A building pathology system in New Zealand – what is possible?

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Acknowledgements

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Abstract

This report explores the feasibility of implementing a building pathology approach to monitoring building defects in New Zealand. The focus of this research is on residential buildings.

Such a system would provide early warning of potential systemic failures. This, in turn, would enable mitigation of the risks associated with poor-quality housing.

A building pathology system would provide a framework for managing the risk of the impacts of building defects. It would do this through analysis of the symptoms, causes, treatment and prevention of issues relating to poor building quality.

The building pathology approach is not one that has existed in New Zealand to date. There is currently no formal method for informing public policy of trends in relation to poor housing quality. Having this information could assist in preventing widespread building failure in the housing sector. This study sets out how that knowledge gap might be addressed.

This research focuses on a consideration of the value and benefits of a building pathology approach that involves repurposing and reanalysing existing data. There is existing data that can provide evidence regarding potential or actual building failures. This report identifies and describes those relevant information sources. We propose a possible systematic approach for utilising the evidence currently available. It is not about collection of new data. We consider this the most pragmatic approach.

This research also considers the extent to which information regarding future trends in housing defects can be utilised. Specifically, information on construction methods, building design and materials and sector capacity and capability has been considered.

Five methodological options are described for how we might use currently available data. The preferred option is for a comprehensive, wide-ranging baseline study of housing defects and/or failures augmented by detailed, focused case studies where required.

It is recommended that a pilot study be undertaken to test the proposed methodology.

This will enable finalisation of the necessary analytical framework. It will also provide us with the opportunity to gain stakeholder buy-in for a more expansive, longitudinal model, which will serve us well in the long term.

Keywords

building pathology, building defects, building failure, housing defects, housing quality, construction methods

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1.   Executive summary

This is the research report for project ER0898 *Understanding and addressing common quality issues and existing solutions through a building pathology approach*.

What do we mean by building pathology?

> Building Pathology is the study of building defects, building decay and building performance in order to develop suitable remedial and management solutions. (Hutton and Rostron, 2017)

The discipline of building pathology is based on the key concepts underpinning pathology systems in the health sector. These systems typically involve the mandatory reporting of specific organisms and require investigators who can detect and isolate the source to prevent disease spreading. A building pathology approach provides a framework for managing the risk of building defects through a consideration of symptoms, causes, treatment and prevention.

A building pathology system seeks to identify and understand trends in terms of common defects and their impacts on building systems. The aim is to understand where a trend is occurring at the earliest possible stage. Predicting trends before they are well established can potentially reduce the impact of defects because we can act to remediate or treat as quickly as possible. Ideally, this may be even before the trend has had time to have serious impact.

It is important to understand that building pathology is about multiple causative factors. Systemic building failures, such as leaky homes, are generally not caused by one factor. Any building pathology approach needs to be able to consider the full context within which a building failure has occurred. This will involve interaction between a number of factors, some of which, on their own, may not lead to defects.

The purpose of this research is to look at how it might be possible to put in place a system to understand residential building defects in New Zealand. Such a system would enable trend analysis and early warning of systemic failure across the housing sector. The research aim has been to examine the possibility of developing a system to produce data that has both predictive and explanatory outputs. That is, the system would enable understanding of what is causing defects and can predict where the trend might be heading.

This research examines current databases and data sources for the value they can offer in terms of providing information on quality issues in New Zealand residential buildings. Our finding is that data that is currently available on residential building quality is fragmented in nature. Limited funding for this type of research has been spread across a number of projects and organisations over time. To date, little effort has been made to consolidate this data into a holistic whole. This has meant it is currently not possible to get a clear picture of the common quality issues.

Our findings are that current evidence could be used to create a building pathology system. However, consolidation is required in order to create a system that meets the sector's needs. Such a consolidation would involve a detailed repurposing and reanalysing of existing data.

We have tested five different possible approaches for utilising the evidence currently available. Two of these five approaches have potential value in terms of offering a systemic overview of building defects. The preferred option is the **consolidated approach**. This involves undertaking a comprehensive, wide-ranging baseline study of housing defects and/or failures from current data sources. This would then be augmented by detailed, focused case studies. Data could be updated annually but be based significantly around the BRANZ House Condition Survey, which is conducted every 5 years. In the intervening years, interim reports identifying trends in housing defects could be provided using other existing data sources. Again, there would be a need to augment this with relevant case studies.

It is recommended that a pilot study of the preferred system be undertaken in the first instance. The pilot would essentially be a case study of an identified issue and would use a sample of source material. The pilot study would test the analytical framework and, importantly, gain stakeholder buy-in for a more expansive, longitudinal model should this option be considered.

More work is needed to finalise the methodology and determine the most cost-effective approaches. However, this research suggests there is value in undertaking further work in this area.

2.   Introduction

2.1   Background

This is the final report for project ER0898 *Understanding and addressing common quality issues and existing solutions through a building pathology approach*. This project sits within the BRANZ *Eliminating quality issues* research programme (see Appendix A).

This research looks at the potential for putting in place a surveillance system that monitors the New Zealand residential building sector for patterns of building failure. We have also assessed the potential value return of such a system. These systems are known as building pathology approaches. Building pathology is simply "the study of building failures" (Architecture.com, 2017). It is based on taking a holistic view of building failure, with a focus on underlying causes (Parrett, 2017).

> Building pathology is a holistic approach to studying and understanding buildings, and in particular, building defects and associated remedial action. In a medical context, pathology is the study of diseases in order to determine their causes and prescribe treatment. Similarly, building pathology involves the methodical study of buildings, their components, and environment, to address failures. (Designing Buildings Wiki, 2017)

The purpose of the research was to look at how analyses of data might enable early warning of systemic failure across the sector.

The aim was to assess the possibility of creating a surveillance system to:

- capture data (existing)
- identify trends
- analyse data for cause and effect
- identify and report on evidence of systemic failure arising.

The objectives include examining current databases and data sources for the value they can offer in terms of improving understanding of quality issues in New Zealand homes.

This report provides recommendations for moving forward and adding value to existing research and monitoring programmes rather than implementing a new surveillance system. It describes a consolidated approach to repurposing and reanalysing existing data rather than collecting new evidence as the default position.

2.2   Purpose of the report

This report is a discussion document that considers the feasibility and value of implementing a building pathology approach in New Zealand through the consolidation of existing information.

It considers the information currently available regarding defects in New Zealand residential building. Also considered is the extent to which information regarding future trends in construction methods, building design and materials as well as sector capacity and capability can be utilised. The desired outcome is the mitigation of the

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risks associated with poor-quality housing and the provision of early warning of potential systemic failures.

The report is based on the premise that, while fragmented, there is a substantial amount of information regarding building quality currently available. We consider that this could be more fully utilised than it currently is.

The research also looks at how current research and surveys could improve their value and cost-effectiveness. Some options could be to increase sample sizes, or to make minor alterations to survey questions.

The focus of the research is residential buildings. This focus has been taken because of the importance of housing quality to the economic and social wellbeing of New Zealand. Housing defects can have significant impact on the health and safety of occupants.

We note, however, that the concepts and methodologies could equally apply to commercial buildings. This is something that could be considered in the future.

2.3   Methodology used

Key stakeholders were contacted, and the value of the study and potential methodologies were discussed in depth. These included representatives from BRANZ, the Ministry for Business, Innovation and Employment (MBIE) and an experienced building surveyor. Discussions included other related programmes of work and how these could be best utilised into a consolidated building pathology approach.

A survey was undertaken of current administrative and research databases to determine which could be of value, either in their current format or with some modification. This information is available in a separate Excel spreadsheet and is briefly summarised in Appendix A and B. In addition, a sample cross-walk of information sources, topics of interest, access and value is included in Appendix C.

3. The New Zealand context

3.1 The research environment

There is a well established and widely held belief that little is known about building quality. Building quality is defined in the context of this research as a building without defects, as per the Building Code.

This is not necessarily due to a lack of information, as demonstrated in the brief summaries of research and other evidence included in this report. Rather, it appears to be due to the breadth and quality of the data collected and the siloed nature within which it occurs. The historical pattern has been for a large number of small, stand-alone studies to be undertaken. These are not then synthesised into a broader body of knowledge. Further, few studies are longitudinal in nature. The result is not so much a lack of information but considerable 'noise'.

Data that is useful as part of a building pathology study may differ from data that is useful for studies of housing quality. This is because it has been collected in relation to two different research aims. Each collection of data needs to be tested for usefulness.

That said, some research duplicates other studies, and some housing quality research has potential to form the basis of a building pathology analysis. The research community should consider the need to be clear about the research purpose in order to avoid duplication of work. This would also ensure maximum benefit from any investment made in understanding housing quality.

Where similar research is undertaken, it is important that common definitions of terms are used. This would enable data utilisation to be maximised.

The following paragraphs summarise the key research programmes and strategies currently contributing to this knowledge base and their potential relationship with a building pathology study. More detail is provided in Appendix A.

3.1.1 Building a Better New Zealand

This research strategy for the building and construction industry (MBIE et al., 2013) was developed with the purpose of addressing key challenges facing industry and to identify research needs for the industry. The intention of the strategy is to coordinate research needs and ambitions and not to duplicate work that has already been undertaken. The study described in this report would support a number of the needs and ambitions identified in the strategy.

3.1.2 New Zealand Housing Review

The purpose of this BRANZ project is to synthesise what is already known about housing quality through the publication of a biennial state-of-the nation type report. The first report is due in 2017. The first publication will focus on five thematic areas One of these is housing quality.

Consideration could be given to the relationship between research completed through a building pathology study and the New Zealand Housing Review. Ideally, any building pathology study would be used to complete the chapter on housing quality in the review. It could also inform any longitudinal analysis and reporting. This would ensure

a broader, more representative and more complete discussion of housing quality than current research delivers.

3.1.3 Housing quality tier one statistic

Work is under way to develop a tier one statistic to measure housing quality across New Zealand. This statistic is likely to utilise evidence from a range of sources including the General Social Survey[1] and the BRANZ House Condition Survey. MBIE has responsibility for this statistic and is currently working on its development and implementation with Statistics New Zealand and BRANZ.

3.1.4 BRANZ research programmes

In 2016/17, BRANZ has invested a significant allocation of the Building Research Levy in four new programmes of work and knowledge-transfer initiatives:

- Medium-density housing that meets the needs of New Zealanders
- Exceeding the minimum
- Eliminating quality issues
- Warmer, drier and healthier buildings.

These programmes are intended to develop end-to-end solutions to some of the most pressing issues currently facing the industry. A number of projects within these programmes are of relevance to the study suggested in this report. This data is most useful if it can be readily consolidated into a wider body of knowledge. These projects are noted in Appendix B.

3.2 The regulatory environment

3.2.1 Building Act 2004

The Building Act 2004 is the primary legislation regarding the construction of buildings in New Zealand and the standards they are to meet. It covers the construction, alteration, demolition and maintenance of new and existing buildings throughout New Zealand. It sets standards and procedures for people involved in building work to ensure buildings are safe, healthy and built right first time. It covers how work can be done, who can do it and when it needs to be consented and inspected.

The underlying philosophy of the 2004 Act places more emphasis on the welfare of building owners and occupants than the 1991 Act it replaced. The purpose of the 2004 Act set out in section 3(b) includes the requirement that "buildings have attributes that contribute appropriately to the health, physical independence and well-being of the people who use them". Individual wellbeing is a broader concept than health or safety. There is a clearer articulation of amenity than in the 1991 Act. Further, there is a broader set of principles regulatory officials must apply. These include acknowledging in section 4(2)(a)(i) the "role that household units play in the lives of the people who use them".

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[1] Completed by 6,000 respondents, this survey is implemented by Statistics New Zealand. In 2018, it will include a housing supplement that will provide information regarding respondents' perceptions of the quality of their homes.

This philosophy impacts on the definitions of building failure and building defects currently used in any consideration of housing quality and would impact on any building pathology analysis.

3.2.2   Building Code

The Building Code (Schedule 1 of the Building Regulations) defines the minimum standards buildings must meet to the extent required by the Building Act. The Building Code is expressed in terms of desired outcomes for buildings. Where these outcomes are not met, a building could be said to have failed. The move to a performance-based approach in 2004 was to allow for greater innovation and a wider range of potential solutions for construction. This related to both construction methods and materials used. However, it has remained contentious, with general anecdotal evidence from conversations with some stakeholders suggesting greater prescription is required.

The Building Code provides functional requirements and performance expectations under the following areas:

- Stability
- Fire safety
- Access
- Moisture
- Safety of users
- Services and facilities
- Energy efficiency.

Buildings constructed after the enactment of the Building Act are required to meet the performance standards specified in the Building Code of the time for each of these areas. This is achieved through the implementation of the building consent system, which is implemented by building consent authorities (BCAs) and overseen by MBIE, the regulatory authority. BCAs are responsible for issuing building consents at the beginning of a project and undertaking inspections at agreed points in the construction process. Requests for information can be issued prior to issuing a building consent where insufficient or inaccurate detail has been provided on the building plans. Further inspections can be required where a building does not pass an initial inspection. Notices to fix can also be issued where non-compliance is identified. Once the construction is complete and the final inspection passed, a Code Compliance Certificate is issued. At this stage, a building is deemed to be fully compliant with the Building Code and to have no technical defects.

Builders have liability for 10 years following completion of a new build under the Building Act. They also have a duty of care to ensure that everything built is fit for purpose. This 10-year time period could be used to determine the sample of houses to be investigated. That is, only information on houses built or renovated within the previous 10 years would be included. This requires further consideration as it does not allow for the impact of poor maintenance to be readily described. This approach also does not allow for a consideration of the sustainability of certain housing types.

4. A building pathology study of New Zealand housing

4.1 What is building pathology?

The discipline of building pathology is based on the key concepts underpinning pathology systems in the health sector. These systems typically involve the mandatory reporting of specific organisms and investigators who can detect and isolate the source to prevent disease spreading. A building pathology approach provides a framework for managing the risk of building defects through a consideration of symptoms, causes, treatment and prevention.

Building pathology "provides a systematic scientific approach to discovering what has gone wrong in a failed building … [The focus is on] what has happened and how it came to happen, rather than with attributing any blame" (de Freitas, 2013, p. 21). It is about "uncovering the causes and symptoms of a problem with a building in order to determine the best treatment" (Maynard Marks, 2014). When carried out on a large enough sample, building pathology investigations will "reveal patterns of building failure by identifying the common features of buildings that have failed" (de Freitas, 2013, p. 21).

4.2 Building failure and building defects

4.2.1 Building failure

Building failure can be said to have occurred when the building is no longer fit for purpose and does not meet the relevant performance criteria outlined in the Building Code. For residential buildings, the definition of 'fit for purpose' would be that the building is habitable and providing for the health, safety and wellbeing of its occupants. Building failure can be due to a single defect or multiple defects. It is more often the case that multiple factors combine to causes serious failure. For example, the leaky homes crisis was the result of the interaction of multiple factors including climate and occupant behaviours.

4.2.2 Building defects

Non-compliance with the applicable Building Code or additional performance standard is the usual criteria used to define a defect. However, not all building defects are related to Code compliance, nor do they all lead to building failure. It is, therefore, necessary to have an operational definition that can be used to classify a broader range of defects and to help assess their severity. Building defects can range from largely aesthetic concerns (where the building does not meet the expectations of the occupants) through to major defects such as the failure of flashings to keep water out. They can be cosmetic, or they can be precursors of more serious building failures.

Defects have also been defined as aspects of the building that were not completed in accordance with the contract or that have failed (Designing Buildings Wiki, 2017). This definition would seem to cover the wide range of defects noted in studies on building quality that have been carried out in New Zealand.

Within this definition, defects have been described as patent (those that can be discovered by reasonable inspection) and latent (those that cannot). Further suggested categories of defects are:

- fundamental – making the building unsafe or non-compliant and requiring immediate remediation
- functional – affecting the occupants' use of the building
- cosmetic – not affecting building use but of concern to the owner.

For any reporting of building defects, it is recommended the Building Code clauses are used to categorise areas of non-compliance. A severity scale would need to be used to indicate the relevant impact of the defect on occupant health, safety and wellbeing. Cosmetic or aesthetic defects could be coded separately. These would be defined in the analytical framework developed as part of the pilot study recommended later in this report (see section 5.5.2).

4.2.3   Causes of defects

Building defects can occur as a result of a wide range of issues such as design deficiencies, material deficiencies, specification problems and workmanship deficiencies. They may be a result of substandard work or lack of expertise at the time of construction. Defects in older buildings may also be caused by a lack of maintenance and repair deficiencies. Other reasons include improper use of buildings or products and environmental and other external factors (Designing Buildings Wiki, 2017).

There is some validity to the argument that general maintenance such as repainting, normal wear and tear or ageing should not be considered a defect. However, this requires some clear guidelines as to the expected lifetime of products. It may be preferable to simply state age or lack of maintenance as the cause of the defect. In some instances, a defect due to lack of maintenance may eventually lead to building failure and as such should not be discounted in a building pathology approach. Anecdotal evidence from conversations with stakeholders is that one of the possible causes of leaky homes is the lack of suitable maintenance for the types of cladding used.

In addition to capability issues (knowledge and expertise), pressures on capacity can also lead to defects. Shortages of skilled workers across the sector can lead to pressure to complete work in order to move on to the next assignment. The result can be that shortcuts are taken. They may be intentional or unintentional. Capacity issues may also lead to the employment of a less-skilled workforce and potentially less oversight of the quality of work being completed.

4.3   Rationale for a formal building pathology approach

The leaky buildings crisis provides an example of where a building pathology reporting system may have improved the timeliness of the response to the increasing incidence of weathertightness defects.

A review of key statistics regarding weathertightness failure trends may have enabled identification of a pattern of failure at an early stage and enabled an early response. What happened was a weathertightness crisis. There was a response to this, and there were considerable changes across the sector, including the regulatory system, to prevent a recurrence.

The existence of defects and/or building failures, if well documented, will enable early patterns to be detected and, potentially, prevent such an occurrence of systemic failure in the future.

4.3.1 Evidence from the Danish Building Defects Fund

The Danish Building Defects Fund is designed to ensure defects are remediated across not-for-profit public housing. A proportion of the building costs of all subsidised housing is used to pay for 1-year and 5-year inspections.

Reporting on this fund, the CREDIT: Construction and Real Estate – Developing Indicators for Transparency project (see Appendix D) provides an example of the benefits of inspections for defects post construction and the value of sharing knowledge gained through the identification and remediation of any defects. While this project provides for purposive inspections, it is possible to undertake a similar methodology using data gathered through multiple sources.

4.3.2 Incidences of building defects in New Zealand

Research studies undertaken in New Zealand recently (Rotimi, Tookey & Rotimi, 2015; Page, 2015) suggest that a significant number of new house owners need to recall their builders to rectify defects. However, it should also be noted that the majority of defects reported after a house is completed are cosmetic in nature. Technical defects are likely to have been remedied during construction, assuming the building consent system is working efficiently in relation to compliance inspections. The BRANZ New House Owners' Satisfaction Survey (annually from 2011) also identifies trends in defects for residential new builds from the house owners' perspective.

These studies highlight the importance of reporting defects and understanding their causes and potential impact. Similarly, the BRANZ House Condition Survey (see Appendix B) reports on defects found in houses across New Zealand. It routinely reports the poor condition of many New Zealand homes, particularly in relation to impacts of high levels of internal moisture, such as visible mould.

Despite these reported incidences of building defects, the building pathology approach is not common in New Zealand. In addition, there is no formal method for such a system to inform public policy and prevent widespread building failure.

4.4 Building pathology in New Zealand

The literature on building pathology is mainly European based. It presents a framework for analysing building defects on the basis that prevention and protecting the public good is the primary goal. The defect-recording systems documented are all based on insurance claims. In contrast, in New Zealand, remediation of building defects is managed via bilateral negotiations between the contributing parties.

The building surveying profession usually plays a significant role in these negotiations since they have the expertise and experience needed. Building surveyors hold the most valuable information for a building pathology system. A sample submission from a building surveyor is provided in Appendix B, which demonstrates what they can offer.

However, there are a range of other possible sources that can provide information pertaining to the nature, frequency and causes of building defects. Currently, this information tends to be siloed and used for specific, well defined purposes. Currently,

any reporting and discussion of defects tends to be through informal channels or within a research report on a specific issue. It generally occurs on an as-required basis or in response to a particular concern or interest. Anecdotal evidence from stakeholders is that there are perceptions of conflicts of interest present. This minimises the value of these information sources and prevents them from being used and applied more systematically.

An approach and methodology for consolidating already existing information into a more formal surveillance and reporting system is suggested. Such a system would enable triangulation of findings and a greater degree of objectivity in the reporting.

5. A New Zealand study

5.1 The consolidated approach

The consolidated approach described in this section is seen as the most cost-effective way to potentially build a building pathology system in New Zealand. This approach acknowledges the current research environment and the value that can be added from it through greater reuse and repurposing of current data that has been collected for other purposes. It also acknowledges the wealth of information that exists in various industry reports and other documentation.

It is recommended that any building pathology approach in New Zealand be implemented through the consolidation of key information sources rather than the collection of new data. It is likely that gaps in evidence exist, but new research should not be undertaken until there is a clearly identified need. A primary concern should be to avoid duplication and maximise the value of information already available. For some key data sources, increasing sample sizes and scope would be beneficial. This would enable a stronger and more reliable contribution to a building pathology system to be made.

The term 'consolidation' is used to reflect the extent to which some data will need to be repurposed and reanalysed rather than the findings simply synthesised. The online Oxford Dictionary defines 'consolidate' as "to combine a number of things into a single more effective or coherent whole", whereas 'synthesis' is defined as "the combination of components or elements to form a connected whole".[2] While the difference is subtle, it is important to emphasise that more than the simple synthesis of current findings is required.

5.2 Study purpose

The purpose of the consolidation should be to provide evidence regarding potential or actual building failures. It should have both a predictive and an explanatory purpose. The identification of concerning trends and/or increasing defects could provide early warning of potential systemic failure. Understanding the risks associated with identified trends could enable changes to be made to the building and construction system to prevent widespread defects occurring. Identification of defects and changes to the materials used or construction methods could similarly avoid widespread failure. Where building failure has occurred, a detailed understanding of what happened and why will help prevent further occurrences.

It should be noted that systemic building failures, such as leaky homes, are generally not caused by one factor. Any building pathology approach needs to be able to consider the full context within which a building failure has occurred. In the case of leaky homes, there was a 'perfect storm' of contributing factors involved. These included the use of untreated timber framing, innovative claddings that the sector and homeowners were unfamiliar with and new house designs.

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[2] https://en.oxforddictionaries.com/
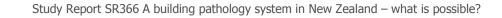
5.3 Methodological options

No detailed consideration of the cost of implementing a consolidated approach has been undertaken. However, there are five scope options that would meet varying budgetary limitations:

- **Option 1:** Undertaking a comprehensive and wide-ranging baseline study of housing defects and/or failures augmented by detailed, focused case studies where required. The basis would be the BRANZ House Condition Survey, which is conducted every 5 years. In the intervening years, this could be supplemented by annual interim reports describing trends in data and/or reporting on detailed case studies. This is the preferred option.
- **Option 2:** Limiting the scope to particular types of housing (for example, medium-density housing), particular quality concerns (for example, the internal environment) or particular materials (for example, claddings). This option would essentially be a case study approach and would be the second most preferred option. There are cost benefits to be gained through limiting the scope, but there are risks associated with predetermining the potential areas of concern.
- **Option 3:** Limiting the purpose of the study to an analysis of building defects and/or failures rather than including explanatory or predictive factors in the analysis and reporting. This would minimise the value of the study and its potential impact on housing quality and is not recommended. The education and improvement focus of any study would be lost.
- **Option 4:** Limiting the information used to what is readily available and easily analysed. This would involve the use of data that has already been reported and analysed rather than the qualitative analysis of extensive reports such as court judgments and surveyor reports. This would, however, severely limit the information available and is not recommended.
- **Option 5:** Retaining the status quo. This would leave it to individual commentators to continue to informally report on building defects and failures. The concern is that this option does not provide a consistent, coherent narrative based on a triangulated and comprehensive evidence base.

5.4 Potential information sources

An initial review of the information available has identified the following sources as potentially being of value in identifying defects and their causes:

- Existing research regarding the building and construction sector (predominantly funded by BRANZ through the Building Research Levy).
- Building surveyor reports of failed buildings (often completed for insurance or other claims).
- Court judgments.
- MBIE determinations
- Regulatory administrative data such as determinations and licensed building practitioner (LBP) complaints.
- Building consent data including requests for information and notices to fix.
- Whats On database.
- BRANZ administrative data such as queries through the BRANZ helpline and applications for Appraisals.
- Statistics New Zealand surveys such as the General Social Survey and the Household Economic Survey.

- Prepurchase inspections.
- Media reports.
- Industry organisation publications.

More detailed information for the core sources identified is provided in Appendix B.

The rigour and depth of the information available, as well as ease of access, varies greatly across these sources:

- The most value is likely to be gained from existing research, building surveyor reports and court judgments. There are some access challenges with regard to building surveyor reports.
- Challenges with access to regulatory administrative data and BCA data will need to be discussed with the regulatory bodies involved. BCA data, in particular, can be difficult to access. The move to building inspection software systems such as GoGet[3] could make this easier. This presumes a willingness from the BCAs to share the data.
- Statistics New Zealand surveys have the advantage of large sample sizes. However, any reporting on housing condition or expenditure is occupants' perception only, and as such, there is no standard benchmark applied.
- The general perception is that, given their variable quality, there is little value to be gained from using prepurchase inspection information. This would need to be tested and may vary across providers.
- Media reports and industry organisation publications should be viewed as indicative of concerns only and would need to be triangulated against other sources.

5.5   Methodology

Regardless of the scope, the basic methodology would remain the same. However, the following summary of key activities is based on the assumption that the preferred option as identified in section 5.3 is undertaken.

5.5.1   Identifying information sources

For this approach to be effective, regular monitoring of potential information sources would be required. This includes media reports and research undertaken in related areas of interest. It is recommended that this monitoring occurs frequently and on a regular basis. A database of information sources should be maintained indicating where relevant information can be found. In addition, key contextual information regarding collection methodologies and the value it provides needs to be recorded. This would help identify potential gaps and point to where additional research may be needed.

5.5.2   Developing an analytical framework

There is a wide breadth and diversity of information currently available. Much of this data is collected over different timeframes. This means a detailed analytical framework will be required in order to understand how each source can contribute to a building pathology system. It would be important to understand the questions each information source is able to answer. This framework will need to clearly identify the sources to be

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[3] www.goget.co.nz

used and the methods for analysing and consolidating the relevant information from each.

Table 1 and Table 2 are samples of the different collection and reporting formats that could be used to manage data consolidation.[4] They also provide some guidance as to the types of information that could be expected to come from building surveyor reports or other detailed inspections.

Table 1. Building overview.

Heading	Description
BCA	Defines the building's administrative body.
Environment	Defines the environmental conditions specific to performance and any extreme conditions related to wind, rain, sun and/or corrosion loading.
Market	Defines any issues related to provision of construction services at the time the building was built, for example, inability to source treated timber.
Consented date	Specifies the Building Code the building must comply with.
Built date	Indicates era of build and any material/practice issues that may relate to defects, for example, availability of treated timber.
Scale	Number of storeys, buildings or units and m^2.
Design interactions	Design and construction issues related to overall risk.
Cost of repair	Total cost to repair defects.
Certification	Reporter's ID to certify data reported and professional obligations fulfilled.

Table 2. Building defect information.

Heading	Description
Defect	The building component that is most implicated in the defect.
Function	Functional item that failed.
Symptoms	Damage requiring repair, loss of function, loss of safety and so on.
Causes	Root cause of defect including why the design, build, supervision, inspection and/or commissioning processes failed.
Cost	Cost to remediate.
Consequential cost	For defects with no damage yet, the consequential cost if left until serious symptoms arise – structural, safety, remediation.
Risk of systemic failure	Installations per annum; % failure over 10 years; cost of repair per failure.
Prevention	Actions needed to prevent future defects.

Appendix C contains a sample framework for identifying the type of information available from each source. It does not include other relevant information such as the methodology used to collect the information, the frequency of collection or the nature of reporting.

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[4] These have been slightly adapted from those in the draft report for this project.

5.5.3   Collecting and analysing information from multiple sources

The following is a brief summary of what would be required to effectively use data from each of the key information source groups.

Using existing research

It is likely that existing data will need to be repurposed and reanalysed. This will enable a different set of questions to be asked than was originally intended. In some instances, it may simply be a case of undertaking more detailed analysis and reporting than has already occurred. For example, recoding of qualitative responses may be required. A consideration of a sample of BRANZ study reports and the surveys used to collect the data suggests more information is available than is currently reported. It may also be preferable to adapt current surveys through the addition of some questions and/or an increase in sample sizes. The added value this would bring is likely to justify additional costs.

Building surveyor reports and court judgments

Sources such as building surveyor reports and court judgments will require detailed coding to enable the information to be aggregated in a rigorous manner. With regard to building surveyor reports, any analysis should be undertaken on anonymised reports, ensuring that individual residences are not readily identifiable. Doing so could mitigate concerns around ethics, liability and the privileged nature of such reports. Further discussion is required with potential providers of the data to determine an agreed methodology and potential costs. Court judgments are already in the public domain and as such do not require any special treatment. Both these sources of information have the potential to provide the detailed contextual information required to fully analyse and understand specific building failures and to identify patterns and trends.

Administrative data

Administrative data has the potential to provide a wealth of information regarding the capacity and capability of the system, including the costs of remediation. This includes data obtained through regulatory systems. This can be augmented through the regular synthesis of survey information. Examples include determinations and LBP complaints data from MBIE and the collation of requests for information[5] or notices to fix records from BCAs.

Consent data such as that available through the Whats On database is a useful indicator of the extent of building work occurring. In some instances, it also provides evidence as to whether the work is remedial with regard to particular defects. However, descriptive information is limited, and the data is more useful in terms of the quantity of work occurring and any potential capability issues.

Other potential administrative sources include records regarding queries to the BRANZ helpline and applications for BRANZ Appraisals. BRANZ Appraisals are independent assessments of building products, materials and systems and their fitness for purpose. The BRANZ Appraisals team are in routine contact with suppliers, installers and building owners and routinely discuss issues arising. Collating this information into a standard template should be relatively straightforward. These sources would provide

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[5] MBIE has undertaken a pilot study considering the usability and usefulness of requests for information data. This study highlighted the potential for records to highlight areas where designer capability could be questioned.

information regarding future trends in the use of materials and construction methods, the level of innovation being considered and areas where increased capability will be required.

Prepurchase inspection reports

While there is a level of concern over the variable quality of these reports and potential access to them, they are worth investigating further. The industry template used for reports would make it relatively easy to combine information. Further, it is possible that, through software such as Report Write,[6] there are multiple building inspection reports stored online. These could be readily accessed and analysed. However, costs of access to this information would need to be considered.

5.5.4   Consolidation of evidence within key areas of interest

Information that is readily available through existing research and information sources would be consolidated under four key areas. This would provide the breadth of evidence required to create a comprehensive building pathology system. The key areas of interest are:

- the condition of houses, including the nature and scale of identified defects and building failures
- the materials used in construction as an explanatory and predictive factor
- the capacity and capability of the building sector as an explanatory factor
- the attitudes and behaviours of homeowners and occupants as an explanatory factor (maintenance and responsibility for identifying and remediating defects).

Connections and inter-relationships between these areas could then be assessed to enable a detailed consideration of the nature and causes of any defects. This would also enable identification of the potential for systemic failure.

5.6   A pilot study

It is recommended a pilot study be undertaken to test the feasibility and efficacy of the consolidated approach. This pilot study could focus on a particular type of housing or area of concern. The scope of the study should be agreed with key stakeholders and be based on an area where there is sufficient research available. Examples of potential topics are medium-density housing or internal air quality.

The pilot study would:

- consolidate existing BRANZ research and administrative information through a repurposing and reanalysis of key datasets
- analyse data from one or two BCAs to determine the value and usability of information
- analyse a sample of court judgments to determine the value and usability of the information
- analyse a sample of building surveyor reports from one organisation to determine both the usability of the information and the opportunities and challenges presented
- undertake a media scan.

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[6] www.buildingsurveyors.co.nz/resources/advertising/report-write

This pilot study would report on the findings from the research, which could be assessed for value in terms of a building pathology system. It would also enable:

- testing of the methodology used and identify the challenges and opportunities in the approach
- development and testing of a detailed analytical framework including coding and analytical methods
- recommendations regarding the future of building pathology studies in New Zealand to be made.

5.7 Methodological challenges

5.7.1 Stakeholder engagement

One of the key challenges is stakeholder engagement. In developing this report, there was a sense of cynicism from many of those spoken to regarding the success of such an approach. This cynicism did not appear to stem from a lack of belief in the need to study building defects and/or failures. Rather, it appeared to be related either to the feasibility of implementing a building pathology approach and/or the interest from key stakeholders in using the potential findings.

This may partly stem from the siloed view some have of the building sector and the information currently available about it. This is understandable given its complexity and size of the sector. Understanding the potential of a consolidated approach to building pathology requires a helicopter view of the information available and an awareness of the potential for repurposing.

A key solution to this challenge is the pilot study recommended in section 5.6. This would provide an opportunity for focused and practical engagement with key stakeholders.

5.7.2 Access to the information

A second challenge is getting access to raw data or reports that are sufficiently detailed to enable the level of repurposing and reanalysis necessary. This is not a problem where the initial research was undertaken by BRANZ. In other instances, such as building consent data and surveyor reports, there are challenges to be overcome. These include:

- the owners of the information seeing sufficient value in sharing their data to do so, particularly where it is not managed in a way that readily enables sharing
- ethical and proprietary concerns with sharing third-party information regarding the condition of private homes
- a willingness within the regulatory environment to support a detailed study of building defects and failures that will make public potential concerns
- potential liability concerns where information is made public that could negatively impact on homeowners, builders and/or material providers.

Overcoming these challenges will require a collaborative approach amongst key stakeholders and a shared understanding of the value and efficacy of what is being suggested. Again, the pilot study should help overcome this challenge. Over time, evidence of the value of the approach should lead to increased buy-in and enhanced access to a wider range of information.

6. Conclusion

New Zealand does not currently have in place a building pathology system for research on housing quality. This limits our ability to identify early trends in building quality failure, which, in turn, limits our ability for early response to those failures.

There is building quality research being undertaken throughout the country. However, one of the key limitations of this research is the large number of projects across which funding is spread. Low levels of funding per project impacts on sample sizes and project scope. As a result, much of the building and construction research undertaken in New Zealand is relatively small and focused on a particular issue or concern. Even where studies are longitudinal in nature, sample sizes are not large. Existing research is also often based on the perceptions of occupants and limited technical inspections. The exception would be building surveyor inspections undertaken on a failed building where detailed information is required. As a result, we have limited ability to generalise findings from this research. This undermines the value, usability and impact of the evidence collected.

There would be value in developing a methodology and analytical framework that ensures these smaller projects can be readily consolidated into a more holistic picture via a building pathology system.

Developing an effective building pathology system faces two significant challenges. Firstly, if this system is to be useful, industry and researchers need to support it and input research data and findings into the system. Secondly, the system needs to be able to be easily accessed and used by the building and construction sector. Design of outputs would need to be carefully considered so they are usable whilst preserving privacy. Utility, however, needs to be the primary driver.

If the research and regulatory communities supported it, a building pathology approach would be able to inform future construction. It would also increase sector-wide knowledge of building quality. This can only lead to improvements in building quality and deliver benefits for all New Zealanders.

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Appendix A: Detailed research context summaries

Building a Better New Zealand

In 2013, a research strategy for the building and construction sector was developed under the banner of Building a Better New Zealand (MBIE et al., 2013). This strategy was supported by MBIE, the Construction Industry Council (CIC), BRANZ and the Construction Strategy Group (CSG).

The purpose of the strategy is to address key challenges facing the industry and to identify research needs. The stated intent is to coordinate research needs and ambitions and not to duplicate work already undertaken. This intent also underpins the approach recommended in this report.

Research priorities are grouped into nine themes. Of these, three are particularly relevant to a building pathology research agenda. They are better buildings, materials performance and maintaining and improving the performance of existing buildings.

Better buildings

The research topics included under this theme are resilient buildings, moisture in buildings, indoor air quality and moisture control, ventilation, acoustic performance and fire.

As a result of historical leaky buildings issues, New Zealand is well aware of the importance of getting the building envelope right. Weathertightness, therefore, remains a high-priority information need. This includes the management of a building's moisture through heating and ventilation. The Christchurch earthquakes also brought the structural elements of a building and the potential impact of natural hazards into focus.

The strategy recognises the importance of making buildings more resilient but also of not overengineering them. Better understanding of the building envelope is seen as one of "the core foundations of our built environment" (MBIE et al., 2013, p. 8). An adapted building pathology approach has the potential to provide significant information in this area in terms of how and why buildings fail. It will also inform the discussion on what is required to increase their resilience.

Materials performance

This is a theme of particular relevance for the approach described in this report. The strategy argues "our future buildings will be shaped as much by the materials used in their construction as by the designers and builders who create them" (MBIE et al., 2013, p. 12). This is a broad research area covering traditional materials, new materials, the best use of existing materials, indigenous materials, low environmental impact materials and performance assurance.

Research topics include:

- the performance of systems and the effect of new materials on existing materials
- the performance of new materials in existing systems
- the performance of existing materials in new applications
- improving the performance of materials and product assurance.

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Maintaining and improving the performance of existing buildings.

The strategy states that "85% of the current building stock will still be with us in 2025" (MBIE et al., 2013, p. 14). More buildings are renovated in a typical year than are built.

The research topics for this theme are retrofit solutions and building condition. Again, these are topics of particular relevance for any adapted building pathology approach, which would seek to describe where and why building defects are occurring. It would answer identified research questions such as:

- How do we best improve the condition of New Zealand building stock?
- What are the priority areas for improving conditions?
- What are the barriers to improving building condition?

New Zealand Housing Review

The New Zealand Housing Review will be a biennial state-of-the nation type report. This report will describe housing across New Zealand, the impacts of housing on the New Zealand population and how it is changing over time.

It will draw on existing research under seven key thematic areas, with the first five prioritised for stage 1 of the project.

- Housing and health
- Housing and society
- Housing quality
- Housing markets
- Housing finance
- Housing sustainability
- Housing innovation.

Work has already begun on the identification of core indicators to be reported against. A core set of 15 indicators has been recommended, three in each of the first five themes:

- Health: excessive winter deaths, excessive winter hospitalisations, indoor temperature.
- Social: housing tenure, household composition, demand for social housing.
- Quality: national house condition survey, perceptions of housing quality, housing problems, satisfaction and tenure.
- Markets: affordability, house values/income, house values/mean rents.
- Finance: housing loan approvals, rent or buy analysis, rental affordability index.

In total, 98 potential indicators have been identified – 32 for health, 14 for social, 12 for quality, 20 for markets and 20 for finance.

The first report is due in 2017, with the identified indicators directly related to the Healthy Housing He Kainga Oranga programme.[7] These are excessive winter deaths, excessive winter hospitalisations, rental affordability and crowding.

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[7] This programme of work focuses on improving health outcomes in low socio-economic areas through interventions designed to promote warm, dry and healthy housing through improved heating and insulation.

This reflects the focus of much of the current research on housing quality. Currently, much of the focus is on low-decile communities, the quality of rental properties and the effects of temperature and humidity.

BRANZ research programmes[8]

Programme 1: Medium-density housing that meets the needs of New Zealanders

The success criteria for this programme include the following:

- The building industry has the technical information to enable the design of quality, affordable and desirable medium-density housing.
- The building industry has the skills needed to design and build quality, affordable and desirable medium-density housing.
- Medium-density housing buildings are maintained to sustain long-term performance.
- Everyone has a shared understanding of how to optimise the journey through the building and consent process for medium-density housing.
- There is increased acceptance of medium-density housing in communities.

One of the identified research projects for this programme is developing an understanding of where quality problems currently exist to inform future developments. The research will carry out on-site surveys to identify potential construction problems associated with designing and building medium-density housing. It will explore the kinds of design features needed to make it easy to maintain these homes. It will also identify possible skills gaps in the building industry that may be contributing to quality issues. This project would provide directly applicable evidence to the building pathology approach described in this report.

Other projects, such as the testing of claddings for performance in medium-rise buildings, have the potential to inform any building pathology approach. They will provide information on potential future failure. Similarly, a project considering fire spread from lower roofs could be of value.

Programme 2: Exceeding the minimum

This programme is intended to help consumers and the building industry understand that the standards in the Building Code are a minimum only. The programme focuses on the real benefits in exceeding the Code.

The success criteria for this programme include the following:

- Consumers and industry understand that the Building Code and standards are a minimum that must be met but can be exceeded.
- The benefits of exceeding the minimum can be clearly articulated based on meaningful terms.
- The barriers to exceeding the minimum have been addressed.
- Consumers expect and demand buildings that perform to a higher standard.
- The industry delivers buildings that perform to a higher requirement in a cost-effective way.

The research undertaken within this programme is unlikely to directly provide evidence for a building pathology approach. However, it can potentially provide understanding of

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[8] This information has been taken from www.branz.co.nz/industry_research.

the behaviours of the sector and potential solutions with regard to changing attitudes and behaviours. It could be of particular relevance where capacity and/or capability issues are driving building failures.

Programme 3: Eliminating quality issues

The building pathology study discussed in this report is one of the projects within this programme. The purpose of this programme is to eliminate quality issues by identifying the most common problems and the possible solutions to them. The programme will also look at why the industry is not making the necessary changes and explore ways in which they can be encouraged to do so.

The critical success criteria for this programme include the following:

- We have identified common quality issues that occur in the building industry.
- We understand why the previous work to solve common quality issues has not been successful.
- We understand how to encourage industry to change their practice.
- We have determined the best way to reduce the incidence of common quality issues.
- We have eliminated common quality issues by using existing knowledge.
- We have eliminated common quality issues by designing new solutions.

Relevant projects include the development of a definition of acceptable quality in different building types. Base data for this project will come from a new survey on housing construction quality. Another project will identify the quality issues that cause the most concern in terms of a building's long-term durability and sustainability. Both projects would directly inform the building pathology approach described in this report.

Programme 4: Warmer, drier and healthier buildings

The work under this programme combines to focus on the provision of solutions that will allow buildings to be warm, dry and healthy over their lifetime. It will also provide the information needed to improve comfort, temperature and heating to support better health outcomes.

Success criteria for this programme include the following:

- There is a shared understanding of the issues that prevent our homes being warm, dry and healthy.
- Solutions to developing warmer, drier, healthier homes and buildings in New Zealand have been successfully identified.
- Industry understands the knowledge, ways of implementing the solutions and benefits provided.
- Owners, suppliers and users of homes and buildings have the knowledge and understanding to make effective decisions in producing and maintaining warm, dry, healthy environments.

Projects to address the first success criterion are scheduled to begin in 2017/18. Other relevant projects include expanding the current data on airtightness in homes built since 2010. The results of this programme will be used to create a national database that can be used to develop ways of mapping, simulating and improving building performance.

Appendix B: Potential information sources for the consolidated approach

BRANZ research

BRANZ undertakes a wide range of research and other activities related to building quality. As such, there is ready access to a wealth of information that could potentially be of value. Appendix A contains a summary of the four main research programmes currently included in the Building Research Levy and knowledge dissemination investments. As identified earlier, some of these projects have direct relevance to the approach described above. In addition, BRANZ undertakes other work that is also directly relevant. The following summarises the key BRANZ sources identified for this project.

BRANZ House Condition Survey

The BRANZ House Condition Survey is completed every 5 years. Since 2010, the sample has been adapted to provide a more representative picture of New Zealand homes. The sample size, however, is only 500 houses,[9] and this remains a major limitation when considering specific subsamples such as houses built since 2005. Based on the 2015 survey, this is likely to be approximately 40% of the total sample (approximately 220 houses). It is possible that, as part of the tier one housing quality programme, this sample will be increased to 1,000, substantially improving its usefulness.

Despite the limitations of sample size, this survey collects detailed information regarding readily perceived defects in houses. There is definitely potential to more fully utilise the data collected and to ask different questions of it than those currently reported. Analysis could focus on areas such as:

- the frequency of different defects reported overall for specific components
- the characteristics associated with particular defects including the age of the house and the materials used.

The value of this survey is likely to be as an indicator of areas of concern to study in more depth. An exploratory study of the presence of defects identified as potentially leading to building failure would provide a valuable guide to developing more detailed case studies of key areas of risk.

Interior condition

The survey asks the assessor to give an overall condition rating for all rooms in the house, specifically the kitchen, bathrooms and other rooms. It also asks for a report on the condition of interior linings and fittings and to identify defects found. Examples of defects found include chipped/peeling paint or wallpaper and discoloured paint/wallpaper. Other defects include those found in joinery. Common defects in staircases relate to handrails and balustrades.

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[9] While this is considered representative in that it is undertaken nationally, it does not readily allow for subsamples to be created such as housing built since 2005. This is because no stratification has been undertaken to ensure representativeness of age.

Exterior and envelope

Individual external components of the house are given a rating. These components include foundations, joists/bearers, fasteners, waterpipes and wastepipes, subfloor and flooring, windows and doors, wall cladding, roof framing and roof cladding.

The survey has the capacity to record the presence and, in some cases, the frequency of a huge range of defects that could affect each of these external components. Some of the most common issues include window and wall cladding defects. The latter include minor cracks, decay/rot and cracking at cladding joints. Other defects include those found in the roof such as corrosion of fixings and missing/loose fixings.

New House Owners' Satisfaction Survey

This survey was first implemented in 2011. The survey is sent to new house owners as identified on building consent information. It aims to find out how the owner of the new home rates their builder's performance. The response rate in 2015 was only 25% (708 respondents from 2,825 surveys). The sample covers 31 territorial authorities.

The question of most relevance to a building pathology study would be the number of respondents reporting the need to call back their builder to fix defects after first occupancy. This could be compared over time to see if there are any trends that could indicate potential concern with the quality of building.

In 2013, the survey asked respondents to identify the defects that needed fixing. Unfortunately, this question was not in the survey in 2015. Rather, respondents were asked to identify which trades needed to be called back. There could be value in revisiting the decision to remove the open-ended question around the nature of the defects.

Physical Characteristics of New Houses

The new dwelling survey dates back to 1998 and collects data on materials used in the construction of new houses. The purpose is to obtain data not available from official sources. The survey form is constantly evolving to include new questions as required.

A database is available of approximately 1,200 new houses per year containing information by building component. It also contains data on design arrangements such as number of floors, prefabrication and efficiency measures.

The components analysed are

- claddings
- framing
- house storeys
- flooring
- floor joists
- insulation
- window frames
- double glazing.

This survey has the potential to indicate changes in the use of building materials, which could indicate higher levels of risk due to potential capability issues or product failure.

New House Construction Quality Survey 2014

This project inspected over 200 new, detached houses at various stages of inspection. These were at post-wall underlay, prelining and final council inspection. The aim of the project was to assess the quality of the work, problems that the builder experienced and the extent of Code compliance of the work.

Defects found were classified into two groups: Building Code compliance defects and quality of appearance defects. Compliance defects are the more serious as they potentially affect the durability and performance of the house. It was arbitrarily assumed that the presence of four or more compliance defects is likely to indicate serious concerns about that house. Approximately 8% of new houses were considered likely to be in that category. The incidences of quality defects averaged over four per house and typically related to interior surface finish defects.

The project found failings in the work of all three sector groups (designers, builders and building inspectors). The primary cause of these failures was reported as being due to capacity and capability issues. In particular, the high workloads currently common across the sector and the pressure to build new homes were important.

Separate to the on-site inspection, a postal survey of a different sample of builders was implemented regarding the issues they have with constructing quality houses. They found their main problem was inadequate detailing, in particular, roof and wall flashings and connectors. Difficulty in obtaining workers with adequate skills was also a major issue.

This study was undertaken only once. If the building pathology approach is implemented, there is value in considering this as a longitudinal study similar to others BRANZ currently implements.

Building Research Levy programmes

Programme 1: Medium-density housing research

The following projects have the potential to provide evidence regarding potential defects that could lead to failure:

- On-site surveys to identify potential construction problems associated with designing and building medium-density housing.
- Testing of claddings for performance in medium-rise buildings.
- Fire spread from lower roofs.

Programme 2: Exceeding the minimum

Projects within this programme have the potential to provide understanding of the attitudes and behaviours of the industry and homeowners with regard to quality and potential acceptance of defects. In a building pathology approach, this would be part of understanding why defects occur and/or remain due to a lack of remediation.

Programme 3: Eliminating quality issues

As already stated, the project discussed in this report is part of this programme. Other projects are also relevant to the identification of defects and/or potential failure:

- A new survey on housing construction quality.

- Identification of the quality issues that cause the most concern from the point of view of owners and in terms of the building's long-term durability and sustainability.

Programme 4: Warmer, drier and healthier buildings

Relevant projects include extending the current data on airtightness in homes built since 2010.

Building surveyor reports

Questions have been raised around the extent to which these are privileged as well as ethical concerns around their use and potential liability. However, there do appear to be solutions to these challenges. The solutions lie in the manner in which the information is accessed and the level of aggregation to ensure anonymity of not only the occupants but also the buildings involved.

Following is an example of the type of information that could be supplied and incorporated into a building pathology study.

Names/address	Auckland
Construction period	2004–2006
Basic facts	>10-level apartment
Repair value	$5 million + (estimated)
Weathertightness defects	
1	Moisture ingress, causing damage, via the level 1 patio due to failure of the liquid-applied waterproofing membrane and inadequate junctions with adjacent membrane systems, causing damage.
2	Moisture ingress via the balcony membranes due to inadequate application of the liquid-applied membrane resulting in the membrane not being impervious and the membrane not being continuous or having a drip edge to the perimeter of the balconies, causing damage.
3	Moisture ingress via the joinery/cladding junctions to penthouse apartment due to these junctions lacking continuous air seals and being reliant upon exposed sealant and also due to open gaps at the folded edges of the sheet metal cladding adjacent, causing damage.
Internal moisture defects	
4	Bathroom floors lacking falls to the floor wastes and with inadequate provision for containment of freewater from water splash or accidental overflow of sanitary fixtures.
5	Inadequate waterproofing of the bath/wall junction, reliant upon only sealant, and inadequate provision for containment of water splash to the perimeter of the baths (with showers above) allowing moisture to penetrate behind linings and into concealed spaces.
Fire safety defects	
6	Inadequately installed fireproofing of penetrations and/or inadequate fire-rated linings to elements
7	Structural steel installed without fire-rated coating or other suitable fire-rated protection.

Another example of the type of information that could be collected is a report entitled *Mid-Rise Case Studies* (Alexander & Co, n.d.). The report contains a list of defects found in mid-rise buildings under the following headings:

1. Structure generally	2. Timber structure
3. Masonry structure	4. Concrete structure
5. Steel structure	6. Design detail generally
7. Durability	8. Serviceability
9. Ventilation	10. Airtightness and IAQ
11. Insulation	12. Bathrooms
13. Windows and doors	14. Floor levels
15. Roof	16. Decks
17. Sound transmission	18. Steel stairs
19. Fire rating	20. Retaining walls

The value of this information for a detailed building pathology study is limited in its current format. It is not intended to be an exhaustive list, nor does it contain quantitative detail regarding the frequency of occurrence of these defects. There is limited contextual information to support a detailed understanding of the causes. However, clearly exemplified is the potential to utilise building surveyor information in an anonymous, aggregated manner. Surveyors could be asked to provide similar reports either as case studies or as aggregated information across all reports they have completed. The type of reports would depend on the purpose and level of detail required.

Following is an extract from this report that exemplifies the information available. This information could be recoded and structured through the approach described in this report.

Structure generally

1. Compliance failure with structural design is often serious and endemic. This may be the result of insufficient coordination and communication between design professionals. In addition, there is often insufficient understanding of the role and requirements of other design professionals.
2. Issues may not be brought to the attention of IPENZ or other professional bodies because:
    a. defects are discovered and just repaired without further reference to the original parties
    b. disputes are settled confidentially
    c. original design professional has no part in subsequent works (and does not wish to be involved)
    d. subsequent design professional has no reporting obligations relating to inadequate work of others in their profession
    e. failures are a very complex mix of facts and circumstances so highlighting a failure to one party is unhelpful as they will just refer to the contribution of others or the dysfunction of the situation.
3. Producer statements often lack clarity as to the scope of the service.
4. There is often insufficient clarity regarding the intended compliance path.

Timber structure

1. Mid-rise buildings are outside the scope of NZS 3604 but often design reliance is placed on NZ 3604.
2. To the extent that NZS 3604 applies, as-built construction is often non-compliant. The frequent example is inappropriate framing size and spacing.
3. Insufficient planning or provision for services installation.
4. There is often insufficient clarity regarding the intended compliance path.

Court judgments

Court judgments are publicly available through Judicial Decisions Online.[10] A search using the words "residential building failure" brought up 597 results. A scan of these suggests not all would be relevant for a building pathology study. Those that are appear to be primarily related to weathertight claims.

Also available is the ability to search decisions from specific tribunals such as the Disputes Tribunal. A scan of available decisions found one where an insurance company was ordered to pay damages related to "water entering the kitchen timber board ceiling which is directly below an internal tiled deck. There is ply on the joists above the ceiling, then a fiberglass waterproofing systems and tiles ... The cause of the leak was from damage to the fiberglass waterproofing membrane."[11]

This information is publicly available, and while it may take time to determine an effective search and coding methodology, there is likely to be value in doing so. Over time, monitoring this source would not necessarily be onerous.

Media reports

Regular media scans as part of a monitoring regime could be useful in indicating potential concerns across the industry. Such scans are often undertaken by information teams in government departments.

A brief scan of media reports and articles through Google found a variety of reports related to housing defects and problems across the building sector.

Headlines included the following:

- Problems with Christchurch repairs
- Commerce Commission to take three firms to court over steel mesh
- Opportunist builders, dodgy steel and shonky standards create new building crisis 'worse than leaky homes'
- $18b construction industry calls for state help to smooth over volatility in sector
- Secret fire-safety deals
- Nearly three-quarters of new homes have defects.

Industry publications

In addition to the published media, a number of industry organisations also include newsletters, editorials, media releases and articles on their websites.

Examples include an editorial by David Kelly available on www.construction news.co.nz. This piece, titled "'We must work together to develop solutions", discusses the need for new ways of operating and new types of buildings.

A second example was found on the NZIBS website. This media release was headed "Shoddy workmanship tip of the iceberg". This discusses the quality of construction in Auckland including concerns around product substitution.

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[10] https://forms.justice.govt.nz/jdo/Introduction.jsp
[11] https://www.disputestribunal.govt.nz/assets/Documents/Decisions/BO-v-YL-2015-NZDT-773-13-April-2015.pdf

Whats On database

This database collates building consent information similar to that reported by Statistics New Zealand. Its main value lies in the ability to monitor trends in building activity including new builds, additions and alterations. As noted in research undertaken by BRANZ (see New House Construction Quality Survey 2014 in Appendix B), capacity is a key issue in the current New Zealand environment. The database contains the following information:

- Local authority
- Consent number
- Issue date
- Sector (residential/commercial)
- Type (new/adds/alts)
- Description
- Dwellings
- Floor area
- Value $
- Address
- Builder name
- Owner name.

The level of detail in the description column is variable, as it is with all consent data. Examples of actual entries:

- Add to existing dwg & add gas fire
- Gge
- Internal alts to existing dwg & replace sfh
- Erect a 3 bdrm dwg with attached gge
- Farm shed for accessory storage
- New single level dwg with attached gge & sfh
- Relocate transportable home office
- Replacement of school swimming pool fence
- Remove existing doors & fit new ranchslider
- Single storey dwg with 4 bedrooms & an attached gge.

Appendix C: Cross-walk of information sources, topics of interest, access and value

The cross-walk in the following table has been developed from a limited knowledge base, and more work would be required to ensure it is complete and accurate. It should be primarily viewed as indicative of what should be done when developing an analytical framework.

This is not a complete summary of all possible research. For example, MBIE routinely undertakes research projects, as do academics. One of the first tasks would be to consider in more detail the parameters of the research to be included. This would involve looking beyond what was done for this report.

Source	Content				Access	Value	Limitations
	Defects	**Materials used**	**Sector capability/capacity**	**Occupant behaviour**	**Access**	**Value**	**Limitations**
House Condition Survey (BRANZ)	Describe condition of house and defects found in all key components	Materials used in key components – direct link to defects			High	High	Sample size
New House Owners' Satisfaction Survey (BRANZ)			Number of call-backs for particular trades, overall satisfaction with builder		High	Medium	Detail of reasons for call-back not included, response rate
Physical Characteristics of New Houses (BRANZ)		Materials used in key components of new houses – identify trends			High	Medium	Response rate
New House Construction Quality Survey (BRANZ)	Inspections and identification of defects at key construction stages		Problems experienced by builders, identifies failing in work across three sector groups		High	Low	One-off survey – would need to be repeated annually

Source	Content				Access	Value	Limitations
	Defects	**Materials used**	**Sector capability/capacity**	**Occupant behaviour**	**Access**	**Value**	**Limitations**
Medium-density housing research programme (Levy funded)	Fire spread from lower roofs	Testing of claddings	Potential construction problems associated with designing and building MDH		Medium	Low	Likely to be small studies and one-offs
Exceeding the minimum research programme (Levy funded)			Attitudes and behaviours of the industry with regard to quality and acceptance of defects	Attitudes and behaviours of homeowners with regard to quality and acceptance of defects, identification of quality issues of most concern	Medium	Low	Likely to be small studies and one-offs
Eliminating quality issues (Levy funded)	Identification of quality issues of most concern with regard to building's long-term durability and sustainability				High	Low	Likely to be small studies and one-offs
Warmer, drier and healthier buildings	Extending current database on airtightness in homes built since 2010				Medium	Low	One-off study and limited sample
Building surveyor reports	Detailed defects information	Will contain information on materials used			Unsure	High	Most detailed information on failure
Court judgments	Reasons for claims	Could include if materials the issue	Could include if claim is about builder capability		Medium	Medium	Legal language to navigate
Media reports	High-level comment dependent on subject	High-level comment dependent on subject	High-level comment dependent on subject	High-level comment dependent on subject	High	Low	Subjective limited content

Source	Content				Access	Value	Limitations
	Defects	**Materials used**	**Sector capability/capacity**	**Occupant behaviour**	**Access**	**Value**	**Limitations**
Industry publications	High-level comment dependent on subject	High-level comment dependent on subject	High-level comment dependent on subject	High-level comment dependent on subject	High	Low	Subjective limited content
Whats On database	Work done may indicate a prior defect		Capacity issues identified through quantity of work		High	Medium	Limited information
BRANZ helpline and Appraisal applications		Material use and potential substitution	Capability based on queries		High	Medium	Unsure of detail available
Determinations data (MBIE)			Concerns with capability		Low	Medium	Potentially only a few instances
LBP complaints			Concerns with capability		Low	Medium	Potentially only a few instances

Appendix D: International examples

The Danish Building Defects Fund

The report this information has been taken from is based on a case study undertaken in one housing project (Olsen et al., 2010). The purpose of the case study was to show the deficiencies and building damage that could be registered 1 year and 5 years after construction has been completed. It included the cost of repairs and explored how inspections of finished buildings could be used in new construction.

The Danish Building Defects Fund is the primary source of information on the building quality of Danish subsidised housing. For all new housing built with public financial support, 1% of the building costs including site costs is paid to the fund. Part of the payment is used for inspections 1 year and 5 years after a house is handed over. Approximately 250 independent firms carry out the inspections. The rest of the fund is used as insurance against building defects.

The formal inspections have enabled the establishment of rapid and effective feedback of knowledge and experiences concerning building methods, components and materials. Inspections have been carried out on approximately 205,000 dwellings since 1986. The inspections report the condition of all parts of the building that are essential for the lifetime of the building. They are assessed against laws and regulations, and any defect or damage is identified.

As a result, the fund has developed an extensive knowledge base regarding defects in housing. This knowledge is disseminated to the industry and clients. Where necessary, the fund also publishes warnings about specific methods, components or materials. It is estimated that the dissemination of information has reduced repair costs by at least DKK100 million per year. Further, the number of estates with defects has reduced from about 30% to 4%.

Elios II Building Pathology data submission

The following table is an extract from the Elios II Building Pathology database (see http://pathologydirectory.elios-ec.eu/pathologies#) reporting on fire in photovoltaic units.

Building pathology form
Name of the pathology case provider: BBRI
Date of filling in this pathology record: 01-03-2014
Source
Type of source for the description of the pathology case: Based on literature, research papers, defect information sheets, websites, etc...;
Name/title of the source: www.vwa.nl "NVWA warns for flammable solar panels"
Construction work where the eco-technology is installed and the defect/failure occurred
Name of construction work or project: 15 known cases in the EU
Country or countries: France; Germany; Netherlands
Is the town where the construction work or project being executed known: Yes
Town where the construction work or project is executed: 15,000 installations placed in EU
Geo-climatic character: Don't know
Type of construction work
• New; Existing

- Individual housing/dwellings
- Building without or with minor extrinsic/intrinsic risks

Starting/end date of the work: 01-08-2009 / 01-02-2012

Has the construction work or project been completed ? Yes

Was there a completion survey? Don't know

Was a Technical Inspection Service (TIS) contacted? Don't know

Eco-technology

Type of eco-technology involved in the defect/failure: photovoltaic panels (PV's)

Specific type of eco-technology: Polycrystalline Superimposed PV panels, Types Multisol P6-48, P6-54, P6-60 and P6-66, supplied in the period August 2009 to February 2012 by Scheuten Solar Systems.

Description of the defect/failure

Approximated year of defect/failure/damage: 2012

General description of the defect/failure: In these solar panels there is a faulty electrical connection that is flammable. These solar panels have caused 15 roof fires in several EU countries. A cable in the junction box behind the solar panel makes a poor contact with the PCB. This may cause sparking.

Type of defect/failure:

- Defect or failure of materials

Defective building component:

- Other

Other type of defective component: Power supply of PV-panel

Failed building component: Other component, namely...,

Description of the consequences/effects of the defect/failure:

- Material damage to the eco-technology itself
- Material damage to the building

Was the defected product repaired or replaced? Not yet

Has the cause of the defect/failure been analysed, or is it known? Yes

If yes, what has been the cause (global or in detail)?

- Other cause for defect/failure

Other, please describe the cause: Faulty electrical connection in the junction box behind the PV-panels causes sparks and makes the housing of the terminal box melt and smoulder. The risk increases as the sun gets stronger or as the PV-panels age.

Quality signs and qualifications

Were there quality signs in place at time of construction? Yes

Type of quality signs related to the eco-technology:

- Don't know

Name of quality signs: don't know

Is the contractor/installer specialized in that technology? Don't know

Lessons learned

For now a good solution hasn't been found. When a save method is available the NVWA will post it on its website www.nvwa.nl. Owners of the PV installations are to be advised to contact a installer and to have their installation safely turned off by an installer

Other comments or remarks

The manufacturer went bankrupt and neglects to take appropriate measures and/or responsibility in this case.