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Changing Training Needs Arising from the Introduction of Off-site Construction Techniques

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The objective of this paper is to examine the changes in training needs arising from the increase of off-site construction in the Republic of Ireland. The methodology employed was a case study using a participant observation research technique. For a period of three weeks, the researcher observed the construction of residential housing, constructed using off-site techniques. From the practices observed and from interviews with the operatives on-site, an account of the differences in skills required between those employed in traditional construction and off-site construction was compiled. Each of the different trades involved in traditional construction was addressed and a comprehensive list of the skills training gaps was compiled. The paper examines the implications of the existence of these gaps in training and makes recommendations for corrective action to be taken by the relevant education and training policy makers.

Keywords: Off-Site Construction, Traditional Construction, Training

1. Background

In the relatively short period of time between the early 1990s and the present day, Ireland has changed from having an economic situation which obliged many of its people to emigrate and seek employment abroad (often to the construction sites of Britain and elsewhere) to its current state of full employment (Central Statistics Office, 2006a). This unprecedented (and largely unexpected) increase in prosperity has brought about dramatic changes. Whereas in the past emigration was a necessary safety valve now it is the reverse with thousands of returned Irish emigrants and new immigrants finding jobs here each year. Most sectors of the economy have benefited but perhaps the most visible and dramatic growth can be seen in the construction sector. This is not surprising since the higher levels of employment, increase in population, lower interest rates etc. would inevitably give rise to an unprecedented demand for housing.

Housing output in Ireland has grown at a phenomenal pace, increasing by 400% between 2002 and 2006. By the end of 2006, Ireland's per-capita housing construction output was higher than anywhere else in Europe. In 2005, for example, Ireland's output was 19 units per 1000 of the population compared to 4 units per 1000 in the UK. This figure increased to 20 units per 1000 in 2006 (Department of Environment Heritage and Local Government, 2006). The Irish house building sector in 2005 with an output of 81,000 units accounted for 16% of GDP and employed 12.2% of the total workforce (Davy, 2005). In turn, this accounted for approximately for 50% of the output of the Irish construction industry. By the end of 2005 it was estimated that total housing stock in the Republic of Ireland amounted to 1.69 million dwelling units in the State in 2005 with 30% of these units having been built in the past 10 years (Central Statistics Office, 2006b). This equates to 400 houses per 1000 persons, which is approaching the EU average of 450 units per 1000 of the population (DKM, 2005). This level of

construction output would not have been possible without the assistance of many thousands of recent immigrants. One in every ten workers employed in the industry in 2005 was a foreign national (DKM, 2005).

2. Off-site versus On-site construction

Until relatively recent times the vast majority of Irish homes were built in the traditional masonry way using the traditional skills of bricklayers, block layers etc. With the traditional method, all load-bearing inner skin walls and load-bearing partition walls are constructed in concrete blockwork. Non load-bearing walls are constructed either in blockwork or timber studwork. Services such as wiring and plumbing are fixed to or chased into the blockwork and covered by the plasterers. The block laying, brick laying and plastering work is usually referred to as the "wet trades" and the electrical and plumbing work as the "follow-on trades" (Allen and Thallon, 2006).

A two storey masonry house for example, is constructed by bricklayers building up both the load-bearing outer and inner walls, one course at a time. The builders fix the insulation inside the cavity between the two leafs of the external walls and they may also fix the window and door frames as they progress upwards. Carpenters are called in to place the floor joists, though sometimes the floor consists of pre-cast concrete floor panels crane lifted into the site. The bricklayers then build the walls up to roof level at which point they hand over again to the carpenters who build the framework for the roof, making way for subsequent felting and tiling.

About two thirds of the work on a traditionally built house involves skilled craftwork, making it very labour intensive and this was one of the external drivers pushing the industry towards greater use of off-site. In Ireland up to recently most residential buildings were built in the traditional way.

In its broadest sense, off-site construction embraces most contemporary construction techniques. Even the traditional bricks and blocks can be regarded as prefabricated components in simplest form (Gibb, 1999). At the other end of the spectrum, whole buildings can now be prefabricated and pre-assembled remote from their final destination and installed in place ready for use with only the minimum of on-site work needed. In all cases, off-site construction invariably involves three stages - factory prefabrication, transportation to site and site assembly. This means that part of the construction that would previously have been done on-site is now moved to a facility away from the site. The percentage of the work done off-site can vary between two extremes reflecting situations where most of the work can be done off-site by factory personnel and situations where most of the work is still done on-site by the traditional craftspeople.

A further part of this research established that approximately 50% of all housing completions in Ireland currently employ off-site construction methods – a large portion of which use timber framed construction as its primary construction method. This makes timber frame construction the off-site market leader in the low-rise residential sector and therefore the primary target of this research.

3. The aim of the research

The aim of the research was to establish the type of off-site systems being used, the extent of that use, the pace at which they are growing and the problems which arise especially at the (on-site) point of assembly and the human resource implications where skilled labour is concerned. This paper is produced as part of that research. The specific objective of this paper is to

examine the changes in training needs arising from the increase of off-site construction in the Republic of Ireland.

4. Research Strategy

Following a significant amount of exploratory research using secondary sources, on-site participant observation was established as the most appropriate method of studying the precise issues that were arising in the increasing use of off-site construction methods. Using this approach, the tradespeople would be observed to establish:

- Their input to the process and stage of construction;
- The nature of the work being completed;
- How the work being done compared to what traditionally had been done;
- Any specific technical or organisational problems that may arise.

5. Refining and Testing the Research Method

The research method was initially tested by through conducting a number of interviews and carrying out a series of site visits to off-site facilities (factory pre-fabrication and pre-assembly) and on-site (assembly and erection) operations. This established the issues to be investigated and these were further through an initial week of participation observation on a small site where a single timber framed house was being erected. This process highlighted the issues that would be confronted in the gathering of information and the level to which the researcher could realistically expect to get involved in the project. It also highlighted the following construction related issues that might be expected to occur during the primary research:

1. Systems delivered with inaccurate dimensions (an off-site problem) which resulted in panels not fitting together;
2. Poor system erection (an on-site problem) which resulted in the system not being assembled properly;
3. Poor system servicing (an on-site problem) which resulted in the system being damaged by follow-on trades.

These issues would then be investigated to establish the changes in training needs that were emerging in the move to off-site construction methods.

The preliminary findings had certain implications for the principal research method chosen and lead to the following conclusions:

- All three problem areas identified would manifest themselves at the on-site stage and therefore could best be investigated at an on-site location. (Problem no.1 is an off-site issue but it is on-site that its effects will be seen and experienced);
- A timber-frame construction project was chosen as the most appropriate on-site location as this system has the biggest market share in the off-site low-rise residential sector in Ireland;
- Participant observation was confirmed as the most appropriate research method because it would enable the researcher to work side-by-side with and observe the craftsmen involved in the erection and assembly of the systems. It would also allow for checking of the dimensional accuracy of the systems components being delivered to the site.

6. Site Selection Process

A participant observation study naturally imposes some constraints with regard to location and duration. In order to make the optimum use of the time available (four working weeks) a timber framed housing project consisting of 104 houses was chosen. Phase 1 of this project was already completed and occupied before the observation commenced. However, Phase 2 had several houses at different stages of construction and thereby provided an ideal opportunity for observation, both of the phases of construction and of the role of all of the different trades in the construction process.

The study was conducted over a four week period from 14th Nov to 12th December 2005 and, with the approval of the contractor's site management team, the researcher engaged in all of the construction tasks associated with timber frame delivery, erection, roofing, servicing and cladding. In this way an opportunity was provided to work closely with all of the craftspeople involved, thereby enabling the recording first hand of observations by means of photographs and diary.

7. Data Collection

The following data collection methods were employed:

- Note-taking - notes were made on a regular basis on the construction site or later in the day. These notes were based on observations and conversations with other workers and often consisted of short phrases or simple keywords to act as subsequent reminders or reference points;
- Visual records - Over one hundred photographs mostly for purposes of record as an aide memoire but some of which could also be used in the presentation of results;
- Data-gathering interviews - informal interviews with site foremen and other construction personnel on specific issues.

During the course of the intensive four-week observation study the researcher participated fully in all of the on-site construction activities of a timber-frame construction project based on off-site methods. This provided a first hand opportunity to see and experience many of the practical day-to-day issues that arise on-site.

The on-site erection of a timber frame house includes the following steps:

1. Site preparation;
2. Scaffolding;
3. Crane/ lifting equipment;
4. Arrival and unloading of the trailer;
5. Erection of ground floor walls (external panels);
6. Erection of ground floor walls (internal panels);
7. Positioning of first floor panels;
8. Erection of first floor walls (external panels);
9. Erection of first floor walls (internal panels);
10. Erection of the roof.

At the outset of the study period the researcher was assigned to work with the erection crew consisting of four carpenters - two fully qualified and two apprentices. This provided the opportunity to develop an insight of the perspectives of an experienced crew member from those of an apprentice.

The entire timber frame kit took ten working days to construct. Although the structure of the house up to roofing stage was completed in the first two days it took a further eight days to

complete. In the period of the participant observation all of the craft areas involved in the building and servicing of a timber frame house were observed.

8. Data Analysis

The trades involved in the building process observed during the four week on-site research period. This was then compared to the standard tasks undertaken by these trades in traditional brick and block building to establish the changes in tasks undertaken when the timber frame construction process is used. Table 1 lists these changes.

Table 1. Tradespeople involved in constructing a traditionally built house compared to a timber frame house

Tasks performed	Traditionally Built House	Timber-Framed House
Foundation	*Masonry*	*Masonry*
Ground floor load-bearing walls	*Masonry*	*Carpenters*
Ground floor non load-bearing walls	*Carpenters*	*Carpenters*
First floor construction	*Carpenters*	*Carpenters*
First floor load-bearing walls	*Masonry*	*Carpenters*
First floor non load-bearing walls	*Carpenters*	*Carpenters*
Roof rafters	*Carpenters*	*Carpenters*
Felt and battening	*Carpenters*	*Carpenters*
Roof tiling	*Roofers*	*Roofers*
External door and window installation	*Installation crew*	*Installation crew*
Cladding	*Masonry*	*Masonry*
Electrical work	*Electrician*	*Electrician*
Plumbing work	*Plumber*	*Plumber*
Insulation installation	*Insulation crew*	*Insulation crew*
Plasterboard attachment	*Plasterboard crew*	*Plasterboard crew*
Internal plastering	*Plasterers*	*Plasterers*
Painting and decorating	*Decorators*	*Decorators*

The extent of changes observed allows each of the trades to be categorised as follows:

- Significantly affected, where trades are being asked to take on additional tasks;
- Moderately affected, where trades are being asked to work in a different manner;
- Not affected.

The traditional trades which most significantly affected are carpenters and masonry workers. Table 2 shows how the tasks are divided up between these two crafts depending on whether the dwelling is being traditionally built or timber-frame built. This illustrates that the tasks required in constructing a traditionally built house the tasks are more or less divided equally between masonry workers and carpenters. A timber-framed house on the other hand relies more heavily on the work of the carpenters. This additional work being undertaken by the carpenters on timber frame raises the need for specific system erection training. Carpenters are expected to assemble the new timber frame systems. Ideally this should require special training to ensure the system is properly assembled. Since the timber frame components are the main structural elements of the building it is essential that they be assembled correctly. Improper assembly can obviously impact negatively not only on the structural stability of the building but also on its thermal performance ability. If for example the panels are not tightly fitted together this will leave air gaps affecting the heat retention capability of the building. These problems can be avoided if the building is properly erected by a trained timber frame erection crew.

The impact on masonry workers is more a question of workload reduction rather than any significant change in the type of work they are required to do.

Table 2. Significantly affected trades

Tasks Performed	Traditionally Built House	Timber Framed House
Foundation	*Masonry*	*Masonry*
Ground floor load-bearing walls	*Masonry*	*Carpenters*
Ground floor non load-bearing walls	*Carpenters*	*Carpenters*
First floor construction	*Carpenters*	*Carpenters*
First floor load-bearing walls	*Masonry work*	*Carpenters*
First floor non load-bearing walls	*Carpenters*	*Carpenters*
Roof rafters	*Carpenters*	*Carpenters*
Felt and battening	*Carpenters*	*Carpenters*
Cladding	*Masonry*	*Masonry*

The training of timber frame erection crews for proper system assembly is being addressed by the Irish Timber Frame Manufacturers Association in conjunction with FÁS (the national training agency). At the moment however there is no government recognised training programme operating in Ireland. The majority of timber frame manufacturers provide a list of certified erection crews but these crews are not endorsed by government certification standards.

It became clear from the direct and participant observation studies at various sites that the majority of the carpenters were trained in all the traditional carpentry skills and for the most part were coping adequately with new demands of timber frame construction. The fact remains however that they were not formally trained to recognised standards in timber frame erection and assembly techniques and the need for such training should not be underestimated. The additional skills needed could be acquired in a relatively short time but they are essential if the quality and structural integrity of the building is to be guaranteed. Additional health and safety training is also needed to ensure the crafts involved recognise the particular hazards of the system of construction, an issue that is now even more relevant with the recent change in building regulations that allows timber frame construction for buildings up to four storeys high.

The tradespeople who are moderately affected are listed in table 3 below. Crafts people in this category are the same for both systems. In this case they do essentially the same jobs but under different conditions.

Table 3. Moderately affected trades

Tasks Performed	Traditionally Built House	Timber-Framed House
Electrical work	*Electrician*	*Electrician*
Plumbing work	*Plumber*	*Plumber*
Insulation insertion	*Insulation crew*	*Insulation crew*
Plasterboard attachment	*Plasterboard crew*	*Plasterboard crew*
External door and window installation	*Installation crew*	*Installation crew*

For example, electricians and plumbers are required to service the building in a similar way for both systems but chasing through concrete is more difficult and time consuming while timber, though easier to penetrate, requires greater care. Similar considerations apply to the installation of doors and windows, the placement of insulation and attachment of plasterboard. The difference in the nature of the tasks here derives from the difference between fixing to concrete and fixing to timber.

The electricians and plumbers have to chase their service lines through the walls of both types of buildings. Chasing through a concrete building is a slower and dirtier job. Timber on the other hand is easier to chase, not only because of the open spaces between the vertical studs, but also because timber is easier to drill through. However, as timber frame is a structural

skeleton, only certain parts of the beams can be drilled. The position of the drilled hole, its diameter size and the number of holes in one area are crucial if the structural performance of the timber beam is not to be compromised. Since the majority of electricians and plumbers are accustomed to working on traditionally built dwellings some additional training is required if they are to install services in timber frame houses.

During informal interviews with the senior electricians and plumbers on-site it became clear that best practice guidelines were both known and understood. It was clear from observation however that proper procedures for drilling were not always adhered to as the drilling or chasing was almost invariably carried out by an apprentice rather than a fully qualified tradesperson. A number of examples were found of multiple holes have been drilled for piping and/or electrical cables in a single beam, many so close to the edge of the beam that the structural integrity of the beam was compromised. In all cases observed, further investigation established that the drilling and chasing work had been done by the apprentices who could not yet be expected to be fully familiar with best practise procedures.

The other tasks that are moderately affected by the shift towards timber frame involve insulation insertion, plasterboard attachment and external door and window installation. The trades affected are merely required to attach the various add-ons to a different material i.e. to timber instead of to concrete. From observation and informal interviews it became clear that these trades found it easier to install in a timber frame compared to a concrete building. It became apparent that sometimes window and door openings from the timber frame kit were delivered either in the wrong size or in the wrong place. This is an off-site problem where the system is delivered with inaccurate dimensions or, as sometimes happens, with openings that were not supposed to be there.

The tradespeople who are not affected are listed in table 4 below. The tasks for these trades are the same for both systems because the working environment in which the jobs are done is essentially the same. These tradespeople confirmed that their jobs were not affected to any significant degree by the shift from traditional to timber frame.

Table 4. Non affected trades

Tasks Performed	Traditionally Built House	Timber-Framed House
Roof tiling	*Roofers*	*Roofers*
Internal plastering	*Plasterers*	*Plasterers*
Painting and decorating	*Decorators*	*Decorators*

Having identified the trades involved in constructing and servicing both systems (traditional brick and block and timber-framed) and the skills which they are bringing to the different tasks it is appropriate at this point to look again at the potential problem areas identified for investigation in the exploratory research in section 5 above.

1. Systems delivered with inaccurate dimensions (an off-site problem), which resulted in panels not fitting together.

No delivery of systems elements with inaccurate dimensions was recorded during the participant observation period. However, the fact that this sometimes did occur was raised by those who participated in the informal interviews on site and confirmation was given that such panels were generally sent back to the factory to be altered prior to redelivery to site.

2. Poor system erection (an on-site problem), which resulted in the system not being assembled properly.

Again the observation study did not identify any major problems affecting the quality of the work carried out by the erection crews. The carpenters were the group most significantly

affected by the shift from traditional to timber-framed construction in that they were engaged in many phases of the work (timber-frame erection and assembly) - phases which traditionally would have been mostly carried out by masonry workers. The tasks however were essentially those requiring woodworking skills and in the circumstances the carpenters were coping reasonably well. There is still however a significant issue in relation to additional carpenter training and the need for some form of certification to ensure that proper procedures are followed.

It is therefore important, that the regulatory authorities and the relevant training organisations become more proactive in this area. Apart from the new skills required by the timber frame system, the add-on training must also embrace health and safety procedures not only for the erection crews but for other site workers as well.

3. Poor system servicing (an on-site problem) which resulted in the system being damaged by follow-on trades.

This is a serious issue in that it can potentially affect the structural stability of the building. Plumbers and electricians, though themselves only moderately affected by the shift from traditional to timber-frame, are sometimes responsible for poor system servicing. This mostly arises when untrained personnel (i.e. apprentices) are allowed to undertake the drilling work for the service lines. The holes if not drilled in the proper locations can seriously impact on structural stability. Poor workmanship in this area can go undetected until the consequences become apparent perhaps years later. A similar training to that envisaged for the erection crews is recommended whereby the follow-on tradespeople can also be certified thus ensuring the maintenance of proper servicing standards.

9. Conclusion and Recommendations

In analysing the findings of the study the crafts or trades involved were divided into three categories depending on the degree to which they were being impacted upon by the new system of construction in which they were engaged. The categories were formed on the basis of whether the trades were significantly affected, moderately affected or nor affected at all.

The trades most affected were the carpenters and the masonry workers. The impact on the masonry workers was more a question of a reduction of workload rather than any significant change in the tasks they were required to do. Not surprisingly the carpenters were involved in many phases of the timber frame construction whereas in a traditionally constructed house the load-bearing walls of the building would have been the responsibility of the masonry workers. Though the carpenters were trained in traditional woodworking techniques they were not necessarily accustomed to erecting and assembling vital load-bearing parts of the building. Ideally this requires special training to ensure that the timber frame system is correctly assembled. The additional skills needed could be acquired in a relatively short time and there is evidence that the regulatory authorities and the responsible training organisations need to be more proactive in this area.

Most of the follow-on trades such as electricians, plumbers, insulation and plasterboard crews were in the moderately affected category. These were doing essentially the same jobs as they would have done in traditionally built houses but under different conditions. The difference in the nature of the tasks derived from the difference between fixing to concrete and fixing to timber. Where plumbers and electricians are concerned, drilling through timber-frame components requires appropriate training if the quality of the finished building is not to be impaired. Follow-on trades such as roof tiling, internal plastering, painting and decorating were not affected because the working environment in which these jobs were done was essentially the same for both systems.

Because the off-site systems used in residential construction in Ireland are at the less advanced end of the market, approximately half of the work still remains to be done on-site. Heavy reliance on the traditional on-site skills to complete this half of the work can give rise to poor system erection, assembly and servicing. These are all issues that could be addressed by further training.

It is estimated that off-site systems as currently practised in Ireland will continue to grow in the future and that there will also be a gradual move from open panel systems to more advanced forms such as closed panel systems and to a lesser extent pods. Such a move would have further implications for the various building trades changing the very nature and location of some of these jobs. A further shift of construction work away from building site to factory could lead to a breakdown of some of the traditional crafts, such as plumbing and electrics, into simpler tasks which would be done by specially trained factory personnel. These factory-trained technicians would in effect be replacing some of the traditional tasks as we know them. These and other issues arising from this study will hopefully provide useful points of departure for further investigation.

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