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Post-handover housing defects: sources and origins

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ABSTRACT

In Spain, the high levels of inexperienced workers and the long chains of subcontracting contribute to poor quality of dwellings. Although the Ley reguladora de la subcontratación en el Sector de la Construcción (Subcontracting law) has established quality measures, the number of customer complaints is still increasing. In this paper, a total of 2351 post-handover defects derived from four Spanish builders and seven residential developments are classified according to their source and origin. The research reveals that the most common defects identified by customers at post-handover were derived from bad workmanship, and were related to construction errors and omissions. Typical defects were found to include incorrect installation, appearance defects, missing item or task mainly related to finishing and considered to be minor. No defects were caused by poor design as they are mainly detected and resolved during construction, or become apparent after some years of use.

This study demonstrates the negative impact of re-doing defective work during the final stages of construction, and provides knowledge to define measures to improve the

quality of the finished buildings, such as understanding customer expectations and preferences, training programs for workers, specialization of subcontractors and tighten the external controls prior to handover.

Author keywords:
Spain, post-handover defects, quality, source, origin, housing.

1. INTRODUCTION

Although many systems are designed to detect and eliminate defects that occur at the design and construction stage, a large number of complaints about defects continue to be recorded at handover (Chong and Low 2005).
Defining the perceived defects by the client after handover, and the rework associated to these defects is a difficult task. Many researchers analyze construction defects and their causes but those defects that still remain after the main contractor has delivered the building are scantly analyzed.

Forcada et al. (2012 in review) analyzed a total of 2351 post-handover defects derived from four Spanish builders and seven residential developments which were classified according to their location, subcontract, and element. The determination of the typical locations, subcontracts, and elements where defects arose in residential buildings provided invaluable knowledge about those areas where builders are likely to make errors, mistakes or deliberately take short-cuts during construction. However, there is a need to define the root causation of defects (Sommerville 2007). Determining the causes of defects will enable preventive measures to be identified, as well as demonstrate to builders and subcontractors the impact of re-doing defective work on their overall profitability.

Therefore, the research presented in this paper is based on the same post-handover defects data from the Forcada et al. (2012 in review) study, extending it by examining the type, source and origin of the nature of defects at the post-handover stage.

2. SOURCES AND TYPES OF DEFECTS CATEGORIZATION

Numerous definitions of defects can be found in the normative literature (e.g., Ilozor et al. 2004; Mills et al. 2009). The most comprehensive definition has been provided by Watt (1999) who defined a defect as a “failing or shortcoming in the function, performance, statutory or user requirements of a building, and might manifest itself within the structure, fabric, services or other facilities of the affected building”.

With the aim of reducing defects and rework, researchers have focused on a range of strategies such as studies identifying causes, magnitude and cost of both construction and latent defects (Burati et al. 1992; Josephson and Hammarlund 1999; Olubodun and Mole 1999; Love and Li 2000; Love 2002; Chew and De Silva 2003; Ilozor et al. 2004; Love and Edwards 2004; Chew 2005; Chong and Low 2005). These researchers analyze information in order to get to the root of the problem, by taking into account various perspectives such as the type of defects, their frequency of occurrence, cost of rectification and defect source and origin.

Sommerville (2007) evaluated the literature on defects and rework in new build projects with an emphasis on housing. He stated that origins of defects and the causes of defects are inextricably linked, and concluded that many authors have identified the various causes of defects in construction by an analysis of their key points.

Josephson and Hammarlund (1999) investigated six different types of building project, and the origins and causes of defects, which are defined as a proven reason for the existence of a defect. They classified the causes of defects into *knowledge, information, motivation, stress* and *risk*; and the origins of the defects by *client, design, site management, workmanship, subcontractors, materials, machines* and *others*. There are often several causes of the same erroneous action, or a combination or chain of causes. Therefore, the term *root cause* was used to describe the most basic reasons for an undesirable condition, and classified them into: *stability in the client organization, client's project control, user involvement, time pressure, composition of the project organization, cost pressure, support to the site organization, and lack of people motivation*.

Atkinson (1999) reported research on the human error causes of defects in supervising new and refurbished building work. His research involved a survey of construction industry practitioners and a statistical study of 23 house-building sites, and concluded that poor or defective management provokes the major defects in construction.

Love and Sohal (2003) studied two projects in Australia to determine the causal nature of rework. They adapted the classification of rework from Burati et al. (1992) and classified rework into *design* and *construction* categories and into *change*, *error*, *omissions* and *damage* types.

Love and Edwards (2004) reported that project characteristics, organizational management and project management practices influence rework occurrences.

Various defect and rework tracking and cost coding systems also incorporate the causes of these defects. Davis et al. (1989) developed a quality performance tracking system to systematically classify the cost of quality. The deviations were categorized into *change* and *error*.

Karim et al. (2006) analyzed defects on three construction projects to develop a decision support tool for long-term management of subcontractor supply chain. Defects were classified by their causes (workmanship, material, damage and design), area of work (kitchen, bedroom, bathroom, etc.), trade (painter, joiner, plasterer, etc.) and subcontractor packages.

Love (2003) designed a prototype project management quality costing system and used a three-tiered defect categorization system (adapted from Farrington (1987) and Burati et al. (1992)). The first level addressed affected phases of the project, that is, pre-planning, design, construction, procurement, construction start-up, operation, and disposal. The second level determined whether the type of rework required was a result of a change, error, omission or damage. The third level referred to the people responsible of the rework, for example the manufacturer, client, occupier, etc.

3. RESEARCH APPROACH

For the purposes of research reported in this paper the definition of a defect proposed by Watt (1999), as noted above is adopted.
In analyzing post-handover defects, data was classified according to the characteristics of the dwelling and defect type. Similar approaches have been adopted by Georgiou et al. (1999) and Mills et al. (2009). Building characteristics include building type, gross floor area of the dwelling, construction cost, number of floors in the building and number of dwellings per development. Defect characteristics include data about the *type of defect* (e.g. appearance, stability/movement, etc.), the *source* (e.g. design, workmanship, etc.) and the *origin* (e.g. error, omission, etc.). No standardized Spanish defect classification currently exists. Therefore, the defect classifications proposed by Georgiou et al. (1999), Mills et al. (2009) and Georgiou (2010) was used as the basis to develop a robust system for the Spanish context.

In addressing the source of the defect, an adaption of Josephson and Hammarlund (1999) classification system was adopted. The source can be traced to the main participants responsible for the defects: designers, contractors, material suppliers, and maintenance contractors. These sources are: design, workmanship, materials, and lack of protection. *Design sources* are those defects caused by poor decisions in design. Designers' decisions include specifications of materials, layout, and integration between different materials and systems. *Workmanship sources* are those defects caused by poor work practices on site, such as poor installation methods, including poor mixing of materials, poor handling of materials, poor planning from the contractor that results in poor completed quality, failure to provide proper joints, gaps or materials to avoid defects. *Materials sources* are those defects caused by inferior material quality derived from suppliers' poor practices. Materials can only be expected to perform to their required standards; however, if they are exposed to excessive force, they will not be considered poor in terms of quality. When this happens, the source can be directed toward design or workmanship. *Maintenance sources* are those defects caused either by materials or systems that are not maintained properly, or maintenance that is irregular or nonexistent at the occupancy stage. *Lack of protection sources* are those defects causes by failure to provide proper preservation of parts of the building already finished while other activities are being carried out.

To analyze the origin of the defects, the system used by Farrington (1987), Davis et al. (1989), Burati et al. (1992), Love (2003) and Love and Sohal (2003), is adopted. This system classifies the origin of defects into *change, error* and *omission*. *Change* is a directed action altering the currently established requirements. Changes may encompass design, fabrication, or construction, and materially affect the approved requirements, the basis of design, the existing scope of the contract plans and specifications, or operating capability of the facility. *Error* is any item or activity in a system that is performed incorrectly resulting in a deviation e.g., design error, fabrication error, construction error, etc. An error requires an evaluation to determine what corrective action is necessary. *Omission* is any part of a system, including design, construction and fabrication that have been left out, resulting in a deviation. An omission requires an appraisal to determine what corrective action is necessary. *Damage* is a physical harm impairing the value, usefulness, or normal function of something.

4. DATA COLLECTION

Akin to Forcada et al. (2012 in review) data was collated from client complaint forms from four Spanish builders' databases. These databases contained information concerning the building and defect characteristics. A total of 2351 defects from seven building developments were identified and analysed. The number of dwellings within each of the seven developments identified ranged from 24 to 146. The building developments were constructed between 2004 and 2006. The size of the dwellings within each building development ranged from 75 to 130 square meters and contained between two and eight floors. Table 1 identifies the main characteristics of the analyzed developments.

Development	Number of dwellings	Size	Floors	Building characteristics	Cost [€]/development	Year
Dev. 1	81	80 m^2	GF + 3	Ground floor with a small terrace, 1, 2 and top floor with balconies concrete structure, continuous foundations, inverted roof, façade (light prefabricated concrete panels)	6.600.000	2004
Dev. 2	110	75 m^2	GF + 7	Ground floor: commercial area, 1 to 7 and top floor with balconies, concrete structure, continuous foundations, inverted roof, façade (brick and ventilated façade with ceramic boards)	11.800.000	2005
Dev. 3	30	150 m^2	GF + 1	Reticular framework, continuous foundations, flat traditional roof and sloped roof with sandwich panels, brick façade	3.095.009	2006
Dev. 4	146	90 m^2	GF + 4	Ground floor without terrace, 1 to 4 and top floor with small balconies, concrete structure, inverted roof, brick façade	10.403.520	2004
Dev. 5	30	130 m^2	GF + 1	Unidirectional framework, continuous foundations, sloped roof, façade (brick and stone slabs)	6.893.000	2004
Dev. 6	24	130 m^2	GF + 1	Unidirectional framework, continuous foundations, sloped roof, façade (brick and stone slabs)	4.696.636	2005
Dev. 7	112	85 m^2	GF + 6	Ground Floor: Commercial area, 1 to 5 and top floor with balconies, concrete structure, isolated foundations, inverted roof, brick façade	9.836.800	2005
Total	533					

Table 1. Building characteristics

The data collected was analysed using the Statistical Package for the Social Sciences (SPSS) for Windows (Version 19.00). A Chi-square test (χ^2) test was used to determine the relationship between the type of defect that was identified with source and origin. In addition, to test the association between variables a Pearson's parametric correlation was computed. This approach made it possible to identify those variables with significant correlations at the 95% and 99% confidence intervals.

Since any defect can be understood as a cause and consequence, and reciprocal or looped in their relationships (Love and Edwards 2004; Love et al. 2011), and can have more than one source and origin, the number of recorded sources and origins could surpass the total number of defects found. For this research, each defect identified was characterized by the source and origin severity as identified in property managers' records.

5. RESEARCH FINDINGS

64.2% of the analyzed defects are derived from bad workmanship, 19.1% due to materials and 15.5% from lack of protection. Only 27 defects (1.1 %) are derived from bad design. See Table 2. This data diverges from the results obtained from defects during the construction stage and also the latent stage. Work undertaken by the Building Research Establishment (1981) over a number of years in the UK indicated that 50% of defects found on construction projects could be attributed to design issues, 40% occurred during the construction phase (as a result of on-site practices), and 10% were due to product failure. In fact, the majority and most significant construction defects such as structural or water proofing defects are caused by poor design (Chong and Low 2005), but are mainly solved during the construction of the building. Lopez and Love (2011) estimated that the mean direct and indirect design error costs are 6.9% and 7.4% of a project's contract value respectively.

Those defects arising from bad design that are not solved during construction are not normally detected during the liability period (post-handover), but are manifested after some years of use. Chong and Low (2006) analyzed various latent building defects and concluded that 60% of the defects were preventable with better design, and 33% with better workmanship.
Moreover, during inspection of the building clients only notice/observe those appearance defects that are normally a result of bad workmanship. Since design defects manifest themselves much later than workmanship defects, it pays to have better design effort.

	Number of defects	Percentage %
Design	27	1,1
Lack of protection	365	15,5
Workmanship	1509	64,2
Materials	450	19,1
Total	2351	100,0

Table 2. Defects by source

Regarding origin, Table 3 demonstrates that omissions (42.1%) and errors (39.8%) are the major factors that contribute to post-handover defects.

Post-handover omissions refer mainly to activities or parts of the building that are left, whereas construction omissions and errors refer to the result of erroneous construction methods or procedures mainly due to poor workmanship. Errors include both aesthetic defects that refer to the appearance of a building element, and technical defects that occur when the workmanship, material or design of a building element hinders its ability to function properly (Sommerville and McCosh 2006). Under the term damage, those defects caused by a subcontractor or inclement weather are included.

The analysis of this data shows that post-handover defects are mainly those minor defects that are not solved during construction, or appear as a result of attempts to resolve construction defects prior to handover, for example when a plumber fixes a water pipe and gets the wall soiled.

	Number of defects	Percentage %
Change	4	,2
Damage	423	18,0
Error	935	39,8
Omission	989	42,1
Total	2351	100,0

Table 3. Defects by origin

Sources and origins of defects are inextricably linked, therefore it is very difficult to discuss one without the other (Love and Edwards 2005; Sommerville 2007). Thus, a contingence and correlation analysis is carried out.

5.1. Analysis of defects by source

Table 4 presents the distribution of defects by source. It can be seen that 88.3% of the defects caused by lack of protection are surface appearance defects (28.2%) and soiling defects (60.1%). Although defects resulting from lack of preservation of finished parts of the building while other activities are being carried out usually become apparent during construction, occasionally they are not resolved and persist until the first occupancy. These defects are mainly stained tiles and door frames, paint staining as a result of poor protection of items such as radiators, and floor damage or broken tiles due to heavy loads from equipment or tools during fit out. Dirty boots of workers can also stain the floor whilst moisture is present (Chong and Low 2005).

The analysis reveals that the majority of the defects provoked by workmanship (76.4%) are missing item or task (32.1%), surface appearance defects (22.2%) and incorrect installation (22.1%). In fact, missing item or task defect was found to be significantly associated with workmanship ($r=+0.990$, $n=533$, $p<0.01$ two tails, $r^2=0.98$) and also with materials ($r=+0.927$, $n=533$, $p<0.01$ two tails, $r^2=0.86$). A missing task relates to neglecting to undertake an activity such as painting, wall coating, plaster, tiling, etc.

This defect is then mainly related to surface appearance defects. Missing item or task was found to be significantly associated with surface appearance defects ($r=+0.821$, $n=533$, $p<0.01$ two tails, $r^2=0.67$). However a missing item includes items such as door handles or imperfect grout, which is mainly related to incorrect installation. However, both of them are classified as functional defects, which are the ones that customers invariably rely upon on to measure the quality of housing (Kang 2006).

Surface appearance defects were also found to be significantly associated with workmanship ($r=+0.885$, $n=533$, $p<0.01$ two tails, $r^2=0.78$). Surface/appearance defects are mainly uneven or unsatisfactory finishing of the floor and wall surfaces and are mainly caused by poor workmanship. Most irregularities were caused by unevenness of the screed that received the tiles. These defects were also caused by workers not laying out the floor materials properly; not using proper guiding lines and rushing to finish the job. Failures to polish to shine the marble surface, and stains during construction from spillages were other examples of such defects with workmanship sources.

Materials are the main source of missing item or task (82.2%). Surprisingly, surface appearance defects are not caused by problems with materials. This incongruence may be because problems with materials were already detected during construction, or that problems such as rust do not appear just after hand over of the building but are detected after some years of use (Chong and Low 2005; Chong and Low 2006). These results also diverge from those obtained from the study of influencing factors of defects during occupation carried out by (Olubodun and Mole 1999). They concluded that the majority of defects derived from poor workmanship are rot, slab failure, dampness in solid floor, water ingress and damp proofing to walls which are mainly defects that do no appear during post-handover but after some years of occupation.

Although detachment, affected functionality and misalignment are defects with less proportion of occurrence at post-handover, they are mainly derived from poor workmanship. 93.8% of detachment defects are related to poor workmanship, mainly because the worker did not fix correctly items such as tiles. 92.8 % of functionality defects are related to poor workmanship. This includes poor installations of ducts, or doors and windows that do not close correctly or scrapes on floor because tiles were not correctly placed. All misalignment defects are also related to poor workmanship.

93.7% of the soiled defects were derived from lack of protection. Soiled defects can be related to general dirtiness of the dwelling at handover, or stains provoked during construction as a result of poor protection. This is mainly caused by the constant rectifications needed during handover.
Although only 20 defects detected were derived from design, it is noticeable that those defects were mainly derived from missing items (50%), incorrect installation (28.6%) and excess moisture (10.7%). As missing items include missing elements and missing activities, some finishing elements were not included in the project, other activities such as floor polishing were also missed. Other design problems were derived from wrong bathroom fittings description and also from bad distribution of the windows, doors and furniture.

Another interesting finding was that workmanship and materials sources were both positively correlated (r=+0.888, n=533, p<0.01 two tails, r^2=0.79). The majority of the defects provoked by materials are missing items. Sometimes it refers to materials that were not placed such as grilles, handrails, terrace drains, and doorstops but they can also be related to missing elements due to poor workmanship such as baseboards. As mentioned previously no single defect has one single source, at times both workmanship and materials sources are interrelated.

Defect	Source				
	Design	Lack of protection	Workmanship	Materials	Total
Excess moisture	3	0	14	2	19
Surface appearance	1	103	335	19	458
Soiled	0	222	15	0	237
Misalignment	0	0	123	0	123
Detachment	0	3	76	2	81
Missing item or task	14	3	485	370	872
Affected functionality	0	0	90	7	97
Incorrect installation	8	3	334	31	376
Broken	1	31	37	19	88
	27	365	1509	450	2351

Table 4. Contingency table between source and type of defect

Table 5 presents the results of a $\chi 2$ analysis which sought to determine test the independence of the type of defect and the respective source. The analysis revealed defect type and source were not independent ($p < 0.05$).

	Value	df	Asymp. sig (2-tailed)
Pearson chi-square	1887,718a	24	,000
Likelihood ratio	1668,436	24	,000
No. of valid cases	2351		

a. 9 cells (25.0%) had an expected count of less than 5. The minimum expected count was 0.22.

Table 5. Chi-square hypothesis test of independence

5.2. Analysis of defects by origin

Table 6 presents the distribution of defects by origin. Taking into account that design defects are mainly resolved during the construction period or not visible until the operation stage, the majority of defects are related to errors and omissions both during construction or prior to handover, are also related to workmanship.

The analysis of the data shows that errors mainly provoke incorrect installation (36.3%), appearance defects (25.8%) and misalignments (12.8%). These defects are mainly considered minor defects. Surface appearance defects were found to be significantly associated with errors (r=+0.964, n=533, p<0.01 two tails, r^2=0.93). Missing item or task defects were also found to be significantly associated with errors (r=+0.891, n=533, p<0.01 two tails, r^2=0.93) and with omissions r=+0.995, n=533, p<0.01 two tails, r^2=0.99). Both surface appearance and missing item or task are mainly provoked by poor workmanship. In fact workmanship cause was found to be significantly associated with error (r=+0.926, n=533, p<0.01 two tails, r^2=0.88) and with omission (r=+0.973, n=533, p<0.01 two tails, r^2=0.95).

Soiled defects were found to be significantly associated with damage (r=+0.961, n=533, p<0.01 two tails, r^2=0.93). The majority of the damaged elements that are still visible during the post-handover are not related to functionality or stability, such as damaged structures, but to finishing (surface appearance, soiled and broken) such as plaster or painting stains that damage furniture, doors, windows or floor tiles. As identified previously, these type of defects are mainly caused by lack of protection during construction. In fact, lack of protection was found to be significantly associated with damage (r=+0.964, n=533, p<0.01 two tails, r^2=0.93).

Finally both materials and omission origins were found to be significantly associated (r=+0.95, n=533, p<0.01 two tails, r^2=0.90).

Defect	Origin				
	Change	Damage	Error	Omission	
Excess moisture	0	2	14	3	19
Surface appearance	0	146	241	71	458
Soiled	0	184	10	43	237
Misalignment	0	3	120	0	123
Detachment	0	9	66	6	81
Missing item or task	0	1	37	834	872
Affected functionality	0	1	94	2	97
Incorrect installation	4	3	339	30	376
Broken	0	74	14	0	88
	4	423	935	989	2351

Table 6. Contingency table between origin and type of defect

Table 7 presents the results of a χ2 analysis, which sought to determine the independence of the type of defect and the respective origin. The analysis revealed defect type and origin were not independent ($p < 0.05$).

	Value	df	Asymp. sig (2-tailed)
Pearson chi-square	2811,230 a	24	,000
Likelihood ratio	2856,488	24	,000
No. of valid cases	2351		

b. 10 cells (27.8%) had an expected count of less than 5. The minimum expected count was 0.03.

Table 7. Chi-square hypothesis test of independence

6. DISCUSSION

The Spanish housing construction boom of the late 1990s and the first decade of the 21st century led to an influx of inexperienced workers and an increase in competition within the industry.
This, in turn, gave rise to an observed decline in quality.

Moreover, the housing industry in Spain operates by subcontracting most of the construction work to specialty trade contractors. Indeed, as much as 90% of the construction work is carried out by different trade contractors. The multi-tiered chain subcontracting system, inherent within the industry has enabled poor communication and coordination to arise, which has had a negative impact on the quality of work produced (ASECE 2011; Tam et al. 2011).

Indeed, as a result of this situation, the last decade has seen a constant clamour from both clients and government for improvements in the quality of the finished product delivered by the construction industry (Sommerville and McCosh 2006).

To that end the *Ley reguladora de la subcontratación en el Sector de la Construcción* (Jefatura del Estado, 2006) (Subcontracting law) hs been implemented in Spain, which has required three quality measures: firstly, the subcontracting levels are reduced to three to facilitate the control of subcontractors' work; secondly, contractors are required to record all subcontracting activities to facilitate the control of subcontractors' work in terms of both quality and occupational health and safety (OHS); and thirdly, construction companies are required to be registered in the *Registro de Empresas Acreditadas* (2008) (Registry of Accredited Companies) to ensure their solvency and the quality of their work. Registration, however, does not ensure that a quality control and assurance procedures will be put into place (Georgiou et al. 2000). Thus, inspection of subcontractors work becomes a necessary part of the construction process. At a fundamental level, compulsory quality certification and occupational licensing of subcontract trades should be put in place to ensure that these defects are reduced (Love et al. 2010).

The different quality perception between builders, promoters and customers seem to be responsible for the large number of complaints from clients. Most customers tend to be technically inexperienced and thereby are more likely to have a strong emotional attachment with the quality of the product itself and the softer issues of quality such as the aesthetics, cleanliness, presentation and look and feel (functional quality) because they view the technical aspect (treated as quality specifications) as a 'given' covered under the various regulations and standards (Craig et al. 2010). These 'soft issues' include terms such as perception, attitude, satisfaction, judgment, experience and expectation which are definable in psychological terms as 'human factors'. These factors are seen differently by each person (Auchterlounie 2009).

Technical complaints are mainly provoked by the high levels of inexperienced workers and the low levels of training. These can be reduced by the implementation and promotion of training and education programs regarding the benefits and processes associated with quality.

However, the gap between technical quality and customer satisfaction exists. It is the 'soft issues' that the customer is more concerned about as can be seen from the results of this research. Customers didn't complain about technical aspects as they might think these aspects had been supervised by professionals and inspected by the warranty provider. Finishing aspects were the most important to them.

Part of the problem is that unlike other industries, house building sector has not tried to define what its customer's expectations and priorities are (Auchterlounie and Hinks 2001; Auchterlounie 2009) despite an increase in customer awareness and sophistication. Customers have to use experiences from friends and relations to make their judgement on quality issues.
Builders may realize that pooling efforts into understanding customer expectations and preferences (Stephenson and Carrick 2006) to improve the functional aspect of quality would result in lower levels of complaints and higher levels of customer satisfaction. This will also improve industry performance and sustainability (Craig et al., 2010).

7. CONCLUSIONS

While legislation is in place to control the subcontracting activities and guarantee the quality of buildings, (*Código Técnico de la Edificación* (Ministerio de Vivienda 2006) (Technical Building Code)) a significant number of complaints from customers can be found in newly built houses in Spain.

Before handover, when the majority of controls take place, builders must ensure the building meets basic technical requirements such as the foundations and structural integrity, but they do not focus on those aspects related to functional quality such as paintwork and aesthetics, which are the factors that customers invariably rely upon on to measure the quality of housing.

This study revealed that defects detected during construction, at post-handover and latent defects are different because of different perceptions of builders and costumers, and the degradation factor that provokes latent defects to appear only after some years of functioning.

The most typical sources of defects detected during the liability period (post-handover) by customers are the result of on-site practices and mainly occur just prior to handover when resolving construction defects. The large numbers and poor coordination of subcontractors, and the sequential, interrelated and standardized construction activities mean some trades cannot finish their work, or defective work is detected once they have left the site. It is then difficult to rectify the problem, or in doing so other defects might appear. This confirms the need to improve the quality of management and control of work in the critical final stages of completion of subcontract work (before the subcontractor leaves site).

The study also revealed that there is a strong correlation between defects and the people who carry out construction (workmanship), and therefore management practices (inspection/checking, “responsibility” issues, etc). Although the majority of construction defects are caused by design problems, clients do not detect them at post-handover because some defects are already reduced and/or eliminated during construction, and the others do not appear until some years of functioning.

Moreover, the most important defects provoked by poor workmanship (missing item or task and appearance defects) were found to be significantly associated with errors and with omissions, which are the major factors that contribute to post-handover defects. In fact workmanship source was found to be significantly associated with errors and with omissions. This is in line with previous studies that concluded that no single defect has only one source and origin, and they are sometimes interrelated.

The large number of claims from end users must be perceived as damaging to the overall reputation and image of the house building industry. Despite this, builders continue to ignore the issue and continue to handover new homes with high number of defects. This situation is mainly caused by the large numbers and poor coordination of subcontractors and the pressure to deliver the building.

The determination of the sources and origins of defects detected by customers in residential buildings after handover demonstrates the negative impact of re-doing defective work during the final stages of construction, and provides invaluable knowledge regarding those areas where the construction industry should direct the focus to improve the quality of the finished buildings. These measures should include understanding customer expectations and preferences, training programs for workers, specialization of subcontractors and hardening external control prior to handover.

Future research will focus on determining the costs of defects, which will demonstrate to builders and subcontractors the impact of re-doing defective work on their overall profitability.

REFERENCES

Asociación Española para la Calidad en la Edificación (ASECE), (2011). "¿Cómo está la calidad en la edificación en España?" ASECE, Madrid.

Atkinson, A. R. (1999). "The role of human error in construction defects." *Structural Survey*, 17(4), 231-236.

Auchterlounie, T. (2009). “Recurring quality issues in the UK private house building industry.” *Structural Survey*, 27(3), 241-251.

Auchterlounie, A., and Hinks, J. (2001). “Assessing customer criteria for quality in new housing.” First post-graduate research conference University of Salford, Manchester.

Building Research Establishment. (BRE), (1981). "Quality Control on Building sites." Garston, U.K.

Burati, J. L., Farrington, J. J., and Ledbetter, W. B. (1992). "Causes of quality deviations in design and construction." *Journal of Construction Engineering and Management*, 118(1), 34-49.

Craig, N., Sommerville, J., and Auchterlounie, T. (2010). "Customer satisfaction and snagging in the UK private house building sector." Proceedings 26th Annual ARCOM Conference, Association of Researchers in Construction Management, Leeds, UK, 1199-1208.

Chew, M. Y. L. (2005). "Defect analysis in wet areas of buildings." *Construction Building and Materials*, 19(3), 165-173.

Chew, M. Y. L., and De Silva, N. (2003). "Maintainability problems of wet areas in high-rise residential buildings." *Building Research and Information*, 31(1), 60-69.

Chong, W. K., and Low, S. P. (2006). "Latent Building Defects: Causes and Design Strategies to Prevent Them." *Journal of Performance of Constructed Facilities*, 20(3), 213-221.

Chong, W. K., and Low, S. P. (2005). "Assessment of Defects at Construction and Occupancy Stages." *Journal of Performance of Constructed Facilities*, 19(4), 283-289.

Davis, K., Ledbetter, W. B., and Burati, J. L. (1989). "Measuring design and construction quality costs." *Journal of Construction Engineering and Management*, 115(3), 389-400.

Farrington, J. J. (1987). "A methodology to identify and categorize costs of quality deviations in design and construction." PhD thesis, Graduate School of Clemson University, USA.

Forcada, N., Macarulla, M., Love, P.E.D. (2012). "Assessment of Residential Defects at Post-handover." *Journal of Construction Engineering and Management*, in review.

Georgiou, J. (2010). "Verification of a building defect classification system for housing." *Structural Survey*, 28(5), 370-383.

Georgiou, J., Love, P.E.D., and Smith, J. (2000). "A review of builder registration in Victoria." *Structural Survey*, 18(1), 38-45.

Georgiou, J., Love, P.E.D., and Smith, J. (1999). "A comparison of defects in houses constructed by owners and registered builders in the Australian State of Victoria." *Structural Survey*, 17(3), 160-169.

Ilozor, B.D., Okoroh, M. I., Egbu, C.E., and Archicentre. (2004). "Understanding residential house defects in Australia from the State of Victoria." *Building and Environment*, 39(3), 327-337.

Jefatura de Estado. (2006). "Ley 32/2006, reguladora de la subcontratación en el Sector de la Construcción." Madrid.

Josephson, P.E., and Hammarlund, Y. (1999). "The causes and costs of defects in construction: A study of seven building projects." *Automation in Construction*, 8(6), 681-687.

Kang, G. (2006). "The hierarchical structure of service quality, integration of technical and functional quality." *Management Service Quality*, 16(1), 37-50.

Karim, K., Marosszeky, M., and Davis, S. (2006). "Managing subcontractor supply chain for quality in construction." *Engineering, Construction and Architectural Management*, 13(1), 27-42.

Lopez, R., and Love, P. E. D. (2011). "Design Error Costs in Construction Projects." *Journal of Construction Engineering and Management*, in press.

Love, P.E.D., Li, H. (2000). "Quantifying the causes and costs of rework in construction." *Construction Management & Economics*, 18(4), 479-490.

Love, P.E.D. (2002). "Influence of Project Type and Procurement Method on Rework Costs in Building Construction Projects." *Journal of Construction Engineering and Management*, 128(1), 18-29.

Love, P.E.D. (2003). "A project management quality cost information system for the construction industry." *Information Management*, 40(7), 649-61.

Love, P.E.D., and Sohal, A.S. (2003). "Capturing rework costs in projects." *Managerial Auditing Journal*, 18(4), 329-339.

Love, P.E.D., and Edwards, D.J. (2004). "Forensic project management: The underlying causes of rework in construction projects." *Civil Engineering and Environmental Systems*, 21(3), 207-228.

Love, P.E.D., and Edwards, D.J. (2005). "Calculating total rework costs in Australian construction projects." *Civil Engineering and Environmental Systems*, 22(1), 11-27.

Love, P.E.D., Davis, P.R., and Worrall, D. (2010). "Occupational licensing of building trades." *Journal of Professional Issues in Engineering and Education*, 136(4), 215-223.

Love, P.E.D., Edwards, D.J., Irani, Z., and Goh, Y.M. (2011). "Dynamics of Rework in Complex Offshore Hydrocarbon Projects." *Journal of Construction Engineering and Management*, in press.

Mills, A., Love, P.E.D., and Williams, P. (2009). "Defect costs in residential construction." *Journal of Construction Engineering and Management*, 135(1), 12-16.

Ministerio de Vivienda (2006). "Código Técnico de la Edificación." 314/2006.

Olubodun, F., and Mole, T. (1999). "Evaluation of defect influencing factors in public housing in the UK." *Structural Survey*, 17(3), 170-178.

Registro de Empresas Acreditadas (2008). <http://rea.mtin.gob.es/rea/> (Jan.15, 2012).

Sommerville, J., and McCosh, J. (2006). "Defects in new homes: an analysis of data on 1.696 new UK houses." *Structural Survey*, 24(1), 6-21.

Sommerville, J. (2007). "Defects and rework in new build: and analysis of the phenomenon and drivers." *Structural Survey*, 25(5), 391-407.

Stephenson, P. and Carrick, C.J. (2006). “Select and accept a new build home: buyers’ experiences expectations and attitudes.“ COBRA RICS Annual Conference, RICS, London, UK, electronic proceedings.

Tam, V.W.Y., Shen, L.Y., and Kong, J.S.Y. (2011). "Impacts of multi-layer chain subcontracting on project management performance." *International Journal of Project Management*, 29(1), 108-116.

Watt, D. S. (1999). "Building pathology: principles & practice." Blackwell Science, UK.