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What is quality in buildings?

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Preface

This is the first of a series of reports prepared during research into the BRANZ work programme on eliminating quality issues. It examines the various aspects of quality in buildings covering Building Code compliance, aesthetics and finishes, and the amenity and services provided by buildings.

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Abstract

Buildings have wide types and uses including residential, commercial, institutional and industrial. These broad categories have varied service requirements, ranging from basic protection from weather for equipment and animals to the enabling of controlled indoor environments for people and contents. This report addresses the quality requirements, in broad terms, of these buildings. Common types of defect are discussed, including a literature review of the causes of these defects. Procedures developed overseas for improving building quality at the various stages of project scoping, design, construction and commissioning are discussed and assessed.

Keywords

Quality, defects, workmanship, client brief, design, post-occupancy evaluation.

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1. Executive summary

1.1 Defining quality

Building quality is not easily defined or measured. This is not surprising when the definition of 'quality' has been debated throughout history. Despite the challenge in settling on a definition, quality is an important concept for designers, builders and users of buildings. Many definitions and ways of measuring quality in buildings have been developed.

This report discusses three levels of quality:

- Basic quality, or a building without defects.
- Enhanced quality, with a focus on buildings that are fit for purpose for users now and in the future.
- High quality, for buildings that are 'beyond good'.

Following the discussion on quality, this report briefly summarises the frameworks that have been developed to measure building quality, focusing first on housing quality and then the quality of commercial buildings.

1.2 Levels of quality

1.2.1 Basic quality

In its most simple form, a basic requirement for a building is that it conforms to specifications, including requirements set out in regulations, industry standards and contractual understandings. In New Zealand, the building regulatory system is performance-based. It sets the standards for what should be achieved but does not require highly specified rules to be followed. How these requirements are met is up to the builder, and compliance must be demonstrated through a building consent process.

Quality beyond compliance is difficult to specify in advance and can require negotiation to determine whether an issue of aesthetic quality is a defect that requires remedy. In New Zealand, the process for determining whether an issue in residential building is a defect is to refer to, in order:

- the contract
- the building consent
- the manufacturer's specifications
- the tolerance schedule
- any relevant standard
- the *Guide to tolerances, materials and workmanship in new residential construction 2015* (Ministry of Business, Innovation and Employment, 2015).

Standards have been developed for individual components (such as carpet or tiles) but generally not for groups of components or joints between components. The guide goes some way to addressing the lack of standards but notes that it is incomplete. In general, aesthetic defects can be avoided if:

- components are installed according to manufacturers' instructions and finished appropriately
- groups of components are consistently installed horizontally or vertically
- joins between components are aligned and sealed.

Surveys of new houses show that, in New Zealand and internationally, very few houses are built without having some form of compliance or aesthetic defects. Researchers have not agreed a definitive list of reasons why defects occur.

However, workmanship, build error, design, construction methods, uncoordinated trades and materials have all been found to have contributed to defects in the building process in New Zealand.

1.2.2 Enhanced quality

When considering enhanced quality, we looked at how construction caters for a range of users over time. We also looked et how the building impacts the environment, which is often referred to as sustainable building.

Buildings often have a lifetime decades beyond their original use and users. In residential building, it is difficult to predict the type of people who will live in a house during its lifetime. One response is to incorporate features in the design that can facilitate use by older persons, as these features are of benefit to all age groups. In commercial building, three general types of changes have been identified:

- Changes in the function of space
- Changes in the load carried by the systems of the building.
- Changes in the flux of people and forces from the environment.

The response has been to incorporate flexibility in design so that the building could adapt to these changes over time.

Sustainability has been considered in different ways, with some frameworks incorporating sustainability as a measure of quality while some researchers identify sustainability as separate from quality. Growing emphasis is being placed on sustainability, not least because research has established that high-performance green buildings (which have sustainability as a key outcome) lead to lower operational costs and higher productivity. Large house size is noted as one variable that affects sustainability, and in New Zealand, house sizes have been increasing over time. The New Zealand Green Building Council notes that several hundred houses have been built to their 6-star standard. Their costs are estimated at about 1.5% more than a house that simply meets the Building Code.

1.2.3 High quality

Extensive searching of academic databases failed to find meaningful descriptions for 'high-quality construction' or 'high-quality buildings'. Assessment of 40 New Zealand websites found that claims of high quality (or superior or top quality) were based on one or more of six types of claim. These were:

- better workmanship based on higher skills and longer experience
- an attitude that focused on quality
- better products
- winning awards for buildings
- client-focused processes
- better methods.

Membership of professional associations was also noted as a way in which clients could trust that their building would be of high quality.

1.3 Measures of quality

1.3.1 Housing quality

Many frameworks have been developed to measure existing housing quality, most with a focus on social housing. Fewer frameworks consider a house during or shortly after construction. Two frameworks of this type that are in use are the Singapore-developed Construction Quality Assessment System (CONQUAS) and the United Kingdom-developed Housing Quality Indicator (HQI). Each of these frameworks requires independent assessment to complete a detailed report. While CONQUAS has been used extensively since 1989, the HQI is generally limited to compliance with procurement requirements for social housing.

1.3.2 Commercial building quality

A range of frameworks have been developed to measure the quality of commercial buildings. Key performance indicators and benchmarks provide indicators of contractor performance but do not measure whether the building meets client expectations over the medium or long term. The Design Quality Indicator (DQI) uses a structured approach to tease out stakeholder priorities using expert facilitation. This approach appears to be used more in the design stage than as a measure of performance. Post-occupancy evaluation (POE) is used to ascertain the performance of buildings from a variety of viewpoints. A portfolio of techniques for POE has been developed to reflect the context, needs and resources of organisations involved.

1.4 Discussion

Quality is an elusive concept that is aspired to in the building sector yet difficult to achieve. Often, the client is the arbiter of quality, making decisions about design, materials, techniques, timing, how the project is managed and trade-offs between immediate and longer-term costs. Quality will mean different things to different people. What is quality in a new building will vary, depending on the needs of present and future users. It is important that designers spend the time to thoroughly understand the needs of their clients, helping them to understand the choices and trade-offs concerned, given the inevitable budget constraints.

It is only at the most basic level of quality that an independent assessment is made. In an ideal situation, the builder would have got it 'right first time'. However, research has consistently found basic quality issues in most new houses. No comparable research has been completed on non-residential buildings. Higher levels of quality depend on the client making trade-offs between current costs and future potential costs. While it is cheaper to design in user-friendly or sustainable components, many clients are unaware of the potential longer-term savings as they focus on meeting current needs. However, environmental sustainability is becoming more of a concern for clients, and a system is in place to rate New Zealand buildings.

CONQUAS is a methodology worth exploring in the New Zealand context. While adoption of independent assessments at the end of construction will result in additional costs, clients and contractors may determine that this cost is worthwhile. For clients, the independent assessment would reduce the need to negotiate with the contractor about visible defects and give peace of mind that the building has been constructed to the standard required. For contractors, the CONQUAS measurement can provide evidence of the quality of their workmanship, an important consideration in securing future work.

2. Introduction

Building quality is not easily defined or measured. Despite decades of research and practice, there is no concise definition nor agreed framework for measurement. Researchers and practitioners have generally agreed that, in the words of Seymour and Low (1990, pp. 13–14), “there can be no absolute definition of quality nor can there be simple, unequivocal standards”.

It is not surprising that building quality is difficult to define when researchers have been debating the definition of quality ‘throughout history’ (Reeves & Bednar, 1994). Four main concepts of quality are conformance to specifications, value, meeting or exceeding customers’ expectations and excellence. Each of these concepts has been used in defining and measuring quality in buildings.

- *Conformance to specifications* is linked to the mass market production age, where a quality product is one that conforms to the design.
- *Value* allows for a less absolute standard, taking into account the consumers’ willingness to pay and the relative level of quality.
- *Meeting or exceeding customers’ expectations* is the most recent concept of quality, where the customers’ viewpoint is considered above all else.
- *Excellence* derives from the Greek word ‘arete’, the definition of which changes according to its context. For Plato, excellence meant ‘the good, the highest form, the highest idea of all’, whether that related to a racehorse or man. (Reeves & Bednar, 1994)

Despite the challenge in settling on a definition, quality is an important concept for designers, builders and users of buildings. According to one study of construction quality and price, it influences the price paid for the building (and therefore the builder’s profit margins). It also influences the price paid when the building is sold at a future date (Ooi, Le & Lee, 2014). Conversely, an American study found that building values as appraised for tax purposes could be a useful basis for a proxy measure of the structural quality of housing (Sumka, 1977).

Many definitions and ways of measuring quality in building have been developed. The earliest known typology is found in the writings of Vesuvius in the first century BC, who proposed that structures must have three aspects: utility, durability and beauty (Construction Industry Council, 2017). The UK Construction Industry Council has loosely translated these as functionality, build quality and impact, which forms the basis of its Design Quality Indicator (discussed later).

This paper discusses three levels of quality:

- Basic quality, or a building without defects.
- Enhanced quality, with a focus on buildings that are fit for purpose for users now and in the future.
- High quality, for buildings that are ‘beyond good’.

Following the discussion on quality, this report briefly summarises the frameworks that have been developed to measure building quality, focusing first on housing quality and then the quality of commercial buildings.

3. Basic quality: a building without defects

In its most simple form, a basic requirement for a building is that it conforms to specifications, including the requirements set out in regulations, industry standards and contractual understandings.

A building that fails to comply is missing the most basic level of quality.

3.1 Compliance standards

Regulatory systems can range from highly prescriptive to highly flexible. In New Zealand, the building regulatory system is performance-based in that it sets the standards for what should be achieved but does not require highly specified rules to be followed (May, 2003).

Under the Building Act 2004 and Building Code, the minimum standards for a New Zealand building are that it will:

- safeguard people from injury or illness:
    - caused by structural failure (along with other property from physical damage), fire, surface water or moisture, hazardous substances,
    - caused by falling, construction and demolition hazards, infection or contamination, extreme temperatures, contaminated water or excessively hot water or unsafe installations
    - during movement into, within and out of buildings (including if main lighting fails) or while using or servicing mechanical installations
    - due to lack of awareness during an emergency (including of escape routes) or lack of fresh air
    - due to low air temperature or inadequate activity space, undue noise, isolation from natural light and the outside environment or adequate lighting or the use of gas
- safeguard people from loss of amenity due to:
    - lack of hot water, fresh air, natural light, water for human consumption, appropriate personal hygiene or laundering facilities or activity space
    - structural behaviour
    - accumulation of internal moisture
    - inadequate direction
    - undue noise transmitted between tenancies
    - isolation from natural light and the outside environment
- safeguard people from the risk of fire or explosion
- facilitate efficient use of energy
- ensure people with disabilities are able to enter and carry out normal activities and processes
- meet all functional requirements throughout its life (Ministry of Business, Innovation and Employment, 2014).

How these requirements are met is up to the builder, and compliance must be demonstrated. The Ministry of Business, Innovation and Employment has provided Acceptable Solutions (specific construction methods) and Verification Methods (testing, calculations and measurements) that, if followed, are deemed to comply with the Building Code.

Any alternative method must be supported with evidence to show how the proposed work will meet the performance requirements of the Building Code (Ministry of Business, Innovation and Employment, 2017).

The Building Act 2004 and Building Code are put into effect through a building consent process. Building work is not to be carried out except in accordance with a building consent.

A building consent authority must grant a building consent if it is satisfied that the provisions of the Building Code have been meet.

3.2 Standards of workmanship

Quality beyond compliance is difficult to specify in advance (Chohan, Irfan & Awad, 2015; Forbes, 2001; Hoonakker, Carayon & Loushine, 2010; Seymour & Low, 1990). It can require negotiation to determine whether an issue of aesthetic quality is a defect that requires remedy.

The basic standards for compliance relate to mainly structural integrity and the durability of the building. The Building Act 2004 also has consumer protection measures to guard against poor workmanship, including that which results in aesthetic rather than structural defects. Aesthetic defects may refer to individual components (for example, carpet), groups of components of the same type (for example, light switches) and joins between components (for example, between benchtops and adjoining surfaces).

BRANZ publishes several series for builders on how to build, including its Building Basics series and Good Practice Guide series. These publications were produced to meet quality issues that BRANZ has observed over the years.

Noting that purchasers may expect different levels of quality, in New Zealand, the process for determining whether an issue in residential building is a defect is to refer to, in order:

- the contract, drawings, specifications and schedule of quantities
- the building consent and supporting documentation
- manufacturers' specifications and installation instructions
- the building contractors' defect tolerance schedule
- any relevant New Zealand standard
- the *Guide to tolerances, materials and workmanship in new residential construction 2015* (the guide) (Ministry of Business, Innovation and Employment, 2015).

Standards have been developed for individual components but generally not groups of components or joins between different components.

The guide goes some way to addressing the lack of standards but notes that it is incomplete. There are areas where what constitutes acceptable tolerances, material and workmanship are not well defined or not included in standards or codes of practice (Ministry of Business, Innovation and Employment, 2015).

Table 1 sets out building components and relevant New Zealand standards.

Table 1: Building components and standards

Topic	The guide	Standards
Landscaping and grounds	Paving	NZS 3116:2002
	Retaining walls	
	Asphalt driveways and paths	
	Concreted driveways and paths	NZS 3114:1987
	Timber decks	NZS 3631:1988
Flooring	Flooring generally	
	Concrete floors	NZS 3114:1987
	Timber-framed floors	NZS 3604:2011 AS/NZS 1170.0:2002
	Timber floor boards	NZS 3631:1988
	Particleboard and plywood floors	
Wall claddings	Wall claddings generally	
	Clay brick and masonry veneer	ASTM C90-14 NZS 4210:2001
	Concrete masonry	ASTM C90-14 NZS 4210:2001
	Stone veneer	
	Stucco	
	Timber weatherboards	NZS 3602:2003 NZS 3631:1988
	Fibre-cement	
	Profiled metal wall cladding	
	Sheet cladding with jointers or cover battens	
	Exterior insulation and finish system	
	Autoclaved aerated concrete system	
Roof cladding	Pressed metal tiles	
	Profiled metal roofing	
	Clay and concrete tiles	
	Membrane roofs	
	Guttering, downpipes and roof vents	
Windows and doors	Windows	NZS 4211:2008 AS/NZS 4666:2012 AS/NZS 4667:2000
	Doors	
Wall/ceiling linings	Plasterboard, fibrous plaster, fibre-cement	NZS 2589:2007
	Plywood	
	Timber boarding	NZS 3604:2011 NZS 3631:1988
	Finishing trim	
Painting		AS/NZS 2311:2009 NZS 1580.601.5
Tiling		
Floor finishes	Carpet	NZS 2455.1:2007
	Vinyl	AS/NZS 1884:2013
	Cork tiles	
	Timber overlay flooring	
Cabinets and benchtops		
Plumbing and drainage		
Electrical fitting and fixtures		
Miscellaneous items	Insulation	
	Installed items	

In general, aesthetic defects can be avoided if:

- components are installed according to manufacturers' instructions and finished appropriately
- groups of components are consistently installed horizontally or vertically
- joins between components are aligned and sealed.

3.3 How well do New Zealand buildings meet basic quality standards?

Surveys of new houses show that, in New Zealand and internationally, very few houses are built without having some form of compliance or aesthetic defects. To determine how well New Zealand buildings met compliance standards, a survey of new houses under construction was completed by BRANZ in 2014 (Page, 2015). The survey examined components systematically and recorded compliance with the appropriate clauses of the Building Code. It found an average of 2.2 compliance defects per house. Many of these defects are likely to have been remedied prior to the Code Compliance Certificate being issued. However, there are no national statistics available on the proportion of buildings that achieve a Code Compliance Certificate or the number and type of defects found and remedied at final inspection. Reasons for defects remaining unremedied are that defects are difficult to see or to repair. Inspectors with incomplete knowledge or facing time pressures may be more likely to miss a defect during inspections. The same survey found an average of 4.3 visible finishing defects per house (Page, 2015).

This finding is confirmed through new home owners' satisfaction surveys in New Zealand, which consistently found a high level of call-backs to fix defects identified at first occupancy by owners (Curtis, 2016). The latter survey asked about levels of satisfaction, and one of these questions was how the new owner would describe their builder. The question found that 30% said they would recommend their builder. However, 17% said they would speak critically of their builder, which is potentially quite damaging for builders in terms of obtaining further work.

Rotimi, Tookey and Rotimi (2015) surveyed 216 new home owners in New Zealand and found the owners had observed an average of 3.5 visible defects per house.

The findings for New Zealand buildings are well below those in the UK, although different standards may have been used. A UK author, Craig (2008), surveyed over 3,600 new homes over a 6-year period and found an average of 53 visible defects per house. Mills, Love and Williams (2009) found rework costs of 4% on average for new housing in Victoria. In Australia, the costs range from 2–10% of the contract value, with an average of 5%. Rework includes late changes by the client as well as design and contractor errors.

Looking at buildings more generally, local industry experts (mainly building surveyors) were surveyed about their experience in finding compliance defects in all building types, categorised by Building Code clauses. The most common defects are non-compliance of the structure (clause B1) and external and internal moisture problems (clauses E2 and E3) in both non-residential buildings and housing. Non-compliant fire safety measures (clauses C1–C3) were quite common in non-residential buildings, often revealed when leaky buildings were stripped back for the rebuild of the cladding systems. The detailed responses of the experts are in Appendix A.

3.4 Causes of basic quality defects

Researchers have not agreed a definitive list of reasons why defects occur. Critical success factors in construction have been identified by many researchers, with lists of variables identified that influence the quality of a building product. While there are some variables in common, no general agreement has been reached on the factors that most influence quality (Albert & Tam, 2000).

This section provides an overview of some examples of these lists, along with a summary of the New Zealand situation.

Josephson and Hammarland (1999) conducted research on seven mainly non-residential buildings in Sweden, recording defects as they arose and interviewing stakeholders to determine the cause of these defects. Causes of defects could be traced to the client organisation, the design team and the contractor. Underlying causes were:

- time and cost pressures, with insufficient time and cost allowed for appropriate design and quality construction
- poor client decision making, with a poorly organised client and appropriate decision-making personnel unavailable
- construction site management, where planning was insufficient to meet timeframes.

A study by Albert and Tam (2000) on the critical success factors for building projects in Hong Kong involved interviews and factor and regression analysis. This was in order to determine what factors had the most influence on quality construction. The researchers found that four factors significantly associated with quality as measured by client satisfaction. These are:

- project management or how effectively and efficiently the construction process is managed
- the construction team leader and how effective they are
- the client’s emphasis on time
- the client’s emphasis on quality.

Love and Edwards (2004b) argue that building-quality issues can arise at any stage of the construction process and result from a failure in any one of:

- specification – where construction professionals have not fully understood and documented client requirements, resulting in changes after construction has started
- project management – when unrealistic timeframes push contractors to focus on deadlines rather than quality
- workmanship – when contractors lack the necessary skills and expertise to carry out work
- quality assurance – when no formal quality management system is in place and inadequate supervision or inspection is carried out.

Love and Edwards (2004b) identify that the market-driven approach with an overwhelming focus on lowest cost is a factor in these causes. However, they place the challenge on designers to improve their design quality management practices and not simply advocate for higher fees from clients.

Love and Edwards (2004a) carried out a survey of 161 Australian industry professionals. They found client changes, ineffectual use of information technology (so that communication and decision making are affected) and design scope freezing (contributing to hasty decisions) were significant factors that increased rework costs. In contrast, value management, which involves a review of the functionality of the initial design with the client, can be significant in reducing rework costs.

In summary, the international literature found the most common causes of defects were:

- poor workmanship
- build error (work in the wrong location)
- material faults
- poor coordination between trades
- poor design (lacking details or difficult to build)
- inappropriate construction procedures (such as construction methods, timeframes and sequencing) (Rotimi, 2013).

It is likely that the New Zealand construction industry faces the same issues.

In 2014, BRANZ conducted inspections of new houses under construction in the New House Construction Quality Survey (Page, 2015). The results were interpreted against the framework proposed by Rotimi (2013). The inspections found poor workmanship and build error accounted for 52% of causes of defects, and materials, work by subcontractors, poor design and construction methods averaged around 12% each.

As part of this project, a different set of builders were surveyed by post on what factors inhibited their ability to produce good-quality new housing. The most commonly cited factors were poor workmanship (27%), followed by incomplete design (22%) then build error (21%). Less commonly cited were faulty construction methods (14%), uncoordinated trades (8%) and faulty materials (7%) (Page, 2015). See Appendix B for more details of the construction inspection survey and the builders' postal survey.

A review by an Auckland building inspector found multiple issues on site that translated into poor workmanship, build error and design being the most prevalent cause of defects. Details are in Appendix C.

Moving from housing to mid-rise buildings, becoming more common in city-fringe areas in New Zealand, a building surveyor sought information on whether the construction systems, as designed, were appropriate for these buildings. The inspection found that, in general, designs failed to consider the greater impact of weather at higher levels. The detailing for weathertightness, ventilation and wind loads was inappropriately borrowed from low-rise residential designs. Details are in Appendix D.

The findings on causes of defects and non-compliance from the above sources are summarised in Figure 1. The chart indicates approximately similar problem areas for the first three sources, with workmanship, builder error and design being the issues. The last bar indicates that design and materials commonly used on low-rise buildings often cause problems in medium-rise buildings.

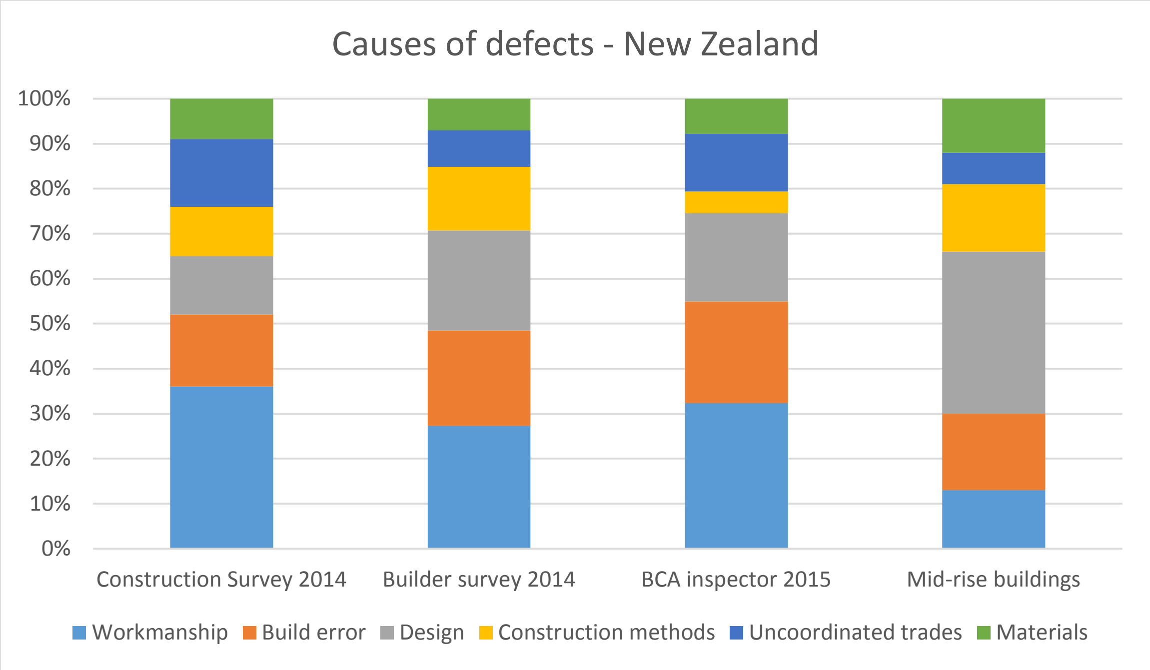

Figure 1. Causes of quality defects in New Zealand.

4. Enhanced quality: fit-for-purpose buildings

When considering enhanced quality, we looked at how construction caters for a range of users over time as well as how the building impacts the environment, often referred to as sustainable building.

4.1 Lifetime design

Buildings often have a lifetime decades beyond their original use and users (Fernandez, 2003). In both residential and commercial buildings, the design stage is where consideration must be given to ensuring the building is fit for purpose over its lifetime. While standards for lifetime design are clear and mostly unambiguous in residential building (Page & Curtis, 2011), commercial buildings fulfil a much wider range of potential uses. The most appropriate solution for commercial buildings is to consider obsolescence for both the whole building and for parts of the building (Fernandez, 2003).

4.1.1 Lifetime design in housing

In residential building, it is difficult to predict the type of people who will live in a house during its lifetime. For example, a house may be used by young students, a family with small or teenage children, large-bodied people, people with permanent or temporary disability, an elderly person or a combination. In each of these cases, the house will be used in a different way. One response to the challenge of designing a residence that is fit for purpose for a wide range of users is to incorporate features that can facilitate use by older persons. These features are of benefit to all age groups (Page & Curtis, 2011).

Standards for a user-friendly house specify:

- minimum widths of doorways and hallways
- minimum sizes of kitchens, bathrooms/toilets and bedrooms
- strength of walls (so that handrails can be fitted)
- height of power sockets and light switches (Page & Curtis, 2011).

Designing in user-friendly features is cheaper than retrofitting a house to meet the standards. Page and Curtis (2011) estimated that, for a single-storey house, the cost of incorporating user-friendly features is around 0.5% of the total construction cost. Retrofitting may involve costs of 5% for internal changes and another 2.5% for external modifications.

Awareness of user-friendly design appears low in New Zealand. A survey of new homeowners in 2011 found the majority of respondents (87%) had not heard of lifetime design (Page & Curtis, 2011). A recent report in the media noted that New Zealand has a shortage of housing stock suitable for people with disabilities (Spink, 2016). Finally, a search of the largest residential property sales website in New Zealand (www.trademe.co.nz/property) using keywords ‘lifemark’, ‘lifetime design’, ‘universal design’ or ‘disabled’ found eight houses with ‘Lifemark’ specified in their listing. However, all but one appeared to be yet to be built. Fifteen houses for sale were marketed using the word ‘disabled’, usually referring to the presence of a wet floor in the bathroom. These listings represented less than 1% of the 24,386 listings on 7 February 2017 (excluding bare land or sections).

4.1.2 Building for a commercial lifetime

In commercial building, three general types of changes have been identified, which are:

- changes in the function of space
- changes in the load carried by the systems of the building
- changes in the flux of people and forces from the environment (Fernandez, 2003).

To meet the potential for change, one approach has been to designate very specific lifetimes, although the results often do not meet expectations. For example, the Eiffel Tower was intended to be dismantled in 1909. Another approach has been to design mobile buildings and use these to augment physical buildings such as hospitals or school classrooms. Finally, flexible and adaptive buildings include those with devices that allow for reconfiguration of physical systems and spaces or deconstruction and reuse of building materials.

Fernandez (2003) recommends that, where it is likely a building will experience a complex lifetime, flexibility is designed in to the building, based on likely future scenarios. This process also calls for design that can be disassembled at the building and detail levels.

The intended use of the building is also a key consideration in design. Institutional buildings, including those for social, cultural, health and education purposes, need to be designed to assist the wellbeing of their occupants. Eley (2004) notes that appropriately designed buildings can make a significant difference in both learning and healthcare. Life cycle costs are also important for these buildings as they are usually subject to robust usage.

Industrial buildings tend to be utilitarian in appearance as befits their function, and for these buildings, initial cost is important. They need to be flexible in layout as manufacturing and storage systems change quite frequently with changes in technology.

Commercial buildings, such as those to be used for retail, accommodation or office work, need to be attractive to potential shoppers, occupants or workers. For these buildings, the internal environment is important as it has a direct impact on customer expenditure and worker productivity.

4.2 Sustainable building

Sustainability has been considered in different ways, with some frameworks incorporating sustainability as part of a measure of quality. For example, the Housing Quality Indicator (Housing Corporation, 2008) and other researchers such as Srdić and Šelih (2011) identify sustainability as separate from quality.

Research has established that high-performance green buildings (which have sustainability as a key outcome) lead to lower operational costs and higher productivity (Gultekin, Mollaoglu-Korkmaz, Riley & Leicht, 2013). As a result, growing emphasis is being placed on the sustainability of building practices and buildings. Sustainable building is about ensuring the building has minimum negative impact on the environment during construction, use and demolition. Initially focused mainly on energy performance, researchers generally agree that sustainability involves consideration of three aspects: environmental, social and economic. (See Akadiri, Chinyio & Olomolaiye, 2012; Al-nassar et al., 2016; Bragança, Mateus & Koukkari, 2010; Grizāns & Vanags, 2009; Passarini, Pereira, Farias, Calarge & Santana, 2014; Sumka, 1977). Bragança et al. (2010) add 'cultural' as a component to be considered. Sustainability has been conceptualised as important throughout the life cycle of a building. Researchers have posited that sustainable design should consider healthier and more resource-efficient models of construction, renovation, operation, maintenance and demolition. As well, design should take into account the full life cycle costs of a building (Cao, Li, Zhu & Zhang, 2015; Deuble & de Dear, 2014; Hassan, 2006; Srdić & Šelih, 2011).

House size is noted as one of seven variables that can reduce CO_2 emissions from residential buildings. Smaller houses have less impact on the environment through heating and cooling activities (Clune, Morrissey & Moore, 2012). In most Western countries, detached house sizes have increased over the last 50 years. In New Zealand, average new house size increased from 128 m^2 in the 1960s to 214 m^2 in 2014 (Quotable Value New Zealand, 2011). At one extreme, promoters of the 'tiny house movement' contend that these houses (of less than 50 m^2) are part of a sustainable approach. Wyatt (2016) notes that tiny houses are gaining in popularity. This is partly due to the success of some tiny home communities, but that the reality of living in such a small space may not meet expectations. They are said to be in demand when more traditional housing becomes unaffordable, and interest in tiny or at least smaller houses may increase in New Zealand over time. Building consent data from Statistics New Zealand indicates this may now be happening, with the latest building consent data indicating an average detached house size of 209 m^2.

The BRANZ Level Sustainability Series (www.branz.co.nz/level) provides advice on how to achieve sustainable outcomes, including passive design, energy use, heating and ventilation, coatings and so on.

The cost of meeting enhanced sustainability standards is estimated at about 1.5% more than a house that simply meets the Building Code. Performance schemes for buildings are run by the New Zealand Green Building Council – Homestar is for houses and Greenstar for commercial buildings. The Greenstar scheme includes measurement of energy and water use, materials and innovation (for example, earthquake resilience). Auckland Council has adopted an enhanced standard for new housing in special housing areas.

Several hundred houses have been built to 6-star level. They feature insulation above the minimum requirements of the Building Code, water efficiency measures and extractor fans to remove indoor moisture (New Zealand Green Building Council, 2017). In contrast, a Building Code-compliant house commonly meets a 4-star rating on the 1–10-star rating system in Homestar. Like user-friendly design, awareness of design for sustainability appears low in New Zealand. Of the 24,386 listings for residential property on www.trademe.co.nz/property on 7 February 2017, 19 included the word 'homestar' in its listing. All but one were for houses that had not yet been built.

5. High quality: beyond good

A high-quality building should be “more than a defect-free building” (Eley, 2004, p. 255). An extensive search of international research databases failed to find meaningful descriptions for ‘high-quality construction’ or ‘high-quality building’. CONQUAS (see section 6.1) allows for perhaps the best proxy for high-quality construction, with building quality assessed on a sliding scale (Ooi et al., 2014). However, the use of the term ‘high quality’ in relation to building and construction services is widespread. Many New Zealand companies market their services using the terms ‘high quality’, ‘superior quality’, ‘top quality’ or simply ‘quality’. Identification of 40 building contractor websites, found using the Google search criteria ‘high quality building New Zealand’ is shown in Appendix E. These sites had six main ways in which building contractors argued their buildings were or would be of high quality construction:

- *Workmanship quality*, in which the quality claim is based on the number of years' experience held by the builder. Additional claims are that there is a dedicated team of professionals/craftsmen/tradesmen and/or that they are the ‘best in the industry’ (18 of 40 websites).
- *Builder attitude*, in that no corners are cut or compromises made and/or that there is a steadfast focus on quality. Other claims are a passion for quality and perfection, a focus on every detail and/or a commitment to deliver (12 of 40 websites).
- *Product-based quality*, in which the quality claim is based on having products that are more cost-effective; more environmentally friendly; more energy efficient or of the highest-quality materials (eight of 40 websites).
- *Award-winning*, where the quality claim is tied to the company's record of winning awards (eight of 40 websites).
- *Client focused*, where the client is listened to; worked in partnership with; or client expectations are exceeded (six of 40 websites).
- *Methods*, where quality assurance processes were described or the ‘best’ methods used (three of 40 websites).[1]

Membership of building associations and associated guarantees/warranties was also noted as a way in which clients could trust that the building would be ‘high quality’.

No website mentioned going beyond compliance as a measure of quality. However, if components such as thermal insulation, earthquake resilience, hygiene facilities and lighting are of a higher level than the Building Code requires, this would result in a higher-quality building.

For existing housing, Quotable Value New Zealand categorises each property as of ‘superior’, ‘average’ or ‘poor’ condition, based on an assessment ‘from the road’ (Pearson, Barnard, Pearce, Kingham & Howden-Chapman, 2014). A more detailed assessment is carried out by BRANZ in its regular House Condition Survey (Buckett, Jones & Marston, 2012). An assessor inspects a sample of New Zealand houses, subjectively assigning a rating of ‘good’, ‘moderate’ or ‘poor’. The physical condition of individual components is rated on a 5-point scale from excellent to serious, the latter requiring immediate replacement.

Further research is needed into what makes a building of high or superior quality.

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[1] The numbers add to more than 40 as multiple types of claims were made on some sites.

6. Measures of quality

6.1 Construction Quality Assessment System (CONQUAS)

CONQUAS was developed in Singapore and has been used to assess residential and commercial buildings since 1989. The assessment covers three components:

- Structural works (during construction) including formwork, steel reinforcement and concrete.
- Architectural works (after completion) including internal finishes, roofs, external walls and works.
- Mechanical and electrical works (during construction) including site inspections and performance tests on selected works.

Assessment is achieved by sampling based on the size of the building, with samples distributed uniformly throughout the construction stages. Scoring is only completed once. Remediation carried out after a sample has been assessed is not included. The scores are aggregated and weighted, with structural works comprising 25%, architectural works comprising 65% and mechanical and electrical works comprising 10% of the total. Finally, each completed building is given an aggregated CONQUAS score out of 100%. These scores are made publicly available through the Building and Construction Authority website, which also makes available the project name and contractor responsible.

CONQUAS has been recognised internationally, with registered trademarks in Singapore, Malaysia, China, Hong Kong, the United Kingdom, Australia, South Africa and India (Building and Construction Authority, 2017).

6.2 Housing quality measures

The following sections describe housing quality measurement frameworks that have been developed. The first two frameworks (sections 6.2.1 and 6.2.2) allow for measurement shortly after construction has been completed, while section 6.2.3 briefly outlines quality measurement frameworks for existing, mainly social, housing.

6.2.1 Housing Quality Indicator (HQI) (UK)

The United Kingdom's housing quality indicator (HQI) framework is an example of a framework that seeks objective and precise criteria. It scores housing projects on various aspects of their developments. These are location, visual impact, routes/traffic movement, house size, layout, noise/natural light, adaptability, accessibility, sustainability and performance in use. Generally, HQI objectively measures design features using qualitative metrics and has many of the features of lifetime design in New Zealand. The latter covers access and movement requirements for various users including young families, the disabled and the elderly. These houses have user-friendly features and a feeling of spaciousness and cost little more than a standard house (Page & Curtis, 2011).

However, HQI is a high-cost measure of quality, due to the nearly 400 questions and inadequate consideration of multi-unit dwellings, where the same information must be given multiple times. Its use tends to be limited to compliance with procurement requirements for social housing in the UK (Eley, 2004).

6.2.2 Quality measurements for existing housing

Multiple measurement frameworks for housing quality have been developed, many with aspects in common. Chohan et al. (2015) reviewed six housing quality frameworks[2] to identify the most common aspects measured. These were:

- site planning and layout
- access to amenities
- appearance
- quality of façade
- refuse collection system.

Chohan et al. proposed a synthesised framework based on the stages of housing design (Table 2).

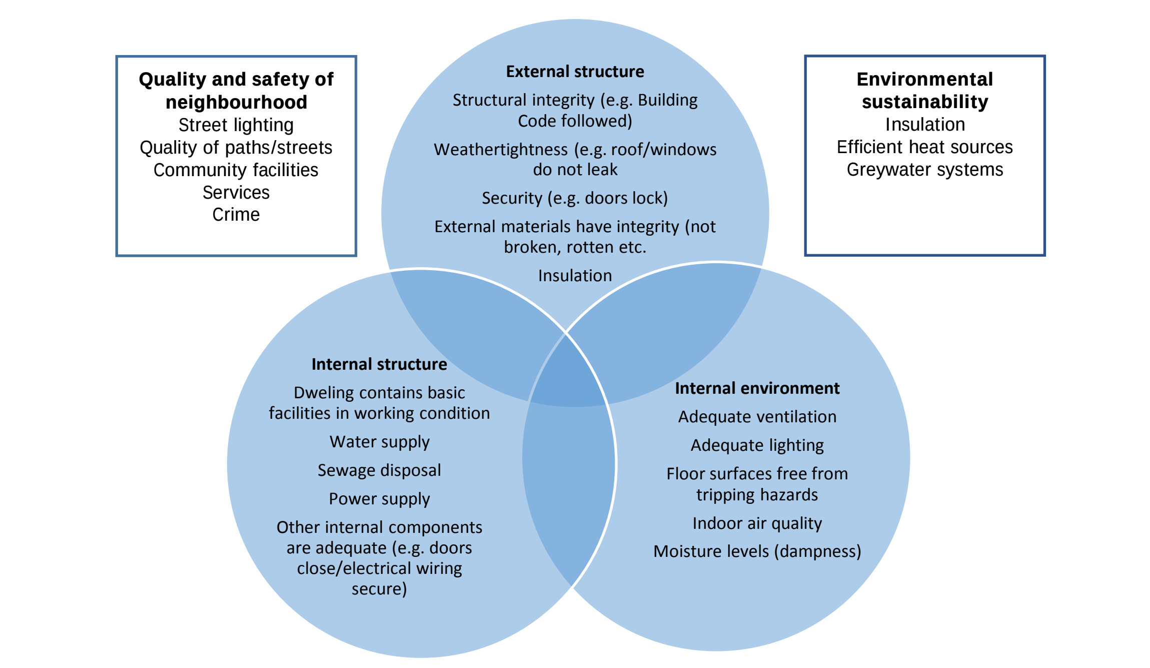
Table 2. Design quality determinants.

Architecture and site planning	Structure and construction	Building services and health, security and safety	User comfort	Maintenance and sustainability
• Site planning and layout • Quality of site and neighbourhood • Access to public transport • Access to amenities • Distinctive character in urban context • Appearance • Space planning (e.g. rooms) • Quality of façades	• Workmanship • Tolerance and stability of structure • Proper material selection • Adoption of conversion/ extension	• Refuse collection system • Internal condition (e.g. lighting, ventilation) • Electricity installation layout • Sanitary appliances	• Environmental conditions (e.g. air quality, noise) • Internal condition (e.g. dampness) • Adequate insulation from noise • Proper ventilation in bathrooms and kitchens • Heating comfort	• Maintenance measures • Sustainable • Lead-free pipes and paint

Source: Chohan et al. (2015).

Housing quality has been recognised as an key gap in New Zealand's official statistics system. In 2015, Statistics New Zealand released a paper to "stimulate discussion on the definition of housing quality and what should be measured" (Statistics New Zealand, 2015a, p. 5). This paper sets out the major components of housing quality, and some elements that can be included in each component. It notes that many elements are already measured through different surveys, although collectively, there is no coherent framework or reporting on New Zealand's housing quality. Figure 2 shows the components and elements of housing quality suggested by Statistics New Zealand, which largely reflect the framework proposed by Chohan et al.

[2] Abdul-Rahman, Kwan and Woods (1998); Scotland Housing Quality Standards; Housing Quality Standards (US); Commission for Architecture and the Built Environment (2006); Housing Corporation (2007); Building Research Establishment.



Source: Statistics New Zealand (2015a)

Figure 2. Components of housing quality.

Housing quality frameworks have been developed for social housing in each of the United Kingdom's administrations::

- Decent Homes Standard (England and Northern Ireland) (Morrison, 2013)
- Welsh Housing Quality Standard (Wales) (Welsh Government, 2016)
- Scottish Housing Quality Standard (Scotland) (Wamuziri, 2013).

Table 3. United Kingdom housing quality frameworks.

	Decent Homes Standard	Welsh Housing Quality Standard	Scottish Housing Quality Standard
Applies to:	Social landlords by 2010 (National programme completed by individual councils still working towards/supporting this standard)	Social landlords by 2020	Local authority and social landlords from April 2015
Criteria:	• Meet the current statutory minimum standard for housing • Reasonable state of repair • Reasonably modern facilities and services • Reasonable degree of thermal comfort	• In a state of good repair • Safe and secure • Adequately heated, fuel efficient and well insulated • Up-to-date kitchens and bathrooms • Well managed • Located in attractive and safe environments • Suit the specific requirements of the household	• Compliant with current tolerable standard • Free from serious disrepair • Energy efficient • Modern facilities and services • Healthy, safe and secure
Pass rate:		2016: 79% of social housing	2010: 39% of all housing

In New Zealand, the University of Otago has been developing a housing warrant of fitness (WOF) targeted at rental housing stock (existing, rather than new houses). The current version of this tool has 29 criteria covering ventilation, heating, safety and hygiene. Each of the criteria is tested by independent assessors, leading to an objective assessment of the quality of the house. Some of the criteria in the proposed WOF (such as water temperature and smoke alarms) relate to installations or settings sometime many years post-construction. As well, the WOF criteria may indicate areas for consideration in new builds, for example, fixed heating appliances or above-standard insulation.

The range of different housing quality assessment tools available reflect a lack of international agreement on what is important in housing quality. This lack of consistency can relate to the nature of the housing stock in place, the priorities of stakeholders (for example, sustainability or health), the attitude towards housing as a private space and the different responsibilities placed on owners or occupiers. The cost of assessment is also a barrier to utilisation (Keall, Baker, Howden-Chapman, Cunningham & Ormandy, 2010).

6.2.3 New Zealand housing quality measurement results

The BRANZ satisfaction survey of new home owners is a measure of quality. It records how satisfied owners are with the finished home, the fixing of defects, value for money and the overall quality of the home. It is an annual postal survey, and the latest is for 2015 (Curtis, 2016). Generally, it has found new owners are satisfied or very satisfied (66%) even though they have a high level of call-backs at 84% of new owners. This is similar to the UK (Craig, Sommerville & Auchterlounie, 2010) where 76% of new owners were satisfied or better, and call-backs were made in 96% of cases.

A 2014/15 survey by Statistics New Zealand noted that housing adequacy is a major contributor to health, education, economic and social outcomes. Focusing on existing, rather than new houses, the 2014 General Social Survey asked questions relating to general condition, dampness and cold. Little difference was found across regions in the perceptions of housing quality. However, nearly half of the people surveyed who rented their houses and one-quarter of homeowners reported a problem with dampness or mould. Further, nearly half of those surveyed reported living in a cold house (Statistics New Zealand, 2015b).

The main source of information on the physical quality of New Zealand houses is the 5-yearly house condition surveys done by BRANZ. On-site inspections are done on approximately 500 detached houses, both owner-occupied and rentals, across the country and for all house age cohorts. The condition of approximately 35 components is recorded on a 5-point scale plus the extent of any damage, and the type of material. Other data such as house size, decade built, storeys, heating appliances, garaging, safety, mould, security, privacy, shading and noise are noted. Socio-economic data is collected via a telephone survey of the occupants, including details of maintenance and renovation undertaken. Since the survey was started in 1994, there has been a slight decrease in the average condition score for the housing stock. The maintenance expenditure has not been adequate to maintain the physical condition in some of the house age cohort groups, and rentals are generally in worse condition than owner-occupied houses. The results of these surveys have been used for a variety of uses including retrofit programmes and the production of maintenance advice for homeowners.

Finally, a test of the University of Otago housing warrant of fitness on 144 houses throughout New Zealand found that only 6% of houses tested passed the WOF. Common failures were unsafe water temperature, lack of security stays, no smoke alarms near bedrooms, handrails or balustrades not up to current Building Code standards and no fixed efficient form of heating. It is likely that the failure rate would be higher in other houses in New Zealand, as only interested landlords took part in the test (Bennett, Howden-Chapman, Chisholm, Keall & Baker, 2016).

6.3 Commercial building quality measures

6.3.1 Key performance indicators and benchmarks

Non-residential building owners are increasingly looking for improvements in the way they procure buildings and need to be able to measure how successful they are in doing this. Development of key performance indicators (KPI) in the UK is described (Cole-Colander, 2003). KPIs include client satisfaction with the building and with the design and construction service, defects on handover, predictability of cost and time, and construction safety. In New Zealand, almost identical KPIs are published annually by Construction Excellence in New Zealand and provide a benchmark of performance for construction firms in the non-residential sector.

These KPIs are a good measure of contractor performance. However, they do not measure whether the building meets the client expectations over the medium and long term in terms of being functional, durable and adaptable. However, researchers have also considered benchmarks for building performance. Dykes and Baird (2014) recommend user perception benchmarks, based on satisfaction scores with the indoor environment quality, administered as part of a post-occupancy evaluation.

6.3.2 Design Quality Indicator

The Design Quality Indicator (DQI) developed in the United Kingdom for non-residential buildings, considers quite subjective needs and opinions. It is based on three qualities of a building: functionality, build quality and impact. These qualities are based on the earliest known typology for structures, found in the writings of Vesuvius in the first century. He established that a structure must have three qualities: utility, durability and beauty (Construction Industry Council, 2017).

The DQI has a structured approach to tease out stakeholder priorities, bringing together clients, designers, contractors, users, building managers and local communities to engage on issues with expert facilitation. Over 1,400 non-residential buildings have been designed using the tool. Critiques of the DQI include that:

- it uses the language of architecture and is difficult for some audiences such as children or the elderly to understand (Eley, 2004)
- it mingles subjective and objective measures but relies on subjective input
- it is unclear whether its purpose is to aid the process of design or assess the product (Markus, 2003).

Prasad (2004) and Gann, Salter and Whyte (2003) respond to this criticism. They highlight that the tool has been powerful in bringing stakeholders together to obtain a shared understanding and facilitate compromises in design. It is acknowledged more work is required to develop a consistent way to measure performance (Prasad, 2004).

Further details of the DQI, and an example of its use, are in Appendix F.

6.3.3 Post-occupancy evaluation (POE)

Post-occupancy evaluation (POE) is used to ascertain the performance of buildings from a variety of viewpoints. The aim of POE is to enable designers to learn what has worked and what hasn't. The intention is that these lessons are used in subsequent designs. In the main, these evaluations have been done on non-residential buildings, usually within a year of construction. These are mainly from the perspective of the employees/users of the building but also canvassing the views of building managers, maintenance and cleaning persons, community groups and sometimes neighbours.

The early researchers hoped a single preferred method of POE could be developed. Instead, it was found the context, needs and resources of organisations varied greatly. A portfolio of techniques has been developed and is provided on www.useablebuildings.co.uk. This site has five categories of techniques so that users can select the one most appropriate to their needs. The techniques available include facilitated discussions between stakeholders, simple audits and questionnaires and checklists to ensure feedback from earlier projects is incorporated in subsequent procurement.

A major review of the methods of POE and results from a range of buildings was reported in a dedicated issue of *Building Research & Information* journal in 2001. This included Cooper (2001) and Whyte and Gann (2001). From New Zealand, Baird (2001) contributed to the journal issue, with his main interest being a comparison of energy performance to what was modelled in the design phase.

6.3.4 Barriers to the use of post-occupancy evaluation

Barriers to the use of POE in the UK were discussed in Bordass (2003) and Bordass and Leaman (2005):

- The organisation had not created conditions for learning from these evaluations.
- POEs expose failures, which are not rewarded in house or by auditors.
- A lack of appreciation that mistakes need to be learned from.
- Procurement staff are too focused on current projects to spend time on past projects.
- Many clients do not have time to make requirements clear to the design team. How will they find time for feedback?
- Why should clients pay for designers to learn for subsequent projects?

A review by Leaman, Stevenson and Bordass (2010) found that feedback from POEs is still not working very well. Between 2001 and 2010, the authors undertook over 700 evaluations of non-residential buildings, but less than 10% of these have been used in published studies. The main reasons for low reporting and promotion of POE include:

- reluctance by owners, developers and designers to have buildings examined in a critical light
- cost and time to produce journal articles
- partial studies that cover energy use only
- commercial self-interest beating altruism in publishing 'lessons learned' articles
- lack of a national umbrella organisation to promote and publish POE
- doubts about the status of POE studies.

They write, on lack of feedback from POE studies, that “people tend to say ‘we know all that’ and then blunder on to repeat the same mistakes”. They attribute this to a number of factors, including:

- lack of technical skills in local and central government procurement
- the design industry still does not know much about how buildings perform in use
- in spite of talk about life cycle costing, the splits between capital and operating budgets remain rigid. Minimised initial cost and ignored ongoing maintenance and operating costs is still a significant outcome of some procurement decisions.

Candido, Kim, de Dear and Thomas (2016) identified three methodological shortcomings for existing POE tools as:

- the ability to contextualise results
- addition of instrumental data to survey results
- the ability to provide meaningful feedback to stakeholders.

6.3.5 New methods for post-occupancy evaluation

In response to these methodological issues, researchers have developed the BOSSA (Building Occupants Survey System Australia) POE system. BOSSA comprises three tools – an occupant satisfaction survey, a checklist to capture details such as design, fit-out and building services and a movable cart that samples physical indoor climate measurements. The three sources of information can be triangulated to identify drivers of occupant satisfaction and collated into the BOSSA scoring system. It provides nine measures of indoor environmental quality and four overall indices: work area comfort, building satisfaction, productivity and health. Longer term, the resulting database will enable analysis of correlations between elements such as fit-out options and productivity (Candido et al., 2016).

Similar to the BOSSA system of measurement, Loftness et al. (2009) summarise the use of NEAT (National Environmental Assessment Toolkit) as a form of POE. NEAT uses five measurement tools, including the use of a cart to do workstation spot assessments, continuous measurements, user satisfaction questionnaires, more detailed questionnaires and walk-through records. The researchers contend that POE is not simply a tool for designers to learn from. POE enables building occupants and managers to take control of their environment, identifying what works and what doesn’t work and catalysing innovation.

According to Leaman et al. (2010), imperatives have given new impetus to POE. In particular, an interest by occupiers in energy performance has forced designers to review their assumptions on how buildings are used and perform in practice. They hope this green interest will reignite more broad-based evaluations of new building performance. Meir, Garb, Jiao and Cicelsky (2009, p. 189) agree and note that POE is an important and probably inevitable step towards making buildings more sustainable.

6.3.6 New Zealand commercial building quality measurement

Baird and his colleagues at the Wellington School of Architecture record the results of POE in a database (known as the Watson database). This now has over 184 buildings (of which approximately 80% are in New Zealand). The database compiles lists of the best and worst features in new buildings from the perspective of owners, users, maintenance and the professionals involved in design and construction. This database is available for designers who wish to make use of it, as it provides evidence of potential issues to be addressed at the design stage.

The buildings represent a range of commercial, institutional and residential buildings and campuses, with large numbers of specialised buildings, for example, 59 court buildings and 58 education sector buildings. Only 10 apartment buildings are included. While not representative of the full range of building types in New Zealand, the results provide a guide to which areas of design need careful consideration.

Evaluations involved stakeholder group interviews, which sought testable observations about the effects of the building on productivity, safety, health and wellbeing. Stakeholders summarised these points by reaching consensus on the three best and three worst aspects of each building (BRANZ, 2017).

Stakeholder participants are designated in the database as:

- employees – those working in the buildings
- clients – students, patients, customers, prisoners, visitors, residents, guests
- maintenance teams – tradespeople, cleaners, facility managers
- project teams – builders, architects, engineers, property, asset and project managers
- others – neighbours, people with disabilities, representatives of future generations, experts.

Stakeholders consistently identified the best features (Figure 3) as:

- appearance (nearly 25% of project stakeholders and 16% of employees)
- ease of movement – allowing easy movement between spaces and/or elements, including accessibility for people with disabilities (ranked by 26% of employees and 26% of others)
- spaciousness – the volume or sense of volume including reference to the surface area of wall or floor (ranked by 17% of clients and employees).

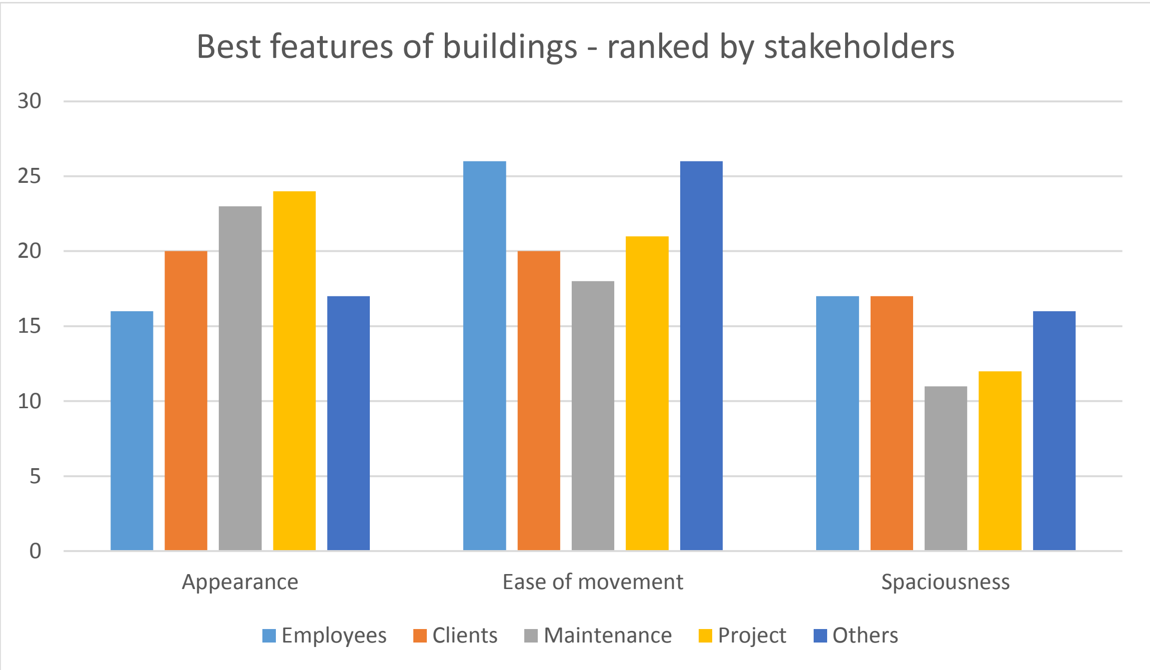


Figure 3. Best features of buildings as ranked by stakeholders.

Approximately 80% of responses are from users of the buildings (employees and clients). Their three main areas of concern (Figure 4) were:

- air quality – the temperature, freshness, humidity, movement and chemical and biological qualities of air including radiant heat and control of these conditions (rated a worst feature by 16% of employees)
- ease of movement (rated a worst feature by 16% of employees)
- spaciousness (rated a worst feature by 19% of clients).

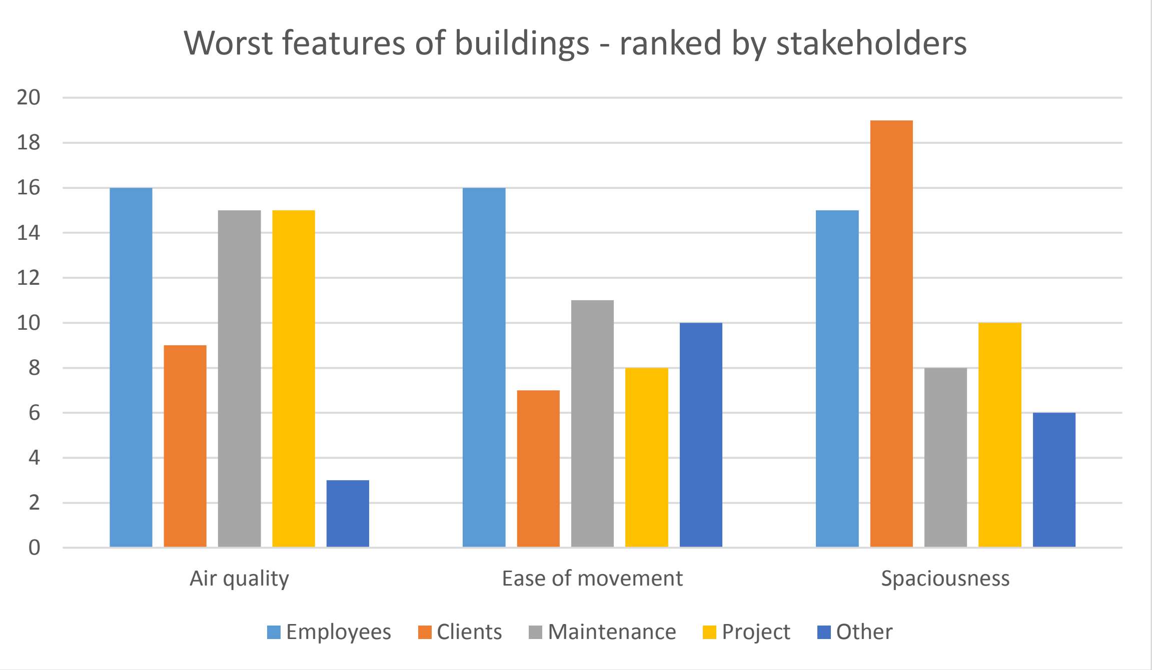


Figure 4. Worst features of buildings as ranked by stakeholders.

Note that ease of movement and spaciousness rated in the best and worst features of a building. It appears that many users identify these attributes as of primary importance and rate them as achieved or not achieved.

Across all building types, the best features were generally agreed to be ease of movement, rated by 39% of apartment building stakeholders, 37% of commercial building stakeholders and 33% of library stakeholders. Spaciousness was seen as a positive quality by 27% of museum stakeholders but only 7% of apartment stakeholders and 6% of retail stakeholders. This indicates priority is placed on different qualities for different types of building.

In contrast, ease of movement was highlighted as a concern across most building types. Air quality was a concern in commercial buildings (30% of stakeholders), and lack of space was a concern in education sector buildings (29% of stakeholders in schools. 22% of polytechnic stakeholders and 15% of university stakeholders). In apartment buildings, the two main areas of concern were security from theft and personal attack, and acoustics or the transfer of noise between apartments. Museums elicited polarising views, with appearance rated as both a best feature (30%) and worst feature (21%).

Further results from an analysis of this dataset are in Appendix G.

7. Discussion

Quality is an elusive concept that is aspired to in the building sector yet difficult to achieve. In all but compliance, the client is the arbiter of quality, although often with less knowledge than anyone else in the construction process. The designer has a key part to play in assisting clients to make informed decisions by understanding their needs and helping them to understand choices and trade-offs given the inevitable budget constraints.

This paper has identified three main levels of quality:

- Basic quality, or an absence of defects.
- Enhanced quality, taking into account how a building meets the needs of its users.
- Higher quality, or how a building impacts users and the environment.

In New Zealand, the Building Act 2004 is designed to ensure that a building meets the requirements of the Building Code and that any aesthetic defects are repaired. Compliance is monitored by building consent authorities along with the client. For defects relating to the Building Code, the client relies on the building inspector to ensure that the building is designed and built to the allowable limits of the Building Code. For aesthetic defects, however, there is no independent authority, and the client must negotiate with the contracted builder to determine whether an aesthetic issue is a defect. If so, they must also determine the timeframe in which the defect will be remedied (within the limit of 1 year set by the Building Act 2004). We note that, in Singapore, CONQUAS involves an independent inspector assessing both structural and aesthetic defects.

In an ideal situation, the builder would have got it 'right first time', and there would be an absence of compliance and aesthetic defects. However, research by BRANZ indicates that compliance and aesthetic defects are common in new houses. The BRANZ New House Construction Quality Survey identifies that the most common defects relate to the walls. In particular, this involves the fixing of cladding, penetrations through the walls, framing cut-outs and installation of flashing. These defects are identified during the construction process, and it is not known whether building inspectors consistently identify all defects prior to awarding a Code Compliance Certificate.

There is no comparable research in New Zealand on non-residential buildings during construction. Advice from experts is that moisture-related issues is the main defect in non-residential buildings. Other defects have become apparent during leaky building repairs, and these relate mainly to penetrations through fire-rated walls.

Functionality relates to how well a building meets the needs of its users. The main contributors to functionality are notions of lifetime design, whether this is to:

- meet the needs of users over a lifetime
- enable flexibility in the building over a lifetime or
- ensure the building takes account of future as well as current users.

New house owners may be unsure how well a house design will suit their needs. This explains the widespread use of show homes by most the large builders and the construction of spec-built houses by both large-scale and small-scale builders.

A key consideration for clients is the price to be paid for building. However, perceptions of additional cost may result in a focus on the needs of the clients ‘right now’ rather than the lifetime of the building. However, this can result in a false economy, with higher energy costs over the longer term and higher costs for retrofitting. Multiple studies have found that, when lifetime components are designed in at the beginning, the cost of implementation is only a small percentage of the total construction cost. For example, the cost of building a single-storey house that caters for all ages and stages is estimated at an additional 0.5% of total construction costs (Page & Curtis, 2011).

Balancing the focus on cost, there is increasing concern from clients about a building’s environmental impact. The New Zealand Green Building Council has a system to enable a ‘green’ rating. This provides some assurance about a building’s energy and water use performance, which is usually a direct cost for the occupier.

Claims of high-quality construction appear to be based on the quality of workmanship, a ‘focus on quality’ and the quality of a product. A higher-quality building may include the provision of features that enhance the comfort of the users. These might include above-Code hygiene facilities, earthquake resilience, thermal insulation and lighting as well as an overall better finish.

The visual impact of a building is very much in the eye of the beholder, and different clients will specify different types of visual impact. The American architect Louis Sullivan said that form follows function and much of modern design follows this principle, especially for non-residential building.

Clients of different types of non-residential buildings have differing priorities:

- Commercial buildings (hotel, retail, office) – there are business drivers to provide buildings that are attractive externally and user-friendly internally.
- Institutional buildings – of primary importance is that the design facilitates the use, such as learning in schools and educational institutions and healing in healthcare facilities.
- Industrial buildings – visual impact is less important, and a utilitarian appearance is common. These buildings need to accommodate changes in technology, manufacturing and storage systems.

The Singaporean-developed CONQUAS measurement may be a tool worth exploring in the New Zealand context. This tool can be used for residential and non-residential building and considers more than just basic compliance with the Building Code. Implementation of this tool would require answering the important question of who pays, as there is no comparable service provided in New Zealand. However, clients may be willing to pay for independent assessment, especially if the assessment provides a shortcut to identifying and repairing any visible defects. This saves clients the challenge of negotiating repairs and gives them peace of mind that the product has been delivered to an acceptable standard. Companies in the building and construction industry may also be willing to pay for evidence that the product they deliver is of high quality.

8. Recommendations

The UK Design Quality Indicator (DQI) has potential for use in New Zealand for non-residential buildings. It is suggested that it be promoted by designers in conjunction with their clients. Use of such a tool will help aid clarity in understanding stakeholder need when planning new buildings.

For residential buildings, the companion tool to DQI is the Housing Quality Indicator (HQI). It considers issues such as transport, location, visual impact and noise as well as building-specific items like layout, accessibility, adaptability and sustainability. It is useful for area-wide redevelopment and large-scale new housing and should be investigated for adaptation to local use.

To produce quality buildings, construction firms should measure their performance on individual projects to learn where improvement is needed. The use of KPIs such as those produced by Construction Excellence in New Zealand are one way to do this.

The CONQUAS tool is another option for measurement of performance of designers and contractors on larger projects during and after construction and is recommended for local use.

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Appendix A: Industry experts' survey

A group of industry experts were asked to assess their experience of compliance failures for new buildings in New Zealand. Seven experts were consulted, and their responses are shown in Table 4. The issues were categorised by the Building Code clauses. A simple 1–3 scale was used, with 1 = no or few problems, 2 = several problems and 3 = many problems. The areas of concern are structural integrity, external moisture penetration and internal moisture accumulation in multi-unit housing. In offices, fire safety/escape paths are an area of concern. Almost all the clauses had some compliance issues. Multi-unit residential had the highest average problem score across all the Building Code clauses.

Table 4. New Zealand Building Code compliance issues.

What problems have you seen on-site in the last year						
(either in construction or in use)	**Enter 1 for a few problems, 2 for several problems, 3 for many problems.**					
			leave blank for no problems			
NZBC Clause	**Objective**	Detached house	Multi-unit housing	Educatn, Health bldgs	Offices, Retail bldgs	Factory Warehouse
			Average scores			
B1 Structure	Safeguard from injury or loss of amenity due to structural failure	2.0	3.0			
B2 Durability	Materials & components are sufficiently durable.	1.5	1.0	2.0		1.0
C1 to C3 Protection from fire, prevention of ignition & spread.	Safeguard people from injury due to fire	1.0	1.7		2.0	
C4 - C6 Fire escape, fire fighters safety, structural strength.	Warnings, escape paths, stability		1.5		3.0	
D1-D2 Access routes, lifts, escalators.	Designed to ensure safety during access/use					
E1 Surface water. Disposal, water not enter building.	People safe from illness/ injury	1.3	1.5	1.0	1.0	
E2 External moisture. Resistance to penetration into building.	People safeguarded again illness/ injury	2.0	2.7	1.5	1.0	1.0
E3 Internal moisture	People protected against illness/ loss of amenity due to accumulation of moisture.	1.7	2.3	2.0	1.0	
F1-F3 Hazardous agents/ materials	Protect people from illness	1.0	1.0	2.0		
F4-F5 Safety from falling, hazards	Protect people from injury	1.0		2.0		
F6 -F8 Warning systems, signs	Protect people from injury. Safety lighting	2.0				1.5
G1-G3 Hygiene,laundry, food prep.	Protect people from illness/ loss of amenity	1.0			1.0	2.0
G4-G6 Ventilation, int enviro, sound.	Protect people from illness/ loss of amenity	1.0	1.5	1.0	1.0	1.0
G7- G8 Natural light, artificial light	Protect people from illness/ loss of amenity	1.0	2.0			1.0
G9-G11 Electricity, gas, piped services	Prevent fire, illness, injury	1.0				
G12-G13 Water supplies, Foul water.	Protect people from illness/ loss of amenity	1.0	2.0			
G14-G15 Solid waste, Liquid waste	Protect people from illness/ loss of amenity		2.0			
H1 Energy efficiency	Building provides for efficient use of energy.	2.0	2.0	1.0		2.0
Average score		1.4	1.9	1.6	1.4	1.4

Appendix B: Defects in the BRANZ New House Construction Quality Survey

The survey inspected 225 houses during construction and recorded the types of defects observed at various stages of construction. It was a one-off survey, though it is likely it will be repeated in the future. These results are shown in Table 5, where the defects have been allocated to causes. The allocation is based on the author's knowledge of the details of the survey, which included observation during visits with the inspectors at the time of the survey.

Table 5. Defects and their causes from BRANZ New House Construction Quality Survey.

Defects (observed in 225 new house inspections)							
(split the defects observed in the BRANZ survey into causes (1 or 2 causes only for each defect)							
		Causes					
	% of houses in BRANZ survey with defect	Poor workman -ship	Builder error	Materials were faulty	Poor work & coord of sub-contractors	Design details missing/ can't be built	Wrong construction techniques/ sequencing
Wall insulation fit	64%	21%			22%		21%
Window reveal fixing	61%		30%			30%	
Straps/ nogs protrude	61%	20%				21%	20%
Interior paint finish	60%	60%					
Loose wall underlay	51%	51%					
Bowed wall frames	41%			41%			
Head flashings	38%	13%		13%		13%	
Cladding penetration seals	38%		19%		19%		
Large framing cut-outs	38%					19%	19%
HD bolt edge dist.	36%		36%				
Vanity/ shower seals	33%	17%			17%		
Window reveal seals	31%	16%					16%
Ceiling insulation	31%				31%		
Underlay penetration tape	29%		14%				14%
Peaking/ popping	29%	29%					
Window scribers	28%	28%					
Poor door fitting	28%	14%		14%			
Cracked linings	25%	25%					
Trim finish	23%	23%					
Brick mortar	21%				21%		
Path-cladding clearance	21%					10%	10%
Window sill bar	20%		10%			10%	
Underlay over head flashings	20%		10%			10%	
Wiring/plumbing work	20%			10%	10%		
Roof cladding damage	19%				9%		9%
Apron flashings	18%				9%	9%	
Sealing cabinets/ benchtops	18%	9%			9%		
Wall clad damage/loose/gaps	17%	8%	8%				
Tapes at wall openings	16%	16%					
Spouting	15%		15%				
Soffit timber bead	14%		14%				
Stop-ends head flashings	10%			10%			
		349%	158%	88%	147%	122%	109%
Normalised (add to 100%)		36%	16%	9%	15%	13%	11%
Number of literature references as per Rotimi		10	6	6	5	5	5
Literature references normalised (add to 100%)		27%	16%	16%	14%	14%	14%

The bottom of the table compares the on-site inspection aggregated results with the summary by Rotimi (2013). The two sources are normalised as percentages adding to

100%. The on-site survey indicates workmanship as contributing a larger share to defects than the literature survey suggested. This may be because the literature review covered all building types, whereas the BRANZ survey was for new houses only. The latter is more intensive in use of labour than for building in general, and hence there is more potential for workmanship error in housing than in non-residential buildings.

Material defects were less in the on-site survey than the literature survey says is the case internationally. This may reflect the quite high standard of material assessment in New Zealand as monitored by councils through use of product technical statements and BRANZ Appraisals.

As part of this project, a separate set of builders were surveyed on the problems they have in producing quality housing. A total of 108 responses were received, and they were transferred into the six cause categories used previously. Details of the conversion are in Table 6. A tick box form was used, and respondents could tick as many issues they liked, though most ticked between one and three issues. The responses were normalised by having the totals add to 100%. In the last column of the table, the responses were transferred into the six Rotimi (2013) cause categories by adding the items in the brackets.

Table 6. Builders' postal survey of quality issues.

Builder respondents reporting a problem				Translate problems into defect causes	
	Problem type	% reporting (1)	normalised (2)	Problem type in brackets	
a	Lack of construction details	42.2%	21.3%	Poor workmanship (b, d)	26.7%
b	Cannot interpret drawings	16.0%	8.1%	Builder error (a)	21.3%
c	Cannot build as per drawings	22.8%	11.5%	Materials faulty (f)	7.2%
d	Requires special on-site skills	36.7%	18.6%	Trades non-coord (e)	8.3%
e	Sub-contractor's work is poor	16.3%	8.3%	Design inappropriate (c,h)	22.1%
f	Material installation instructions inadequate	14.3%	7.2%	Const methods faulty (g,i)	14.4%
g	Specifications are unclear	14.3%	7.2%		100.0%
h	Services clash/difficult to install	21.0%	10.6%		
i	Any other problems	14.3%	7.2%		
		197.8%	100.0%		
(1) Most respondents had more than one problem type, which is normalised in column (2).					

Appendix C: Building inspector's issues

Discussions with a building inspector in a major BCA found the following issues on site for new buildings in general:

- Building wrap that has been installed too high in a cavity resulting in the wrap being level or above the bottom plate.
- Unsealed penetrations in the wrap and cladding.
- Double nailed weatherboards.
- Exterior frames on temporary supports cantilevered out past the slab.
- Flashings missing, especially backflashings.
- Flashings installed with an inward slope directing water into the cavity.
- No stop-ends on window top flashings with overcut big gaps from the top of the flashing to the underside of the cladding.
- Slabs cut to remedy set-out failures, leaving reinforcing steel exposed.
- Brick cavities with excess plaster filling the bottom of the cavity, excess plaster in the joints not cleared away with a trowel, leaving wicking points to the cavity wrap.
- Incorrect wall to roof junction flashing.
- Cladding not installed to the manufacturer's specifications.
- Cladding nails completely missing the stud for every weatherboard in a storey.
- Cladding still letting in water at a pre-lining inspection.
- Scribers cut incorrectly.
- Downpipes directed onto upper floor decks.
- Bottom plate fixings missed or incorrect or too much cut out of the bottom plate.
- Bottom plates chopped out for other services such as power or air conditioning.
- Power boxes in the incorrect positon in brace panels.
- Discontinuous studs in a high timber wall.

These were the most frequent reasons for a request for information (RFI):

- Incomplete documentation.
- No details regarding investigation of site conditions carried out.
- Build over approval missing.
- EAP (engineering plan approval not yet ready).
- Producer statement not provided (especially peer reviews).
- Issues with producer statements and what they actually cover.
- Compliance path incorrectly interpreted.
- Agreement to provide producer statement not included.
- Performance requirements of the Building Code not properly understood.
- Alternative Solution not achieving compliance.
- No proper quality check performed by the designer.
- Scope and limitation of product/specification not checked/understood.
- Issues with section 112 of the Building Act and interpretation of "as nearly as practicable requirements" when changing use of a building.
- Change of use – section 115 of the Building Act being stretched/in some instances refusing to accept change of use.
- Variation in design as the project proceeds (may be due to QS/cost issues).
- Designer working outside their competency (designer competent in residential trying out medium/complex commercial job).
- Designer not keeping pace with changes in legislation and Building Code.

Allocation of the on-site construction issues into six causes is shown in Table 7.

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Table 7. Auckland inspection issues.

Auckland council inspectors defect issues	Poor workman -ship	Builder error	Materials were faulty	Poor work & coord of sub-contractors	Design details missing/ can't be built	Wrong construction techniques/ sequencing
Building wrap installed too high in a cavity resulting in wrap being level /above the bottom plate.	100%					
Unsealed penetrations in the wrap and cladding	50%					50%
Double nailed weatherboards.		100%				
Exterior frames on temporary supports cantilevered out past the slab.				100%		
Flashings missing especially back flashings.		50%			50%	
Flashings installed with an inward slop directing water into the cavity.		50%	50%			
No stop ends on window top flashings	50%		50%			
Big gaps from the top of the window flashing to the underside of the cladding.		100%				
Slabs cut to remedy set out failures leaving reinforcing steel exposed.				100%		
Brick cavities with excess plaster at bottom of the cavity, excess plaster in the joints not cleared.	100%					
Wall to roof junction flashing.			50%		50%	
Cladding not installed to the manufacturers specifications.		50%				50%
Cladding nails completely missing the stud for every weatherboard in a storey	100%					
Cladding still letting in water at a pre-lining inspection.	50%				50%	
Scribers cut incorrectly	100%					
Downpipes directed on to upper floor decks.		50%			50%	
Bottom plate fixings missed or incorrect or too much cut out of the bottom plate.	50%	50%				
Bottom plates chopped out for other services, power or air con etc.				50%	50%	
Power boxes in the incorrect positon in brace panels.					100%	
Discontinuous studs in a high timber wall	50%				50%	
Total defects	650%	450%	150%	250%	400%	100%
Defects normalised to 100% total	33%	23%	8%	13%	20%	5%

Appendix D: Mid-rise design/construction issues

These are issues observed by an experienced building surveyor on several multi-storey apartment projects. His area of concern relates mainly to the design features used, which, in the cases reported, have been inappropriately transferred from low-rise timber-frame construction to medium-rise buildings. However, the surveyor noted other defects as well relating to workmanship, materials and other problems. From the report prepared by the surveyor, the number of various incidents of defects and design faults was counted. The results are in Table 8.

Table 8. Defects noted in mid-rise new buildings.

Mid-rise building defects		
(10m to 25m building height)		
	# occurances	%
Poor workmanship	9	13%
Builder error	12	17%
Materials faulty	8	12%
Trades non-coord	5	7%
Design, inappropriate	25	36%
Const methods faulty	10	14%
	69	100%

Appendix E: Building company claims of high quality

Table 9. Building company websites found using the search term 'high quality building New Zealand' 9–10 February 2017.

Company	Website
AJ Saville	www.ajsaville.co.nz
Robinson Construction	www.robinsonconstruction.co.nz
Custom Kit	www.customkit.co.nz
Urban Homes	www.urban.co.nz
New Zealand Build	www.nzbuild.co.nz
Box	www.box.co.nz
Senior Construction	www.seniorconstruction.co.nz
Carl Taylor Homes	www.carltaylorhomes.co.nz
Q Commercial Construction	www.qconstruction.co.nz
Bell Building	www.bellbuilding.co.nz
A1 Homes	www.placemakers.co.nz/group-builder
Pure Build	www.purebuild.co.nz
Holloway Builders	www.hollowaybuilders.co.nz
Landmark Homes	www.landmarkhomes.co.nz
Barrett Construction	www.barrettconstruction.co.nz
Form Steel	www.formsteel.co.nz
JBH Building - Tauranga	www.jbhbuilding.co.nz
MagRoc	www.magroc.co.nz
Custom Kit	www.customkit.co.nz
Milestone Homes	www.milestonehomes.co.nz
Fletcher Living	www.placemakers.co.nz/group-builder
Fusion Homes	www.fusionhomes.co.nz
Mike Greer homes	www.mikegreerhomes.co.nz
Phil Benton Builders	www.philbentonbuilders.co.nz
Nova Construction	www.novaconstruction.co.nz
Redgwell Construction	www.redgwell.co.nz
Penny Homes	www.pennyhomes.co.nz
Finesse Residential	www.finesseresidential.co.nz
Haimes Building	www.haimesbuilding.co.nz
Kennedy Construction	www.kennedyconstruction.co.nz
Coastbuild	www.coastbuild.co.nz
Cranston Homes	www.cranston.co.nz
The Complete Building Company	www.thecompletebuildingcompany.co.nz
Ainsworth Collinson	www.ainsworthcollinson.co.nz
Webber Building	www.webberbuilding.co.nz
Signature Homes	www.signature.co.nz
QPC Builders	www.qpcbuilders.co.nz
Lockwood Homes	www.lockwood.co.nz
Coleman Quality Builders	www.qualitybuilder.co.nz
Refresh renovations	www.placemakers.co.nz/group-builder

Appendix F: Design Quality Indicator (DQI)

This section provides more details about the UK DQI. It is a tool used by the client, end users, designers and constructors to ensure the views of these stakeholders are understood and considered in the design. The original aim was to develop a tool to benchmark design quality. However, as it developed, that aim changed because different stakeholders had different aims and views on quality.

Its main purpose is to achieve a clear understanding of what is the intention of the building. For some projects, client thinking on the purpose of the building is not clear, it has conflicts with other features or the building use is not clearly understood by the designer. The DQI tool was developed to help resolve this and other issues.

The core of the tool is a questionnaire used by the client, users and designers. It starts with collecting general information about the respondent, the type of building and their aims for the building. The three main parts of the questionnaire are on function, impact and building quality.

- Function has detailed questions on access, use and space (3 subsectors).
- Impact has questions on form and materials, internal environment, external integration and character/innovation (4 subsectors).
- Quality has questions on expected building performance, engineering systems and construction quality (3 subsectors).

Each of these three sections has up to 20 questions. Respondents are asked to weight how important each subsector is relative to the other subsectors. This is done using a points system.

The results for each respondent are presented graphically as a doughnut diagram. This shows the relative weights of the three main criteria (function, impact and quality) and how well the design scores within each aspect (see Figure 5).

In Figure 5, the responses are shown for an office building after the preliminary drawings of elevations and typical layouts have been inspected by stakeholders. The chart indicates the scoring for three typical stakeholders (client, designer and users). The weights given of the three main criteria are shown, adding to 100%. For example, in the client panel, the yellow/orange slices add to 37%, the grey/dark grey slices add to 30% and the blue slices (quality) are the rest (32%).

The stakeholders' assessment of how well these criteria are met is also shown as a percentage. The assessment is in the doughnut and is shown as the lighter hue in each of the three main segments. In Figure 5, the client score for function is only 42% of the yellow/orange slice. The designer thinks they have done better, and their function slice covers 76% of the yellow/orange segment.

In this office example, the scoring and weights differ somewhat for the three stakeholders. These differences are a basis for discussion, with the potential to achieve better understanding and communication between stakeholders and resolution of conflicts and trade-offs.

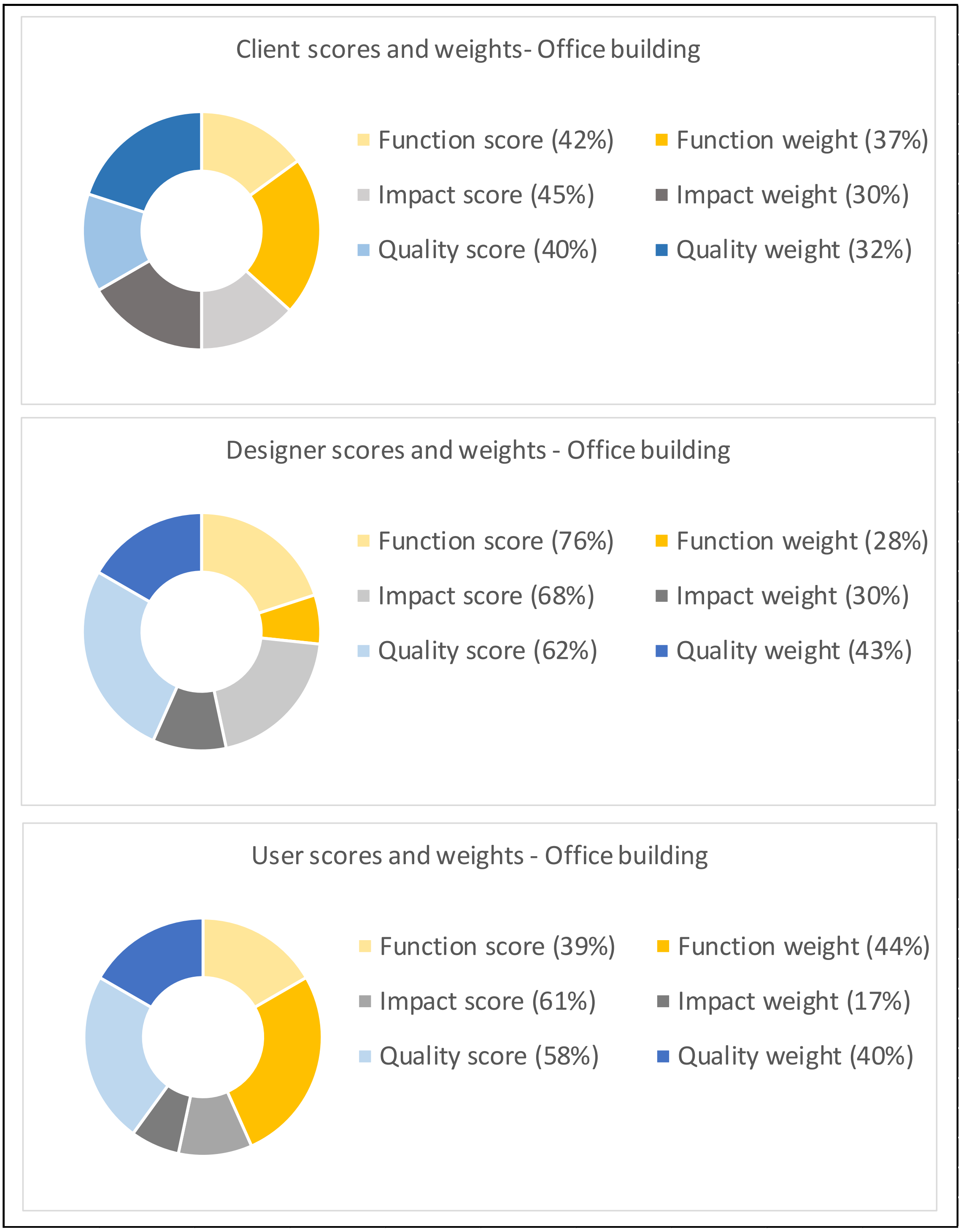

Figure 5. DQI doughnut graphical output.

Appendix G: Post-occupancy evaluation New Zealand database

The Watson database of approximately 180 new buildings in New Zealand buildings is available on the BRANZ website.[3] The evaluations are the views of various stakeholders, who were asked to nominate the three best and the three worst features of their building. The results for the best and worst features, by stakeholder, are shown in Table 10.

The results are mainly from the users' and employees' viewpoint, as these two groups accounted for about 80% of the responses. Their three main areas of concern were air quality, ease of movement and spaciousness.

The next table, Table 11 shows worst features by type of building. Air quality was a particular concern in commercial buildings. Ease of movement was a concern across most building types. Lack of space was, in particular, a complaint in education buildings.

For apartments, the two main areas of concern were security and acoustics. The former is security from others regarding theft and personal attack. Acoustics mainly relates to inter-tenancy noise transmission.

Note that there are quite large numbers of specialised buildings in the database – for example, court buildings with 59 buildings. The education sector, with 58 buildings, is also well represented. Apartment building numbers are 10, which is large enough to be indicative. However, overall, the database is not representative of the whole range of building types. For example, accommodation, health and industry buildings are not included. Even so, the results are useful in suggesting which areas of design need careful consideration for the large variety of people using our larger buildings.

The best features are shown in Table 12. Somewhat surprisingly, two of worst features in Table 11 appear in the best features, namely ease of movement and spaciousness. It appears that many users rank these attributes as being of prime importance in a building and rate them in black and white terms. These criteria are either achieved or not achieved, and there seems to be little leeway in these assessment for many users. Landmark buildings such as museums were also polarised, with 21% rated as having their appearance as an unfavourable feature and 30% with appearance as a favourable feature.

[3] http://www.branz.co.nz/cms_display.php?st=1&sn=284. This site contains the database of over 180 buildings in New Zealand listing their best and worst features from the viewpoint of various stakeholders. See also www.PostOccupanctEvaluation.com maintained by architect Chris Watson, which explains the database in more detail.

Table 10. Best and worst features in the Watson POE database by stakeholder.

The best features of the buildings in the New Zealand post-occupancy evaluation survey - by stakeholder

Stakeholder	Number persons	Acoustics	Air quality	Appear-ance	Complete per speci	Ease movemt	Light	Bldg manager	Privacy	Safety	Security	Shelter	Spacious ness	Storage	User - friendly	Visual connectn	Way - find	Other	Total
Clients	209	3%	3%	20%	0%	20%	9%	9%	0%	1%	1%	1%	17%	0%	5%	3%	0%	7%	100%
Employees	489	1%	4%	16%	0%	26%	10%	2%	0%	0%	3%	1%	17%	1%	5%	6%	0%	8%	100%
Maintenance	37	0%	2%	23%	0%	18%	8%	2%	0%	0%	4%	0%	11%	0%	2%	7%	0%	23%	100%
Project	74	0%	2%	24%	3%	21%	9%	4%	0%	1%	1%	0%	12%	0%	5%	4%	1%	13%	100%
Neighbrs, disabled	44	2%	0%	17%	0%	26%	13%	1%	1%	3%	3%	1%	16%	0%	3%	3%	2%	8%	100%
Not recorded	57	2%	4%	17%	1%	34%	10%	3%	1%	1%	1%	0%	10%	0%	2%	1%	0%	14%	100%
All	910	1%	3%	18%	0%	24%	10%	3%	0%	1%	2%	1%	16%	1%	5%	5%	0%	9%	100%

The worst features of the buildings in the New Zealand post-occupancy evaluation survey - by stakeholder

Stakeholder	Number persons	Acoustics	Air quality	Appear-ance	Complete per speci	Ease movemt	Light	Bldg manager	Privacy	Safety	Security	Shelter	Spacious ness	Storage	User - friendly	Visual connectn	Way - find	Other	Total
Clients	209	8%	9%	8%	2%	7%	5%	10%	2%	5%	3%	5%	19%	1%	3%	2%	6%	6%	100%
Employees	489	9%	16%	4%	3%	16%	5%	3%	3%	2%	3%	3%	15%	3%	5%	4%	3%	5%	100%
Maintenance	37	1%	15%	5%	5%	11%	7%	0%	0%	4%	5%	1%	8%	3%	3%	1%	0%		70%
Project	74	4%	15%	11%	11%	8%	4%	7%	1%	2%	2%	4%	10%	2%	4%	1%	2%	9%	100%
Neighbrs, disabled	44	3%	3%	10%	1%	10%	8%	5%	1%	7%	5%	2%	6%	1%	10%	6%	6%	16%	100%
Not recorded	57	12%	9%	12%	2%	9%	6%	7%	2%	2%	5%	4%	13%	3%	3%	2%	5%	4%	100%
All	910	8%	13%	6%	3%	13%	5%	5%	2%	3%	3%	3%	14%	2%	5%	3%	4%	7%	100%

- Clients are people receiving services within the building (i.e. the building users).
- Employees are people employed in the building on a daily basis.
- Maintenance are the maintenance people and cleaners.
- Project are those involved in the design and construction of the building.
- Neighbours and the disabled group also includes peer group people (mainly designers not involved in the project).
- Maintenance stakeholders had 23% and 30% scores for the Other column. These omitted items in Other included durability and cleanliness, each with a score between 7% and 15%. These two features were omitted because they distort the shading in the table, because of lack of room in the table and because they have low percentages with the other stakeholders.

Table 11. Worst features in the Watson POE database by building type.

The worst features of the buildings in the New Zealand post-occupancy evaluation survey																			
	Number buildings	Acoustics	Air quality	Appear-ance	Complete per speci	Ease movemt	Light	Bldg manager	Privacy	Safety	Security	Shelter	Spacious ness	Storage	User - friendly	Visual connectn	Way - find	Other	Total
Apartment	10	11%	14%	4%	2%	5%	7%	3%	0%	8%	16%	6%	4%	1%	4%	1%	4%	11%	100%
Commercial	5	6%	30%	2%	9%	11%	11%	4%	2%	2%	0%	0%	4%	11%	0%	2%	0%	6%	100%
Council	7	12%	21%	9%	0%	8%	5%	2%	0%	2%	2%	3%	17%	2%	2%	9%	2%	8%	100%
Justice	59	9%	12%	5%	2%	20%	5%	2%	3%	2%	5%	2%	11%	2%	9%	4%	2%	7%	100%
Library	4	13%	11%	6%	0%	13%	6%	4%	9%	0%	0%	0%	15%	4%	6%	6%	4%	4%	100%
Military	17	5%	17%	4%	5%	13%	6%	6%	5%	4%	3%	5%	10%	2%	3%	1%	0%	10%	100%
Museum	15	4%	2%	21%	1%	8%	11%	3%	1%	0%	1%	6%	8%	2%	1%	3%	21%	7%	100%
Polytechnic	9	15%	11%	6%	2%	8%	3%	9%	1%	1%	0%	6%	22%	5%	2%	1%	1%	6%	100%
School	32	8%	11%	5%	5%	8%	2%	9%	1%	5%	1%	6%	29%	3%	3%	2%	0%	4%	100%
Retail	5	0%	6%	4%	0%	8%	4%	4%	13%	13%	4%	6%	9%	2%	4%	9%	13%	2%	100%
University	17	10%	20%	4%	4%	11%	5%	8%	1%	2%	0%	1%	15%	2%	5%	2%	4%	8%	100%
All	180	8%	13%	6%	3%	13%	5%	5%	2%	3%	3%	3%	14%	2%	5%	3%	4%	7%	100%

- Red and orange cells are the worst features.

Table 12. Best features in the Watson POE database by building type.

The best features of the buildings in the New Zealand post-occupancy evaluation survey -building type																			
	Number buildings	Acoustics	Air quality	Appear-ance	Complete per speci	Ease movemt	Light	Bldg manager	Privacy	Safety	Security	Shelter	Spacious ness	Storage	User - friendly	Visual connectn	Way - find	Other	Total
Apartment	10	4%	6%	4%	0%	39%	8%	3%	1%	2%	4%	0%	7%	0%	4%	4%	0%	15%	100%
Commercial	5	0%	0%	15%	0%	37%	12%	2%	0%	0%	0%	0%	15%	0%	4%	10%	0%	6%	100%
Council	7	0%	1%	17%	0%	29%	17%	1%	0%	0%	1%	0%	19%	0%	4%	6%	0%	3%	100%
Justice	59	1%	3%	17%	1%	24%	8%	2%	1%	1%	4%	1%	18%	0%	6%	5%	0%	8%	100%
Library	4	0%	10%	12%	0%	33%	19%	2%	0%	0%	0%	0%	6%	0%	6%	8%	0%	6%	100%
Military	17	1%	2%	8%	0%	31%	10%	1%	0%	1%	1%	0%	19%	3%	3%	6%	0%	17%	100%
Museum	15	1%	5%	30%	0%	12%	5%	9%	1%	0%	0%	1%	27%	0%	1%	3%	1%	5%	100%
Polytechnic	9	1%	1%	29%	0%	28%	7%	7%	0%	0%	1%	0%	12%	0%	2%	3%	0%	8%	100%
School	32	2%	5%	17%	1%	15%	11%	3%	0%	2%	1%	3%	14%	1%	7%	4%	0%	13%	100%
Retail	5	2%	0%	18%	0%	24%	10%	20%	2%	0%	0%	0%	6%	0%	8%	2%	2%	6%	100%
University	17	4%	1%	21%	0%	25%	16%	5%	0%	0%	1%	0%	9%	0%	3%	7%	1%	9%	100%
All	180	1%	3%	18%	0%	24%	10%	3%	0%	1%	2%	1%	16%	1%	5%	5%	0%	9%	100%

- Green-shaded cells are the best features.
- Building types with only two examples (i.e. archives, hospitals) were omitted from the analysis.
- Commercial are privately owned profit-seeking building owners and are mainly office and retail buildings.
- Air quality is the temperature, freshness, humidity, movement and chemical and biological qualities of air including radiant heat and control of these conditions.
- Complete per specifications is completion of the building as per the contract documents.
- Ease of movement is the spatial relationship allowing easy movement between spaces and/or elements, including accessibility for able-bodied and disabled people.
- Building manager are the occupancy practices including management and behaviour of occupants.
- Safety is personal safety from accidents and health hazards.
- Security is protection from deliberate actions by others (injury, theft).
- Shelter is exclusion of the elements.
- Spaciousness is the volume contained within an enclosure, sense of volume, including reference to surface area of wall or floor.
- Storage is the ability to keep items without obstructing operations and easily retrieve them in good condition.
- User-friendly is in accordance with universal design principles.
- Visual connection is the ability to see between rooms and inside/outside visibility.
- Way-finding are aspects enabling navigation including signs, logical layout and ability to see the destination ahead.