

# A LONGITUDINAL INVESTIGATION INTO UTILISING CROSSWALL CONSTRUCTION FOR MULTI-STOREY RESIDENTIAL BUILDINGS

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To address the under-supply and poor build quality of housing in the UK, the use of offsite technologies has been promoted. Precast concrete crosswall is an offsite technology encouraged for use for multi-storey developments. However, the uptake of crosswall is slow, which constitutes a risk to long-term housing delivery. This paper addresses this risk by revealing an insight into the utilisation of crosswall for multi-storey residential buildings in the organisational context. The paper reports on longitudinal case study research of 20 crosswall buildings, consisting of 1930 apartments in total, constructed by a leading UK housebuilder in recent five years. The case study involved document analysis and personal interviews with the company and their supply chains. The rationale for utilising crosswall included considerations of design, technical, commercial, procurement and construction. The primary driver was simplicity from both procurement and contractual aspects, which enabled the developer to construct buildings up to 20 storeys without engaging specialist main contractors. Other benefits included reduced on-site duration, enhanced quality of finish, reduced waste, improved health and safety and cost savings, whilst issues existed in design, procurement and construction. To fully realise the potential benefits from utilising crosswall requires modifications to existing design process and supply chain management and cultural support to innovation and learning. Strategies are developed from the longitudinal learning process. They should encourage the uptake of crosswall and improve quality and efficiency of housing supply in the future.

Keywords: innovation, learning, offsite construction, precast concrete crosswall.

## INTRODUCTION

The use of offsite construction technologies, or ‘Modern Methods of Construction’ (MMC), has been encouraged in the UK to improve quality and efficiency of housing supply (ODPM 2003). The government seems to be a strong advocate and, via its funded schemes (see POST 2003), it aimed to help deliver a step change in using modern techniques and encourage the private sector to invest in offsite technology (ODPM 2003). However, government influence on private-sector housebuilding to use offsite has been limited. Although a few large private housebuilders have invested in offsite or MMC factories (POST 2003), they are largely restricted to individual firms, and there are very few established mechanisms for learning and information sharing amongst leading firms (Roy *et al.* 2005). The uptake of offsite technologies is slow. Pan *et al.* (2007; 2008) studied the perspectives of large UK housebuilders on

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utilising offsite technologies and developed strategies for improving their practices. An important part of the strategies is related to offsite integrated design and construction process, supply chain management and learning. They recommended further research to explore the organisational context to realise the strategies. This paper builds on previous research and focuses on one important type of offsite technology, i.e. precast concrete crosswall construction. The paper aims to develop strategies for utilising crosswall for multi-storey developments. The study tracked down the innovation journey (Geels *et al.* 2008), or innovation trajectory (Egbu 2004), of utilising crosswall in a leading UK housebuilder over a period of five consecutive years from 2004 to 2009. This period represents the time covering the boom in the housing market with the UK government's policy focus on offsite and MMC and the current housing market downturn within the general economic recession. The focus on one housebuilder, as the 'unit of adoption' of the innovation (see Egbu 2004), coupled with their supply chains, enabled the in-depth analysis of the innovation process in the intra- and inter-organisational settings. The paper aim is achieved through four research objectives: 1) review the rationale for utilising crosswall for multi-storey residential buildings, 2) compare the benefits achieved and issues encountered, 3) map the innovation journey of utilising crosswall in the organisational setting, and 4) develop strategies for managing innovative construction for residential buildings.

## **PRECAST CONCRETE CROSSWALL CONSTRUCTION**

Crosswall construction employs factory precast, precision engineered, concrete components, each of which is custom designed and manufactured offsite to suit the specific project (The Concrete Centre 2007). The use of precast concrete dates back to the late 1800s but had been limited until around the 1950s when the UK government promoted it to address the housing problem following the Second World War (Glass 2000). By 1960, over 165,000 precast concrete dwellings had been built, ranging from single storey bungalows to multi-storey buildings. However, such type of construction suffered a significant setback as a result of the Ronan Point collapse in 1968 coupled with problems arising from 'social engineering' and the social malaise of high-rise dwellings (*ibid.*). Such setback lasted until the late 1980s when an economic boom and preference for Post-modernist architecture improved its fortunes (Glass and Pepper 2006). Following the recommendations by Egan (1998) on taking up prefabrication and preassembly techniques, the use of crosswall has been encouraged by the government again. The housing policy focus on sustainable communities and urban regeneration (ODPM 2003) has also provided an opportunity for crosswall for multi-storey developments. However, the current extent of crosswall applications in the domestic sector is particularly 'rare' (Pan *et al.* 2008). This appears paradoxical given that precast concrete construction has developed and improved and moved away from its historical problems with design and construction (Glass 2000) and the evidence of the benefits from using crosswall (The Concrete Centre 2007). Although many large housebuilders believed that external and internal walls offer the greatest potential for offsite solutions (Pan *et al.* 2008), crosswall is new to UK housebuilding and its adoption is being considered innovative and risky by many companies.

## **INNOVATION AND LEARNING**

The Neo-Schumpeterian research views innovation as an evolutionary process which is interactive, cumulative, institutional and disequilibrating (Jones and Saad 2003). Underpinning the many definitions of innovation in the literature is the view that innovation is not a single nor an instantaneous act, but a whole sequence of events

which occur over time and involve all the activities of bringing a new product or process to the market (ibid.). Nelson and Winter's (1982) 'search and selection' theory suggests that the innovation approach adopted by a firm be dynamic and shaped by new internal and external requirements and therefore not always be similar to those adopted by other firms operating in the same industry or environment. The search for new solutions to particular problems involves significant learning procedures as well as search processes based on R&D activities (Trott 2002). Given the complexity of innovation, its management requires a thorough understanding of the main stages through which an innovation is developed. One of those stages is implementing, which was modelled by Saad (2000) to cover 'adoption, adaptation, modification and re-invention'. Through the process, skills and knowledge are acquired by individuals and organisations, and learning is recognised as a key to innovation in response to the challenges of the changes (Jones and Saad, 2003). Such process was examined in the longitudinal research on which this paper reports. This logic enabled the use of innovation theories to examine the results from the study, and vice versa.

## **METHODOLOGY**

The investigation was carried out through case study research in the longitudinal utilisation of crosswall methods by a leading UK housebuilder. There were eight projects covered in this research, labelled A to H (Figure 1), which, altogether, included 20 multi-storey buildings, providing 1930 units of apartments. The superstructure of all buildings was constructed using crosswall. The case study involved document analysis and personal interviews and workshops with the personnel of the company from both senior managerial and project operational levels which covered the roles including design, technical, construction, estimating, buying, innovation and sustainability. The focus on the housebuilder was based on the fact that the company took the leadership in the process, which is required to bring about substantial internal and external structural and attitudinal changes needed (Jones and Saad 2003). Their supply chains were also included in the relevant interviews as their input improved validity of data on utilising crosswall methods. The longitudinal research design was grounded on theory of innovation as a complex and challenging multi-factor process (ibid.), for which the period of five years and the cross-project nature of the investigation enabled a valid and reliable in-depth case study (see Yin 2003) of the innovative technology.

Case study data consist of interview notes, observations, documentary data, impressions and statements of participants, and contextual information. In effect, all information that accumulates on each crosswall project or building went into the overall case study. As the diverse sources make up the raw data for case analysis and can amount to a large accumulation of material (Patton 2002), the process of constructing case study data suggested by Patton was used for analysis, which included assembling the raw case data, constructing a case record and writing a final case study narrative presented chronologically and thematically. Given the data diversity and mixed nature, the approach suggested by Miles and Huberman (1994) was used for making sense of the data and sharing their interpretations with the audience, which consisted of three concurrent flows of activity: data reduction, data display and conclusion drawing and verification by follow-up discussions with key participants. The analytic procedures and strategies enabled the meaningful presentation of the case study and the establishment of relevant arguments.

Table 1: Rationale\* for utilising crosswall construction

Project	Rationale (for Project F, see note)
A	<p>Achieve fast construction</p> <p>Enable ‘in-house build’, i.e. without engaging any specialist main contractor</p> <p>Minimise interfaces between build elements to reduce contracts to control</p> <p>Improve site space efficiency by just-in-time deliveries and reduce operatives on site</p>
B	<p>Achieve quality benefits, e.g. eliminating shrinkage issues normally associated with timber frame, although a timber frame solution would be possible for the 5-storey building</p>
C	<p>With experience from Project A and B, crosswall was considered as the definitive high-rise build method from a ‘cost, management and risk’ perspective.</p> <p>Previous learning had developed an effective design, procurement and construction team.</p>
D	<p>Crosswall was considered as a proven and preferred solution.</p>
E	<p>The 4-storey building could be constructed using timber frame and was initially considered less cost-effective in crosswall. However, the development of 125mm walls rather than usual 150mm brought cost savings and allowed crosswall construction.</p> <p>Learning from Project C enabled undercroft car-park design to be tailored for crosswall to avoid the use of insitu concrete frame contract.</p>
G and H	<p>Further development of the crosswall system with sandwich panels eliminated the use of on-site envelope fixing</p>

\* For all projects except A, a common rationale was to sustain benefits achieved previously.

## RESULTS AND ANALYSIS

### Rationale for utilising crosswall

The rationale for utilising crosswall in the company was based on the combined considerations of design, technical, commercial, procurement and construction. It developed over the time and projects (Table 1).

The interviewees emphasised that the primary driver for utilising crosswall was its simplicity which underpinned the rationale. This simplicity enabled the developer to construct buildings up to 20 storeys using ‘in-house’ management without the need to engage any specialist main contractor. This was seen as a major gain from both procurement and contractual aspects. The rationale developed over the projects shows a clear learning curve of the housebuilder in terms of managing and implementing crosswall technology.

### Benefits achieved

The benefits achieved cumulated through the process and were consistent with the rationale for utilising crosswall. The fundamental benefit was that the company trialled and proved a new opportunity for constructing buildings up to 20 storeys without engaging external scaffold. Other main project benefits were centred on costs savings, reduced on-site duration, reduced contract risks, enhanced quality of finishes, improved health and safety, very little or zero waste and simplified interface detailing. Coupled with these project benefits were the gains on the organisation level, which included improved knowledge of offsite and MMC, uplifted organisational culture embracing innovation, streamlined business processes and procedures, and established partnering relationship with national and multinational supply chains. All these benefits and gains were considered significant and contributed to the corporate image of the company as a leading innovative developer in the UK.

Table 2: Issues\* encountered during the utilisation of crosswall

Project	* Only main issues were included in this table
A	<p>A late design decision to use crosswall changed from timber or insitu concrete frame.</p> <p>All floors needed to be on grid, which constricted floor layouts.</p> <p>Temporary floor waterproofing was required to avoid leakage to fit-out works below.</p> <p>Maximum potential programme savings were at risk of not being realised as other trades work did not catch up.</p> <p>There existed a knowledge gap in the management team, and cultural resistance was evident in the company.</p>
C	<p>Off-grid undercroft car parking could not be achieved with crosswall construction, because of which a separate contract was required for reinforcement concrete frame contractor for the undercroft level. This proved contractually demanding and generated programme delays for insitu concrete works.</p>
D	<p>Maximum potential programme savings were reduced due to external envelope delays outrunning internal fit out of the blocks.</p> <p>Installation services from different crosswall contractor (for Project A) were proved less efficient. Grouting detailing from this contractor required remedial work.</p>
F	<p>Tower crane interface between lower floors insitu work and upper floors of crosswall required design, engineering and contractual solutions.</p>
G and H	<p>Interface detailing for sandwich panels required cross team solutions. Sandwich panels sourced from the continent were fitted in the factory with windows and balconies from the UK, for which logistics was developed.</p>

### Issues encountered

The issues encountered (Table 2) apparently challenged the previously existing design, procurement and construction management of the company. These issues were mainly attributed to the facts that crosswall construction was new to the company and the supply chain had not been established in the UK market.

### Addressing the issues and learning

During the period researched, the company adopted the initial crosswall method, adapted it to the business context and project specifics, and vice versa, modified the approach, and re-invented a more appropriate construction technology to achieve better value. The modifications to the initial method included 1) replacing full external scaffold by mast climbers, 2) developing 125mm crosswall panels from usual 150mm, 3) re-engineering design to enable on- or off-grid crosswall undercroft/podium structures to avoid insitu concrete work, and 4) modifying design, engineering and contractual solutions to suit partnering (Figure 1). These modifications to the initial innovation sustained the use of crosswall in the subsequent projects by not only improving the technical and management performance but also providing a series of 'cost engineering' means for reducing costs. The re-invention of the innovation was crosswall sandwich panels which integrated cladding in the factory and, therefore, eliminated the use of external scaffold on-site. The innovation journey clearly demonstrated an effective learning process (Figure 1). A learning environment was evident in the company and reflected in their routine management processes and procedures. The routine learning mechanisms used by the company included the Corporate Management Committee and the Managing Directors' Advisory Group at the corporate level, the Intervention Meeting at the company level, and the Project Development Meeting at the project level (Figure 2).

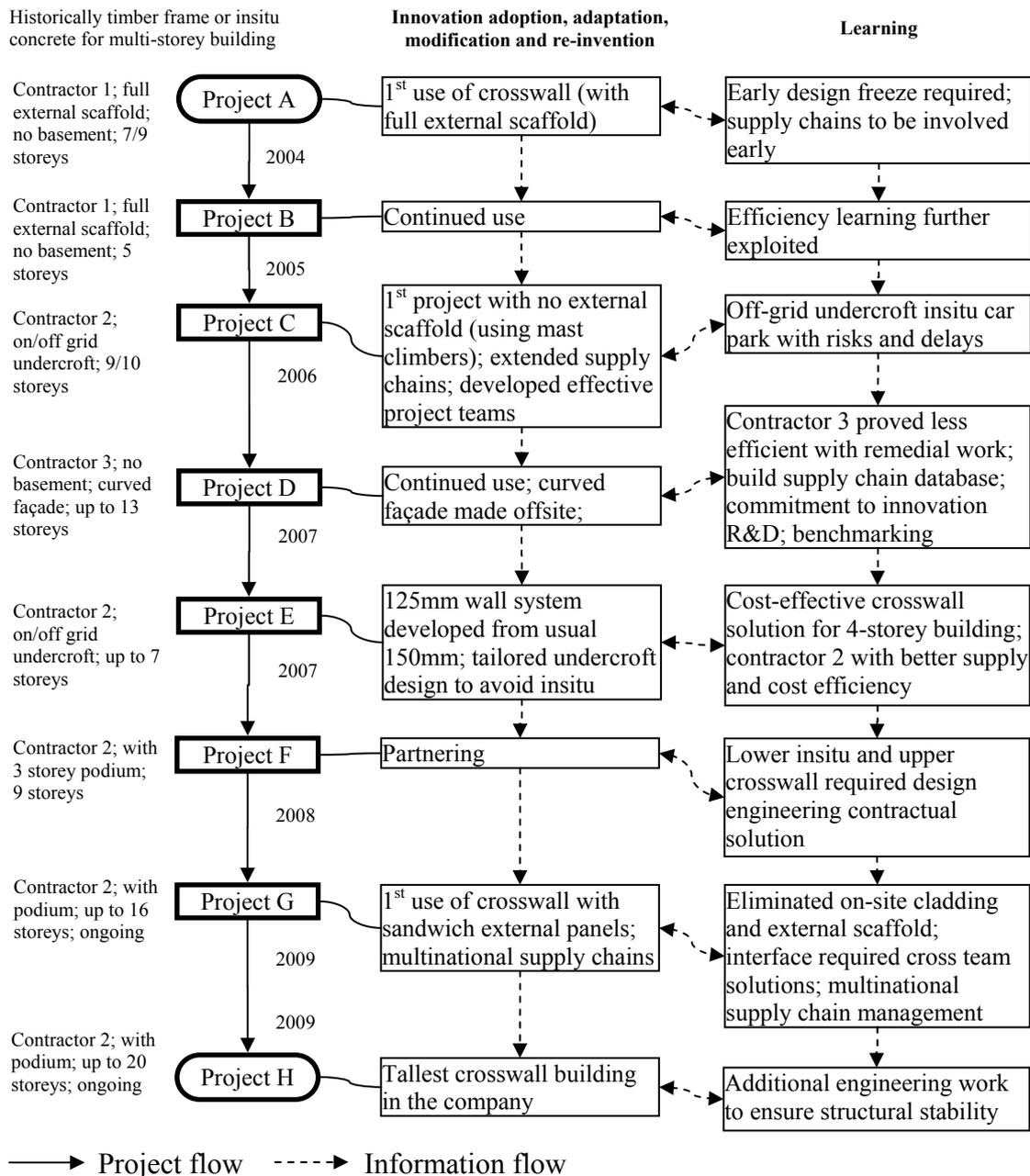


Figure 1: Mapped innovation journey of utilising crosswall methods

There were also a few interviews/workshops with the crosswall contractors and suppliers, in which the project teams, with input from relevant departments of the company, explored the use of crosswall. However, these activities were organised on an ad hoc basis. In more recent years, several cross-departmental multi-disciplinary forums (Figure 2) were established in the corporate, which attempted to improve business efficiency in response to market competitions and current economic conditions. These forums in effect provided a platform for sharing information and learning from best practice across the corporate. The learning mechanisms, coupled with the newly established forums, ensured the effectiveness of implementing and managing innovative technologies including crosswall, albeit the interaction between the forums and existing routines was subject to further development for improving efficiency.

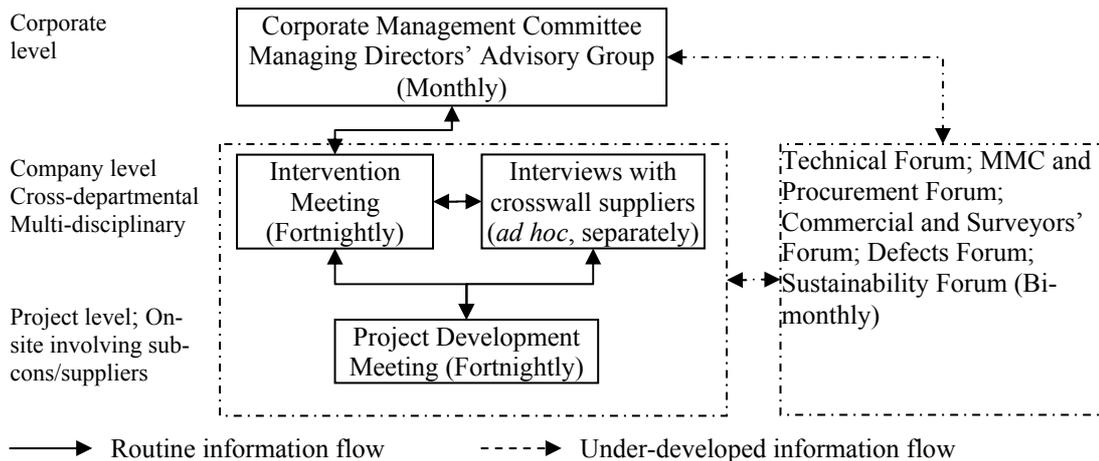


Figure 2: Learning mechanisms in the company for managing innovation

## DISCUSSION

The rationale for utilising crosswall and the benefits achieved by the company demonstrated a general consistency with the benefits claimed by previous research in offsite (e.g. Pan *et al.* 2008) in terms of time, quality, health and safety, waste and efficiency. More interestingly, the journey of adopting, adapting, modifying and re-inventing crosswall methods provided ‘cost engineering’ means and, therefore, enabled project costs savings over conventional timber frame or insitu concrete frame methods. This finding is important as most large housebuilders perceived offsite to be associated with higher capital cost than conventional methods (Pan *et al.* 2007) and such perception exists among many industry players and forms a significant cost barrier to the uptake of offsite (Goodier and Gibb 2007). Another useful finding is that the five-year implementation and development of crosswall methods enabled the company to construct buildings up to 20 storeys using ‘in-house’ management which streamlined the design, procurement and construction and, consequently, minimised contractual risks. This empirical evidence supports the procurement strategy for utilising offsite claimed in previous research (e.g. Pan *et al.* 2008; Goodier and Gibb 2004). It also provides a caveat for the argument that the strong reliance on subcontracting in UK construction projects (Loosemore *et al.* 2003) creates problems for using innovative building techniques (Ball 1999) by suggesting that such problems are not inevitable as long as there is a leading party in the supply chain, e.g. the housebuilder using ‘in-house’ management, who commits to innovation and manages the supply chain. This leading role also addresses the concerns of Hong-Minh *et al.* (2001) that current housing supply chains are fragmented and underpinned by poor communication, adversarial relationships and a lack of trust and commitment. Given that relationships between the players in the supply chain are still characterised by a cost-driven agenda (Wood and Ellis 2005), ‘cost engineering’ means, as demonstrated in this paper, can be developed to reduce the cost of offsite solutions. All these commitments require housebuilding companies to change their mind-set, become process-orientated and improve communication and learning (Hong-Minh *et al.* 2001).

The revealed learning mechanisms used by the company provide a worked example to address the concerns of Roy *et al.* (2005) about the lack of established mechanisms for learning and sharing knowledge and good practices in the UK housebuilding industry. The housebuilder’s aspiration to increase knowledge through learning and benchmarking reflects the concern that the industry does not efficiently utilise the knowledge of the employees and the organisation as a whole (Egbu *et al.* 2005).

Table 3: Framework of strategies\* for utilising crosswall

Category	* Strategies are developed from the housebuilder's perspective
Leading and championing innovation	<p>Commitment from senior management to innovation is needed to enable structural and attitudinal changes and empower individuals and organisations to work more collaboratively.</p> <p>The leader or champion, e.g. the housebuilder, should be proactive in exploring alternative contractors/suppliers, nationally and multi-nationally, for multi-storey schemes, for which conventional tenders can have significant price variances.</p>
Learning to support innovation	<p>R&amp;D should be encouraged in close collaboration with different departments in the company and wide supply chains to capture and create new knowledge.</p> <p>Performance of crosswall should be measured and best practice is benchmarked across the company for wide learning.</p>
Procurement and supply chain management	<p>Supply chains should be involved in early design stage, and early design freeze is required.</p> <p>There is a need to explore alternative crosswall contractors or suppliers to ensure best value is achieved, for which a supply chain database would help.</p> <p>Specific performance criteria need to be developed for specifying and assessing crosswall installation services.</p>
Designing and engineering innovation	<p>Considerations for undercroft/podium structures should form part of design and engineering. On-grid undercroft/podium structures may enable a cost-effective solution for crosswall but can constrain functional efficiencies. Off-grid structures normally require the use of insitu concrete construction, which can be contractually demanding and programme-wise risky.</p> <p>The use of full external scaffold should be designed out, for which innovative ways of climbers or sandwich crosswall panels can be used.</p> <p>Modified innovative crosswall can allow cost-effective solutions for buildings with lower storeys, e.g. 4 to 6, which can be easily constructed using timber frame or insitu concrete but are generally considered less cost-effective in crosswall.</p>

Housebuilding stakeholders must develop their organisational learning as the core of managing innovation. Despite the learning strategy, risk-averse attitudes existed among many senior managers of the company. This is consistent with the statement in Seaden *et al.* (2003) that, although innovation leads to improved competitive advantage and greater profitability, it is risky, requires significant investment and is often resisted within the firm. This justified the involvement and commitment of senior management of the company and the importance of a learning and knowledge-sharing culture (see Dainty *et al.* 2006; Loosemore, *et al.* 2003) to support innovation. Despite the learning mechanisms and forums established in the company, it is clear that supply chains need to be integrated into routine management processes and procedures for fully realising the potential benefits of offsite technology. From the discussion above several strategies (Table 3) are developed for utilising crosswall for constructing multi-storey buildings, which is also useful for implementing and managing other types of innovative building technologies.

## CONCLUSIONS

This paper has presented the results from the investigation into utilising crosswall by a leading UK housebuilder for 20 multi-storey buildings. Significant benefits were achieved at both the project and organisational levels, which offered the company competitiveness from cost, procurement and contractual aspects. Through the process

the developer explored a new opportunity to construct buildings up to 20 storeys without the need to engage any specialist main contractor. Despite the issues with design, technical, procurement and construction, the company, leading their supply chains, managed the challenges in a proactive manner. Effective learning mechanisms were established crossing the corporate, senior management and project operational levels and integrated into the routine business management processes and procedures.

This paper makes contribution to knowledge in two main aspects. Firstly, it provides a detailed account of implementing and developing crosswall technology in a large UK housebuilding organisation. The commitment of the company to offsite and MMC demonstrated through the journey and the benefits achieved should add to confidence of the housebuilding industry with taking up offsite technologies, albeit the market share of offsite is low in construction (Goodier and Gibb 2007). Secondly, the paper presents a real case of managing innovation. The mapped innovation journey updates the debate in previous research that housebuilding lacks innovation (e.g. Ball 1999) and there exist real and perceived barriers to the uptake of innovative building technologies (Pan *et al.* 2007). The journey of the company of utilising crosswall confirms the process of implementing innovation suggested by Saad (2000) that includes adoption, adaptation, modification and re-invention. Also, the learning mechanisms utilised by the company strengths the approach of learning to support innovation (Jones and Saad 2003). However, this paper focuses on the management in the company and their immediate supply chain parties, e.g. crosswall contractors, but not includes other stakeholders in the wider environment such as the government, legislators, building controls, customers. This important de-limitation should be considered when interpreting the findings, and it by no means underestimates the importance of the wider environment to managing innovation (*ibid.*) which, however, will be picked up in future research. The strategies developed in the paper are interrelated with each other and, used together, should encourage innovation and learning. Although an increased uptake of crosswall in the domestic sector might not be evident due to the current economic conditions, the framework is believed to be of value for improving quality and efficiency of housing supply in the long term.

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