Handover defects:
comparison of construction and post-handover housing defects

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Abstract: Although inspections occur during construction or at handover, customers do not normally participate. This situation creates a gap between quality perceived by contractors and customers. An analysis of 52,552 handover defects in 2,179 flats in Spain is presented which identified their nature, the building element and trade where these defects are located. These results are compared to previous studies that analyzed defects detected during the construction stage and those that remain after handing over the building to the client. The research reveals that structural defects are resolved during construction due to existing quality standards. However, other aesthetic and functional defects remain and/or arise at handover. Some defects are not resolved until customers complain after they first occupy the dwelling. Many functional defects arise due to the lack of involvement of end users in the early project stages.

Keywords: construction defects, defects, customer complaints, housing, quality control, Spain

Introduction

Numerous studies have analyzed the factors affecting the quality of housing (e.g., Craig, et al. 2010, Chong & Low, 2005, 2006, Johnsson, 2009, Georgiou et al., 1999, Ilozor et al., 2004, Mills et al., 2009, Sommerville & McCosh, 2006). In Spain, research on housing defects has been confined to the studies undertaken by Forcada et al. (2012, 2013a, 2013b, 2014).

Within the housing sector, there are two major opportunities for a builder to rectify defective elements:

- during construction
- prior to the building handover when a range of inspections occur by site management, and relevant warranty and guarantee providers.

In previous studies, Forcada et al. (2014) analyzed those defects detected during construction in 68 residential building developments undertaken by two large Spanish contractors. The research revealed that the most common defects that arise during construction technical faults related to the stability of the structure and inappropriate installation of roofs and façades caused by poor workmanship rather than the quality of the materials or products used (Forcada et al., 2014).

An alternative approach to understanding defects is to examine client complaint forms. Forcada et al. (2012, 2013a, 3013b) analyzed the defects that remain after handover from four Spanish builders' databases. The most common defects identified after handover by customers were predominately functional rather than technical in nature (Forcada et al., 2013a). In general, post-handover defects were found to be incorrect or missing grouting / sealant in tiles, fixtures and fittings in toilets, failure to apply second coats of paint to walls or surface/appearance defects such as floor or wall unevenness, stains, mess, small cracks and marks mainly caused by lack of protection (Forcada et al., 2013b).

Although building defects have been widely addressed in previous research in relation to their concepts, profiles and causes (Georgiou 2010; Yung and Yip 2010; Macarulla et al 2013) they have mostly been examined within the context of their associated studies, while there is little cross-context comparative analysis and a lack of fundamental exploration of the nature and features of building defects.

The aim of the current research is to detect if quality control measures adequately fulfil their roles. Therefore, the research presented in this paper examines the nature of defects that remain at handover and compares it with those defects identified by customers when they first occupy the dwelling (Forcada et al., 2013a; Forcada et al., 2014). Understanding the nature of defects, who detects them and when are they resolved can enable appropriate quality strategies to be developed and implemented. Therefore, to support the implementation of these strategies, this research provides knowledge of those elements and trades where builders are likely to make errors, mistakes or deliberately take short-cuts.

The current study and the results drawn on from other studies used the same classification system to analyse data derived from the non-conformances, checks and/or clients complaints forms obtained from Spanish contractors' databases. This enables a consistent approach to the analysis of the defects at different lifecycle stages.

The housing sector

In Spain, the demand for housing increased significantly in the mid-1990s, leading to a rise in prices and increased activity in the construction sector. When the economic situation changed, leading to higher unemployment and interest rates, the construction sector faced challenges that affect its future viability and that of the entire national economy (Forcada et al 2012). Nevertheless, the construction industry still accounts for 7.2% of gross domestic product, and the housing sector represents 66% of the total building sector (Asociación de empresas constructoras de ámbito nacional (National association of construction companies) 2013).

The Spanish housing construction boom of the late 1990s and the first decade of the 21st century, along with the ease of entering the market, 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 (Forcada et al 2012). Moreover, the marginal role played by end users in defining functional and quality requirements has fostered a perception of poor quality at the time of purchase. This lack of quality is observed in the form of defects.Construction defects can exert significant impacts on project performance, time and cost increase. In fact, the cost of rework on residential, industrial, and commercial building projects were estimated to range from 2% to 6% of their contract values (Josephson and Hammarlund, 1999). Similarly, Love and Li (2000), found rework direct costs to be 3.15% of the contract value in residential projects and Mills et al. (2009) found defects represent 4% of the contract value of the new dwelling or renovation.

Consequently, the costs of defects reduce the profitability of the builder and the estate management organization. In addition, building defects can damage the reputation of the builder and reduce customer satisfaction (Sommerville and McCosh 2006; Forcada et al. 2012). Therefore, building defects impose significant impacts on industry and society, and are a critical issue to be addressed.

Methods

For the purpose of the research reported in this paper, the definition of the term "defect" proposed by Watt (1999) is adopted:

> "Defect is the term used to define 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."
>
> (Watt 1999)

Regarding the stage were defects occur and are manifested, different terms are used:

- 'Construction defect' is defined as "that defect that is manifested during the construction stage" (Forcada 2014).
- 'Handover defect' (i.e. 'snags' in the UK) is defined as "that defect which is absorbed during the construction/building process and which is usually corrected before practical completion; and, that which is "visible" to the contractor and home buyer once the home is deemed ready for occupation" (Sommerville and McCosh 2006).
- 'Posthandover defect' is used to describe "that defect which is still remaining after handing over the building but only during the liability period, which usually lasts 12 months" (Forcada et al. 2013a).
- 'latent defect' is used to describe "that defect that appear during the occupancy of the Building" (Chong and Low 2006).

Handover defects data were collated from handover check forms for 16 developments from one of the largest Spanish building company's database.

To enable the analysis of data and extraction of conclusions, information must be organized, possibly re-formed and expanded where necessary (Georgiou 2010). Therefore, the original structure of handover checks used by the company was analyzed and adapted to the standardized classification system used by Forcada et al (2013a, 2014). Similar approaches have been adopted by other authors such as Trotman (1994), Georgiou et al. (1999), Olubodun and Mole (1999), Mills et al. (1999), Chew (2005), Chong & Low (2005 and 2006) and Craig et al. (2010).

Building characteristics include gross floor area (GFA), number of flats and construction cost.

Handover defects include the type of defect (e.g. appearance, stability/movement, etc.), the affected building element (e.g. internal wall, window, etc.) (Watt, 1999) and the respective trades (e.g. foundations, coatings, etc.).

These data were used to:

- Determine the most common defect types
- Determine the distribution of defects by building element
- Analyse the influence of the building element on the defect type
- Determine the distribution of defects by trade
- Analyse the influence of the trades on the defect type
- Compare the nature of defects and the building elements where these defects are detected with those detected during construction and at handover.

When selecting data source, an important consideration is to minimise the subjectivity of inspections, accuracy and reliability. To reduce the variation in subjectivity, this study uses data from the same database and from the same inspectors. However, caution should be taken when generalising these results. A limitation of this study is the data capture and data source are derived from one main contractor. Although 2,179 dwellings are analysed, all of them were constructed by the same contractor and therefore may not be representative of the whole Spanish housebuilding industry. It should also be noted that some contractors who are responsible for registering inspection results might neglect to register some of them.

The standardized format used by the company for the handover check forms and its translation to the standardized method adapted in previous studies (Forcada et al (2013a, 2014) increased the accuracy and reliability of the analysed data.

The data was analysed using the Statistical Package for the Social Sciences (SPSS) for Windows (Version 17.00).

Chi-square ($\chi2$) test was used to determine the dependence between the building element and the trade and the defect type. This test allows comparison of the observed and expected frequencies. For a chi-square test, the null hypothesis is that the two sets of frequencies (i.e., observed and expected) are equal. The alternative hypothesis is that they are unequal.

To identify those variables with significant correlations at the 95% confidence intervals, the asymptotic significance should be less than 0.05.

Data Collection

A total of 52,552 handover defects from 16 building developments were identified and analysed. The number of dwellings within each of these 16 developments ranged from 60 to 369. The size of the developments ranged from 6,270 - 41,697 m^2. All building projects were private construction projects undertaken by a major contractor and there were no temporary joint ventures with other contractors during the project. The cost per development ranged from €4,493,447 to €23,449,039. Table 1 identifies the main characteristics of the analyzed developments.

Insert <Table 1. Building characteristics>

Results

The analysis of the defect data revealed that the most common defects, as noted in Table 2, were: 'surface appearance' (64.5%), 'tolerance errors' (9.3%) and 'affected functionality' (6.8%). 'Surface/appearance' defects include colour, type, uneven surfaces, hit and scratches, peeling and cracks. 'Tolerance errors' include those dimensional errors in pavements such as parquet flooring, woodwork, etc.'Affected functionality' defects refer to disabled building elements or systems that must be replaced because their functionality is completely affected. Typical 'affected functionality' defects during handover include problems with the boilers, noises in heating tubes, sockets located in not accessible places, impossibility to open the door of the fridge, door scrapes on the floor, etc.

Insert <Table 2. Handover defects by type of defect>

Analysis of Defects by Construction Element

Tables 3 and 4 present the distribution of defects by building element. The results show that 'internal walls' (59.9%), 'windows' (17.2%) and 'mechanical and electrical Systems (M&E)' (8.5%) were the building elements where most defects arose. Table 4 presents the results of a Chi-square ($\chi 2$) analysis that sought to determine the independence of the defect type and the respective building element. The analysis revealed that the defect type and building element variables were not independent ($p < 0.05$).

Insert <Table 3. Defects by building element>

Insert <Table 4. Building element and defect type>

Insert <Table 5. Chi-square test of independence: Building element and defect type>

Results revealed that the most common ‘surface appearance’ defects were mainly detected in interior walls, pavements and doors. For interior walls, the most common ‘surface appearance’ defects were related to color, dents, scratches and uneven surfaces. For floor surfaces, defects in the polish and stains were also very common. Spilled paint and chemicals caused most of the stains. Other complaints were related to plaster work on uneven walls and ceilings and protruding joints.

Most of the ‘inappropriate installation’, ‘missing item or task’ and ‘tolerance errors’ defects were mainly identified in interior walls. The ‘inappropriate installation’ defects were mainly related to setting out the walls and inadequate dimensioning of wall elements such as the joint between the wall and the floor slab, while ’missing item or tasks’ were mainly due to by the lack of the second coat of paint.

The majority of the ‘affected functionality’ defects were mainly related to door and window locks, handles or doorbells. Aluminium frames and glass were also parts of doors and windows with ‘affected functionality’ defects.

‘Water problems’ were mainly detected in P&S systems, and they took the form of leaking pipes, goods not plumbed in or pipes not earth bonded and in the roof. However, results revealed that ‘water problems’ only accounted for 3.2% of the construction defects.

The most important M&E defects were mainly ‘detachment’ of electrical and mechanical elements such as tubes, pipes, fluorescents and sockets.

Analysis of defects by trade

The analysis of trades broadens the results obtained from the analysis of construction elements. Tables 6 and 7 identify the main trades where defects arose. ‘Partitions and enclosures’ (51.1%), ‘doors and windows’ (20.7%) and ‘facilities’ (20.7%) were identified as being problematic subcontractors due to the number of defects associated. Table 10 presents the results of a $\chi 2$ analysis that sought to determine the independence of the type of defect and the respective subcontractor. It was revealed that the defect type and subcontractor variables were not independent ($p < 0.05$).

Insert <Table 6. Defects by subcontractor>

Insert <Table 7. Subcontractor and defect type>

Insert <Table 8. Chi-square test of independence: Subcontractor and defect type>

In addition to the results obtained from the analysis of defects by construction elements, the analysis of defects by trade indicates that the most common defects in built-in furniture and appliances are ‘affected functionality’ defects, specifically kitchen appliances, cupboards, hoods, fridges and ovens that cannot open or do not work properly. Doors and windows also present ‘affected functionality’ defects.
Facilities are mainly related to water problems and detached elements while the majority of coating defects are related to painting and tiling.

Comparing construction and handover defects

Chong and Low (2006) argued that the defects detected in each stage of a building’s lifecycle (e.g. construction, handover, post-handover, and maintenance) are different.

The comparison of the nature of defects with those detected during construction (Forcada et al 2014) and those remaining and/or arisen at post-handover (Forcada et al 2013) can enable appropriate quality strategies to be developed and implemented.
This analysis revealed that although the same or similar terminology is used to refer to defects, they differ depending on the stage of the construction process (Table 9).
NB: construction and handover defects are recorded by contractors, but post-handover defects are obtained from customers' complaints forms.
Insert <Table 9. Comparison of defect type among construction, handover and post-handover>

Although 'inappropriate installation' and 'surface appearance' defects are the most common construction defects, they mainly refer to structural elements, such as dimensioning of construction elements, honeycombs in concrete or poor application of grouting materials to the floor (Forcada et al 2014). These defects are mainly corrected during the construction process due to quality control and inspections implemented during design and construction (Georgiou et al., 1999; Chong and Low, 2005; Mills et al., 2009) and the existing regulation about warranties (Forcada et al. 2014). Stability defects can cause major consequences during the defects liability period (DLP) (Building Regulation Act) (Jefatura del Estado, 1999). Therefore, contractors focus their quality control in structural elements.
No structural defects were identified at handover but 'surface appearance' (65%) was a prominent problem which included colour, type, uneven surfaces, dents and scratches, peeling and cracks. The majority of these are defective work that arise in the final stages of the construction due to lack of protection (stains, cracks, etc.) or unfinished work (second coat of paint, fittings, etc.). The most surprising result is the prevailence of the

same or similar ‘surface appearance’ defects at post-handover. These defects are detected after subcontractors have left the site and are often difficult to rectify. This is because many subcontractors typically embark on new projects elsewhere which makes it difficult to return to rectify the problem (Love 2002). Consequently, some work will need to be undertaken during the post-handover stage, after customers have moved into the dwelling.

Defects detected by customers when moving into the dwelling pertain to finishing items such as applying finishing coats, plugging holes in walls and attending to surface cracks, stains and dents (19% (surface appearance) and 37% (missing tasks)) (Forcada et al. 2013a).

Incorrect installation or specifications of items such as toilets, TV sockets, radiators, general purpose outlets or wrong specification account for 16% of the total defects detected by customers when moving into the dwelling. These defects are not detected at handover because they are not technical in nature and contractors do not take care about them. However, defects of a functional nature arise due to a lack of customer involvement during the formative stages of a project and may tarnish a builder’s reputation and image. Thus, it is imperative that builders understand customer expectations, preferences and their needs so as to ensure value (Stephenson and Carrick, 2006; Sommerville and McCosh, 2006).

Regarding building elements, the most affected building elements during construction are structural elements (25%) with honeycombs, bumps, dips or wrong dimensioning of bars. At handover no defects in structures are detected, which means they are resolved during construction or remain undetected. However, construction defects in partitions (12%) such as uneven surfaces or the boards for prefabricated walls still remain at handover. Partitions (60%) are the element with the highest levels of defects, which consist of uneven walls, protruding joints or lack of a second coat of paint. Defects not repaired prior handover include internal walls (Forcada et. al, 2013), but others arise due to lack of protection. Defects detected by customers in partitions are high (14%) but much lower than those detected at handover. These remaining defects are related to holes or chips in plasterboard and chipped and broken tiles.

Insert <Table 10. Comparison of elements where defects are detected among construction, handover and post-handover>

Although door and window defects only account for 6% of the construction defects, at handover they account for 17% and at post-handover they are even higher and are the most defective elements (25%). At construction stage, problems in doors were associated with their misalignment while at handover they relate to affected functionality of locks, handles, or doorbells, aluminium frames and glass and at posthandover they are mainly aesthetic and functional in nature and due to minor stains and scratches.

14% of construction defects are detected in M&E systems and attributed to wrong execution of ventilation grilles; incorrectly executed pipe insulation; air conditioning ducts which were covered by other mechanical elements; obstructed shunts, etc. (Forcada et. al, 2014). A similar percentage (12%) of defects in M&E systems remain at handover defects although they take the form of leaking pipes, goods not plumbed in or pipes not earth bonded and in the roof and ‘detachment’ of electrical and mechanical elements such as tubes, pipes, fluorescents and sockets. Surprisingly, only 5% of defects in M&E are detected by customers when they first occupy the flat and are more concerned about incorrect installed general-purpose outlets (GPO), TV sockets, and grilles (Forcada et. al, 2013a). Therefore, it seems that defects in facilities are repaired in each stage of the construction process but new defects arise in different stages. Defects in fixtures and fittings are only detected by customers at handover (19%) and take the form of missing or wrongly specified shower stands, screens, cap taps, inspection hatch caps, door handles, doorstops, grilles or entry-phones.

Despite incorporating quality inspections and controls during construction and handover, defects in newly built dwellings remain common. In fact, new defects appear at handover and mainly not rectified until customers complain about them. This defective work regards to lack of protection (stains, cracks, etc.) or unfinished work (second coat of painting, fittings, etc.) and although detected at the final stage of the construction process, contractors often have difficulties to bring subcontractors back to rectify the problem. Consequently, this situation result in customers becoming increasingly dissatisfied with the builders. Those defects detected by contractors at handover (during inspections and supervisions) but remaining until the client moves into the dwelling are mainly provoked by the increase of building costs and the high levels of inexperienced workers.

The increased of building cost, in regard to the fulfilment of technical and environmental laws such as Código Técnico de la Edificación (Ministerio de Vivienda (2006) (Technical Building Code), has provoked the use of non-skilled, cheapest subcontractors and also reduced the material quality in elements such as internal walls and floor finishes (Forcada et al 2014). To ensure the quality of subcontractors' work registration in the Registro de Empresas Acreditadas (2008) (Registry of Accredited Companies) is compulsory. Registration, however, does not ensure that quality control and assurance procedures will be put into place (Georgiou et al. 2000).

At a fundamental level, compulsory quality certification and occupational licensing of subcontract trades should be implemented to ensure that detected defects are solved (Love et al. 2010).

Customer complains include more than these technical defects and embrace other functional aspects. The different quality perception between builders, promoters and customers and thus the insufficient understanding of customer requirements seem to be responsible for the large number of complaints from clients which are not detected at handover (Forcada et al. 2013a). Customers did not complain about technical aspects as they might assume these aspects had been supervised by professionals and inspected by the warranty provider (Craig et al. 2010). Therefore, their focus is on those functional aspects such as aesthetics, cleanliness, presentation and look and feel.

The problem of the gap between technical quality and customer satisfaction is that the housebuilding sector (unlike other industries) has not tried to define what its customers' expectations and priorities are (Auchterlounie 2009). This is further compounded by an increase in customer awareness and sophistication. Builders may come to realize that collective efforts to understand customer expectations and preferences (Stephenson and Carrick 2006) for 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).

Despite efforts to detect defects by the contractor at handover and inhabitants complaints when they first occupy the dwelling, other defects might only become apparent after some years. These defects may be caused by design errors, poor workmanship or poor quality material. For instance, water seepage is normally detected after some years of construction and might be caused by poor material performance (concrete and waterproofing membrane), workmanship (poor method for laying waterproofing membrane and concrete work) or design (failure to provide moisture barriers) (Chong and Low, 2005). However, defects may also arise from poor maintenance, degradation or local conditions ,(meteorological or climatic conditions or settlement such as stains caused by moisture from rain, dirt from occupants, capillarity, cracks, dampness or efflorescence.

In relation to M&E systems, customers might not initially detect improper functioning but this may become apparent over time and use (e.g. actual energy consumption is much higher than initial predictions). This gap might be caused by poor management of systems but often is a result of design and/or installation problems. Addressing these latent defects and comparison can be done through a systematic adoption of post-occupancy evaluation. This has the potential to integrate actual performance and satisfaction with the remediation of defects.

Conclusions

Although inspection can occur during the construction stage of residential buildings, not all defects are addressed prior to handover. Therefore, the rework entailed by these defects has an inconvenient and negative impact on efficiency, productivity and competitiveness.

The detailed analysis of 2,179 flats in Spain identified that the most common defects detected at handover are ‘surface appearance’ (64.5%) including colour, type, uneven surfaces, dents and scratches, peeling and cracks; ‘tolerance errors’ (9.3%) such as dimensional errors in pavements for instance parquet flooring, woodwork; and ‘affected functionality’ defects (6.8%) such as problems with the boilers, noises in heating tubes, sockets located in not accessible places, impossibility to open the door of the fridge or door scrapes on the floor.

The results also show that 'internal walls' (59.9%), 'windows' (17.2%) and 'M&E systems' (8.5%) were the building elements where most defects arose.

Comparing the results of this study with those obtained from the analysis of construction defects (Forcada et al 2014) and post-handover defects (Forcada, et al., 2013), it can be concluded that, although many defects during construction are similar to those detected at handover stage, they are different in nature.

These results also revealed that structural defects and inappropriate installation of roofs and façades during construction are resolved at during the construction stage due to existing quality standards, while other aesthetic and functional defects remain and/or arise at handover. These remain unresolved until customers make complaints when they first occupy the dwelling. This forces reluctant subcontractors to return to the site. Finally, although minor in nature, many functional defects are only detected by customers due to the lack of involvement of end users at the first stages of the project.

This study provides evidence that the special characteristics of the housing sector, with inexperienced customers, quality standards set and managed by the contractors, lack of registration and licensing of subcontractor trades and high levels of standardization contribute to inadequate quality inspections. Quality construction regulations and certification exists. However, adaptation of these regulations to the real needs of the sector, emphasizing functional aspects and the involvement of customers at the very beginning of the process, are needed to improve the quality of housing and customer satisfaction.

The identification and comparison of the typical nature of defects, building elements and trades where defects arose in residential buildings provides useful information about those areas where builders are likely to make errors, mistakes or deliberately take short-cuts during construction.

Further research will be focused on investigating the financial implication of defects identified at different stages of the lifecycle of new residential buildings. This will enable an understanding of the severity of the problem of defects on the performance of house developer organization, and consequently on the productivity of the construction industry. At present, an accurate estimate of the financial impact of defects does not exist in Spain. An estimating model that can accurately calculate the cost of defects to both the house building sector and the wider construction industry would be beneficial. Further research will also focus on analysing residential latent defects (for buildings more than 2 years old) where construction defects caused by poor workmanship or poor material performance might become visible.

Tables

Table 1. Building characteristics

Development	Number of flats	Size (m2)	Cost [€]/development
Development 1	104	12,896	11,800,000 €
Development 2	100	14,253	17,299,000 €
Development 3	113	14,916	13,200,000 €
Development 4	80	11,760	7,466,000 €
Development 5	172	21,151	10,379,000 €
Development 6	135	22,465	23,449,039 €
Development 7	138	14,766	13,401,303 €
Development 8	235	25,145	19,556,314 €
Development 9	60	6,270	5,996,021 €
Development 10	141	17,343	10,699,328 €
Development 11	132	15,708	12,886,381 €
Development 12	369	41,697	19,695,986 €
Development 13	72	8,064	5,566,032 €
Development 14	128	9,085	8,324,077 €
Development 15	128	9,342	11,041,593 €
Development 16	72	6,946	4,493,447 €

Table 2. Handover defects by type of defect

Defect Type	Number of defects	%
Surface appearance	33,890	64.5
Tolerance errors	4,905	9.3
Affected functionality	3,559	6.8
Detachment	2,960	5.6
Inappropriate installation	2,424	4.6
Missing item/task	2,011	3.8
Water problems	1,705	3.2
Soiled	575	1.1
Misalignment	337	.6
Broken/deteriorated	145	.3
Flatness and levelness	41	.1
Total	52,552	100.0

Table 3. Defects by building element

Element	Number of defects	%
Internal wall	31,454	59.9
Window	9,017	17.2
Mechanical & Electrical Systems	4,474	8.5
Door	2,644	5.0
Plumbing & Sanitary Systems	2,015	3.8
Pavement	1,936	3.7
Furniture and Devices	505	1.0
General	377	0.7
Roof	77	0.1
Exterior wall	53	0.1
Total	52,552	100.0

Table 4. Building element and defect type

Type of defect	Building element										
	Window	P&S Systems	General	M&E systems	Furniture and devices	External wall	Internal wall	Pavement	Door	Roof	Total
Surface appearance	0	33	0	100	1	6	2	2	1	0	145
Soiled	0	1,365	136	204	0	0	0	0	0	0	1,705
Misalignment	2	1	0	20	1	0	0	1	16	0	41
Detachment	3	43	0	870	1	0	1,502	0	3	2	2,424
Tolerance errors	1,285	0	0	276	357	0	0	1	1,640	0	3,559
Stability	78	196	0	44	18	34	1,350	46	228	17	2,011
Missing item/task	2	373	0	0	1	0	4,279	250	0	0	4,905
Affected functionality	0	0	0	2,960	0	0	0	0	0	0	2,960
Inappropriate installation	223	0	0	0	0	0	113	0	1	0	337
Flatness and levelness	39	1	241	0	17	0	1	143	131	2	575
Water problems	7,385	3	0	0	109	13	24,207	1,493	624	56	33,890
Broken/deteriorated	0	33	0	100	1	6	2	2	1	0	145
Total	9,017	2,015	377	4,474	505	53	31,454	1,936	2,644	77	52,552

Table 5. Chi-square test of independence: Building element and defect type

	Value	df	Asymp. sig (2-tailed)
Pearson chi-square	112,254.52[a]	99	0.000
Likelihood ratio	61,167.50	99	0.000
No. of valid cases	52,552		

[a] 29 had an expected count of < 5. The minimum expected count was 0.25.

Table 6. Defects by subcontractor

Subcontractor	Number of defects	%
Partitions and enclosures	26,835	51.2
Doors and windows	10,896	20.7
Facilities	6,488	12.3
Coatings	5,017	9.5
Pavements	1,840	3.5
Furniture and devices	1,268	2.4
General	158	0.3
Total	52,552	100.0

Table 7. Subcontractor and defect type

	General	Facilities	Furniture and devices	Partitions and enclosures	Pavements	Doors and windows	Coatings	
Broken/deteriorated	0	133	1	7	2	1	1	145
Water problems	0	1,569	0	136	0	0	0	1,705
Flatness and levelness	0	21	1	0	1	18	0	41
Inappropriate installation	0	913	1	1,502	0	6	2	2,424
Affected functionality	0	276	1120	0	1	2,162	0	3,559
Missing item/task	0	240	18	4	46	306	1397	2,011
Tolerance errors	0	373	1	4,279	205	2	45	4,905
Detachment	0	2,960	0	0	0	0	0	2,960
Misalignment	0	0	0	113	0	224	0	337
Soiled	158	0	17	2	226	168	4	575
Surface appearance	0	3	109	20,842	1,359	8,009	3,568	33,890
	158	6,488	1,268	26,885	1,840	10,896	5,017	52,552

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Table 8. Chi-square test of independence: Subcontractor and defect type

	Value	df	Asymp. sig (2-tailed)
Pearson chi-square	92,208.13[a]	77	0.000
Likelihood ratio	60,809.48	77	0.000
No. of valid cases	52,552		

[a] 18 had an expected count of < 5. The minimum expected count was 0.25.

Table 9. Comparison of defect type among construction, handover and post-handover

Construction period (Forcada et al. 2014)		Handover		Post-handover (Forcada et al. 2013)	
Inappropriate installation	24%	Surface appearance	65%	Missing item/task	37%
Surface appearance	15%	Tolerance errors	9%	Surface appearance	19%
Affected functionality	12%	Affected functionality	7%	Inappropriate installation	16%
Missing item/task	12%	Detachment	6%	Soiled	10%

Table 10. Comparison of elements where defects are detected among construction, handover and post-handover

Construction period (Forcada et al. 2014)		Handover		Post-handover (Forcada et al. 2013)	
Pillar	14%	Internal wall	60%	Fixture and fittings	19%
Facilities	14%	Window	17%	Doors	15%
Internal wall	12%	Facilities	8%	Windows	14%
External wall	11%	Door	5%	Internal wall	14%

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