr	£	90.91	£	8,000.00
Invoiced	Scoots'	88	nr	£	95.67	£	8,418.76
Main Contractor	Positioning and Adjustment	88	nr	£	164.01	£	14,433.00
	Protection to pods						
Invoiced	Plywood and locks for temp doors	88	nr		21.00	£	1,848.00
Labour Abstracts	Labour for fixing temp doors	44	hr		20.00	£	880.00
	Pod floors						
Tiling tender	Tiling to floors; approximate floor area per pod 4m^2	88	nr	£	189.28	£	16,656.64
Tiling tender	Strada board	88	nr	£	127.36	£	11,207.68
M&E tender	Heating mat	88	nr	£	295.55	£	26,008.40
Tiling tender	Corex flooring protection to tiled floors	440	m^2	£	2.10	£	924.00
Tiling tender	Thresholds	88	m	£	26.87	£	2,364.56
	Sliding doors						
Fit out tender	Bathroom sliding door laquered profiles	88	item	£	212.73	£	18,720.00
	Unforseen Costs						
M&E var	Retesting	88	nr	£	75.00	£	6,600.00
Metalwork var	Drilling through drainage	88	nr	£	15.00	£	1,320.00
Tiling var	Additional screed to pod floors	88	nr	£	120.00	£	10,560.00
Joinery var	Mastic to thresholds	88	nr	£	14.86	£	1,307.68
	Cleaning of pods due to tiling, repair works and unauthorized usage	176	hrs	£	12.00	£	2,112.00
	Removal of inadequate traps and replacement of a thicker trap	88	per	£	90.00	£	7,920.00
	Resealing around pan connections	88	per	£	31.50	£	2,772.00
	Total each pod					**£**	**17,725.81**

*Tower crane - used for others
**Tiles free issue by pod/kit manufacturer
*** replacment of hemp was by ensuite
****6 level suite has larger floor area (double)

Table 3 provides a summary of the manufacture, delivery, unloading, installation of the bathroom 'kits' that were provided by the pod manufacturer. These panelised kits were installed into the bathroom areas and then tiling and decoration to the walls and ceilings was undertaken in a traditional manner. In comparison with the pods the 'kits' required greater labour input and the materials and labour associated with the decoration and finishes. Unlike the pods, the 'kits' required extensive snagging following installation. The snagging was required to make good the defects identified following the decoration and finishes installed on site.

Despite the reduced costs associated with delivery, craneage, interface management and the additional on site works required in relation to design alterations, the bathroom pods appear to be a more economical solution when compared on a like for like basis with the pre-engineered bathroom 'kits'. The reliance upon traditional on site trades for decoration and final finishes has contributed to the increased cost of the kits. However, the kits were used in the construction of bathrooms being constructed in the refurbished building and provided an improved standard of decorative finish over and above that commonly achieved with traditional bathroom construction techniques. It would be advantageous to conduct a further study in comparing the pre-engineered bathroom 'kits' with traditional bathroom construction materials and processes.

Table 3: Summary of bathroom 'kits' cost data

Information Source	Description	Qty	Unit	Rate	Total
	Cost of manfacturing and delivery of kits				
*	Prototype	1	nr	£ 8,275.91	£ 8,275.91
Invoice	Standard kits	12	nr	£ 6,200.00	£ 74,400.00
	Unloading, construction and installation of kits				
	Unloading of kits	27	hrs	£ 18.00	£ 486.00
Labour abstracts	**Installation of the kits	1,184	hrs	£ 25.00	£ 29,592.86
Labour abstracts	Forming holes for fixtures and lighting	13	hrs	£ 20.00	£ 257.14
	Concrete	12	nr	£ 65.00	£ 780.00
Tiling tender	Thresholds	12	m	£ 26.87	£ 322.44
	Tiling to kit floors and walls				
M&E tender	Heating mat	12	nr	£ 295.55	£ 3,546.60
Tiling tender	Strada board	12	nr	£ 127.36	£ 1,528.32
Tiling tender	Tiling walls; approximate wall area per bathroom 8m^2	12	nr	£ 378.58	£ 4,542.96
Tiling tender	Tiling floors; approximate floor area per bathroom 4.5m^2	12	nr	£ 212.94	£ 2,555.28
Tiling tender	Corex flooring protection to tiled floors	60	m^2	£ 2.10	£ 126.00
	Decoration to walls and ceilings				
Decoration tender	walls; approximate wall area per bathroom 6m^2	72	m^2	£ 3.90	£ 280.80
Decoration tender	ceilings; approximate ceiling area per bathroom 4.5m^2	54	m^2	£ 3.90	£ 210.60
	Sliding door				
Fit out tender	Bathroom doors to the Lawnmarket	12	nr	£ 913.99	£ 10,967.86
	Additional costs				
Labour abstracts	Snagging	549	hrs	£ 20.00	£ 10,971.43
	M&E	12	nr	£ 850.00	£ 10,200.00
	Firestopping and coring				£ 1,285.71
	Total each kit				**£ 20,947.08**

* kits were based on a the prototype
**including all materials and labour for forming of partitions and ceilings

Allied partitions £137.258 per m; fire barriers £33.39 per m

CONCLUSIONS

The case study has identified a range of additional costs, installation and interface issues that may be encountered when using bathroom pods and pre-engineered 'kits' for the construction of hotel bathrooms. An insight was provided into the practical on site issues that can result from design decisions undertaken at the concept design stages. Issues relating to the use of factory installed doors as a means of controlling access to the pods and the installation of all finishes and fixtures in a factory environment can reduce the costs associated with remedial works and snagging due to unattributable damage. The financial comparison of the two methods provided evidence to show that pods can successfully contribute to the economical delivery of high specification hotel bathroom suites. Pre-engineered bathroom kits procured in a similar manner to bathroom pods can provide an economical means of building bathrooms in the refurbishment of buildings. In direct comparison, the pods provided a cheaper alternative over the pre-engineered kit of parts. However, the use of both techniques may have specific advantages depending on whether they are used in new build or refurbishment projects. Every project requires careful control and programming of trades and ensuring the security of highly serviced areas such as bathrooms. It is essential that pods are considered as a sealed and closed element with only external works being undertaken on site. Furthermore, if non-UK manufacturers are employed with design responsibility, it is essential that they are manufacturing to UK Building Regulation standards. This will lead to a reduction in the costs associated with remedial works and retro-fitting to combat damage and non-compliant components. A further study is required to undertake an economic comparison with pre-engineered bathroom kits and traditional construction techniques in refurbishment and retro-fitting projects to determine the most economical method of construction.

REFERENCES

Buildoffsite (2008) Your guide to specifying modular buildings: maximising value and minimising risk, Published in Association with BAA Ltd, Available at: http://www.buildoffsite.org/downloads_publications.htm#mod [Accessed 17 November 2008].

Blismas, N, Pasquire, C and Gibb, A (2006) Benefit evaluation for off-site production in construction. "Construction Management and Economics", 24, 121-130.

Finnmore, B (1989) Houses from the factory: system building and the welfare state, Rivers Oram Press, London.

Gibb, A G F and Isack, F (2003) Re-engineering through pre-assembly: client expectations and drivers. "Building Research & Information", 31(2), 146-160.

Herbert, G (1978) Pioneers of prefabrication: the British contribution in the nineteenth century. The John Hopkins University Press, Maryland, United States of America.

Johnsson, H and Sardén, Y (2008) Industrialised timber housing: from trial to production. In Dainty, A (Ed) Procs 24th Annual ARCOM Conference, 1-3 September 2008, Cardiff, UK, Association of Researchers in Construction Management, 155-164.

Meyer, P (2008) What it costs: bathroom pods. Building, 20th June.

Pan, W, Gibb, A G F. and Dainty, A R J (2007) Perspectives of UK housebuilders on the use of offsite modern methods of construction. "Construction Management and Economics", 25(2), 183-194.

Ritchie, B. (2002) Standardisation and pre-assembly: report on capturing the learning from integrating bathroom pods into timber frame structures on a general needs social housing project. A report prepared by the Department of Trade and Industry Fast Track Programme by Willmott Dixon Housing Ltd. 13th August, Bedfordshire, UK.

Ross, K., Cartwright, P. and Novakovic, O. (2006) A guide to modern methods of construction. NHBC Foundation, Published by HIS on behalf of NHBC Foundation, Bucks, UK.