buildings

MDPI

Article

Post-Construction Defects in Multi-Unit Australian Dwellings: An Analysis of the Defect Type, Causes, Risks, and Impacts

Michael Denman [1], Fahim Ullah [1,*], Siddra Qayyum [1,2] and Oluwole Olatunji [1]

[1] School of Surveying and Built Environment, University of Southern Queensland, Springfield Central, Ipswich, QLD 4300, Australia; siddra.qayyum@unisq.edu.au or sqayyum@bond.edu.au (S.Q.); oluwole.olatunji@unisq.edu.au (O.O.)
[2] Faculty of Society & Design, Bond University, Robina, Gold Coast, QLD 4229, Australia
* Correspondence: fahim.ullah@unisq.edu.au

Abstract: Due to the rising prices of houses and rent, apartment buildings have become the preferred and most utilized dwellings in Australia. However, there have been cases of serious defects in multi-unit dwellings (apartment buildings), posing various risks to and reducing potential residents' confidence in such dwellings. To address this issue, the current study investigated the types, causes, risk severity, and impacts of defects on residents in mid- to high-rise multi-unit dwellings in Australia. The study utilized a mixed approach involving quantitative (online questionnaire) and qualitative (interviews) methods. Data were collected from 104 apartment building residents in Brisbane, Queensland, Australia, with support from interviews with six experienced local construction professionals. The results revealed that there are 11 key defects present in local apartment buildings, with waterproofing, internal finishes, and structural issues being the most frequently reported. Residents typically report these defects to building owners, agents, and managers, who take more than three months, on average, to rectify them, adding to the residents' psychological issues and their inability to use the property as intended. The reasons for the delayed rectification of defects include non-responsive owners, agents, and building management teams, scheduling conflicts, litigation, and high costs. The interviewed professionals acknowledged the presence of defects and identified the reliance on Design and Construct (D&C) and fixed price contracts, lack of public awareness, and absence of a system to capture builders' reputation, as well as a manipulative quality check system, as key reasons for defects. This study addresses the defect concerns in multi-unit Australian dwellings (apartments) and expects to spark a much-needed debate around reforms in the construction sector to address these issues and minimize their risks and impact on residents.

Keywords: apartments; Australia; construction defects; high-rise units; risks

Citation: Denman, M.; Ullah, F.; Qayyum, S.; Olatunji, O. Post-Construction Defects in Multi-Unit Australian Dwellings: An Analysis of the Defect Type, Causes, Risks, and Impacts. *Buildings* **2024**, *14*, 231. https://doi.org/10.3390/buildings14010231

Academic Editor: David J. Edwards

Received: 9 December 2023
Revised: 6 January 2024
Accepted: 10 January 2024
Published: 15 January 2024

1. Introduction

Apartments have become an increasingly prominent feature of Australia's annual construction of dwellings [1]. According to Shoory [2], the number of apartment constructions in Australia remained stable for 15 years up to 2009 before experiencing a significant expansion in the years since. The Australian Bureau of Statistics [3] also reports an 81.7% increase in apartment commencements between the 2004-05 and 2018-19 financial years. Much of this increase has occurred in mid-rise, high-rise, and super-high-rise apartment construction, as depicted in Figure 1. Therefore, apartment buildings constitute a significant and growing aspect of Australia's construction sector and dwelling composition. The industry also contributes significantly to the Australian economy, accounting for approximately 11% of the country's gross domestic product (GDP), and employing approximately 9% of the workforce [4].

Despite the growing importance of apartment buildings and dwelling composition in Australia's construction sector, construction defects are rising [5]. Common apartment

defects include water ingress, cracking, poor energy consumption, and noise insulation [6]. Several high-profile residential apartment projects, such as Opal Tower and Mascot Towers in Sydney, have experienced significant defects, garnering widespread media attention and bringing the issue to the public's attention [7,8]. Safety concerns ultimately led to the evacuation of residents in both towers, with far-reaching implications for owners, industry, and regulatory bodies. Samples of the discussed damages can be seen in a report on Opal Towers as published by Hoffman et al. [7].

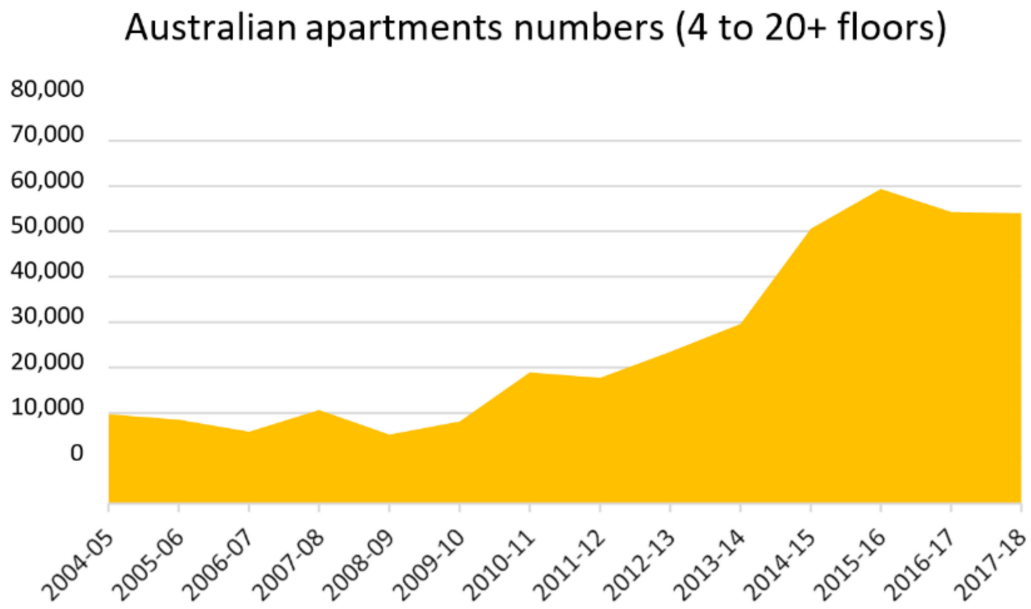


Figure 1. Australian apartment buildings four stories and greater (Source: ABS [3]).

A similar issue occurred with the fire incident at Grenfell Tower in the UK, which uncovered widespread flammable cladding issues in structures in the UK and throughout Australia during local investigations [9]. These issues prompted several investigations and reports into the Australian construction sector, highlighting various issues contributing to poor-quality outcomes for owners and residents. As a result, confidence in the apartment construction industry and the buildings themselves has diminished, which may further erode investor and potential residents' confidence if these issues are not addressed promptly.

The impetus for this study is in line with the concerns of the Australian construction sector, as defects appear to be widespread and growing in mid-rise and high-rise apartments [1]. The objective is to thoroughly examine the multi-unit Australian dwellings (apartments) industry, identifying and reviewing the defects, their causes, severity, impact, and contributing factors. However, as noted by Crommelin et al. [10], little research has been conducted on apartment defects, in contrast to the house-building sector. Given the changing trends of home ownership where more people prefer apartments to live closer to cities [11], increasing house prices, and associated unaffordability in Australia [12], more research is necessary in this area to ensure the sustainability of apartments as a viable housing option for the country's growing population.

Identifying the causes of defects can offer several potential benefits, including raising awareness of their prevalence and helping to focus targeted efforts on reducing their frequency and severity in Australian apartment buildings [1,5]. The study collects and investigates defect information and relevant data from the residents' (as end-users) perspective because they are best positioned to notice how the apartment performs its necessary functions [13]. Any limitations in the performance or function of the apartment will have the most significant impact on the residents. While the high-profile defect examples men-

tioned earlier are major in nature, minor defects are also widespread and will also be a focus of this study.

This study aims to identify the types of defects occurring within Australian apartments through a combination of historical and new defect data collection. The study also seeks to evaluate the severity and impacts of these defects by gathering data from both apartment residents and service providers. The study's primary objectives are as follows:

1. To review and classify the various types of defects observed in multi-unit Australian dwellings.
2. To capture the residents' perspective of defects in multi-unit Australian dwellings.
3. To identify the causes and severity of defects in multi-unit Australian dwellings and evaluate their impacts on building residents.

Although there has been a growing interest in investigating the area of apartment defects in Australia, there has been little research on the types of defects commonly identified, their severity, and their impacts on apartment residents. This highlights the novelty and necessity of conducting the current study, which focuses on apartment buildings four stories or higher, with increased complexity relating to structural loads, utility services, and materials, which can increase the likelihood of defect creation. Moreover, commercial pressures related to time and profit can incentivize activity in constructing these buildings, leading to substandard outcomes [14]. Lastly, these dwelling types are often sold sight unseen to buyers, limiting the ability of prospective purchasers to inspect or gain an in-depth understanding of what they are purchasing or monitoring the works as they progress [15].

Through an investigation of local apartment defects, it is possible to determine the best course of action for future work with targeted defect reduction activities [1]. Industry professionals can also gain a greater insight into where to focus their managerial and quality assurance efforts for the greatest effect. Furthermore, by highlighting the issues most frequently noted by residents, efforts can be focused on improving customer satisfaction for developers and building management professionals. The data will also represent the defects that residents notice most regularly, as well as those that have the largest impact on their habitation of a property.

2. Literature Review

Selecting a suitable definition for "defect" is crucial in a study dealing with identifying defects and analyzing their types, causes, risks, and impacts (likelihood and severity). In risk management literature, the likelihood refers to the chance or probability of occurrence of an event, and severity refers to the amount of damage or harm a hazard could create.

Different stakeholders involved in the construction and operation of buildings may have varying perceptions of what constitutes a defect. In this study, it was found that the definition provided by Watt was the most frequently referred to in the reviewed literature. According to Watt [16], a defect is a term used to describe a failing or shortcoming in the function, performance, statutory, or user requirements of a building. Defects may manifest themselves within the structure, fabric, services, or other facilities of the affected building [17].

The current research focuses on defects within dwellings commonly referred to in Australia as apartments or flats. These dwelling types share common characteristics, such as not having private grounds and usually sharing a common entrance foyer or stairwell [18]. However, the construction methods used in building apartments are unique and require separate consideration when it comes to addressing defect issues compared to other types of dwellings, such as freestanding houses, terraces, or townhouses [1,5].

The published literature has identified several key concepts related to quality issues in residential apartment buildings. Atkinson [19] and Qin and Stewart [20] examined how human errors contribute to defects and identified two areas requiring further research: forms of communication and the qualities of managers. Atkinson [21] created a conceptual model demonstrating the differing effects, timeframes, and impacts of "Primary" errors caused at the defect location, more remote project factors identified as "Managerial" and

"Global" factors within which the project operates. The managerial factors relating to communication were highlighted as the highest-ranked cause of defects, followed by time pressures and correlated issues with poor formal communications between the study and other prior research.

Josephson and Hammarlund [22] followed seven building projects to determine the causes of observed defects. They found that a lack of motivation and knowledge were major contributing factors to defects. Aljassmi et al. [23] presented a method for determining the importance of defect causes to prioritize defect prevention efforts. As defects can have many causes, it may be necessary to rank these causes in importance. The pertinent study used importance measures and fault trees, looking at the frequency and severity of causes to rank the project defects and associated risks.

In Australia, with a focus on multi-unit dwellings and defect issues within them, the pertinent literature review has identified three comprehensive studies. Firstly, Johnston and Reid [24] investigated the defects in multi-owned properties, with a focus on their impacts, the construction regulatory environment, and how these defects are managed. As part of their research, building audit reports were collected to identify the defects occurring in these dwelling types. The study found that the building fabric and cladding were the building elements most impacted by defects, followed by fire protection and waterproofing. It also developed a building defects categorization model to analyze the collected data.

Another Australian study [25] focused on issues relating to strata management to manage construction defects. The study noted major concerns with the impact of defects on strata communities, issues relating to responsibility limit identification due to complexity surrounding shared boundaries, information management, and issues relating to the funding and planning of long-term maintenance activities for buildings. Additionally, the study noted issues relating to timely access to information for apartment purchasers, which persist for owners after handover.

The third study [10] found a high incidence rate for defects in apartment buildings and looked at defect types. The study noted that issues relating to water ingress and structural issues were the most common defect types. It also identified significant issues surrounding the availability of information for prospective apartment purchasers, regulation issues, and broader issues around information for the industry.

2.1. Common Defect Types, Causes, and Contributing Factors

Foster et al. [1] pointed out that there has been limited research conducted to produce a comprehensive list of defects and their causes in apartment buildings. Nevertheless, Georgiou et al. [26] attempted to develop a system for classifying defects, consisting of 12 categories of defects, including drainage, external leaks, and structural adequacy, as well as 35 building system components grouped into eight broader categories by trade (such as carpentry and plumbing). Although this example primarily concerns residential home construction, similar efforts have been undertaken for larger apartment buildings. Johnston and Reid [24] established a defects matrix for apartment buildings by examining building defect reports and defining types of defects based on 13 construction systems, such as building cladding, fire protection, and structural elements.

Construction defects can have various causes [27]. Josephson and Hammarlund [22] monitored seven building projects over six months and collected data on almost 3000 defects. They found that attributing the causes of defects can be challenging, as direct causes are often assigned to individuals who work under the influence of broader project conditions. The authors also noted that individuals typically have the necessary knowledge and information but may lack the motivation required to prevent defects. Atkinson [21] examined the relationship between human error and defect creation and identified a link between defects and management methods. The author identified human error and environmental exposure as the two primary causes of defects in completed apartment buildings. Jingmond and Ågren [28] also recognized the impact of the project delivery environment, recommending that defect prevention efforts should focus on the managerial and strategic levels

of project delivery rather than individual levels. Furthermore, wider industry trends such as a 'boom' period can also influence the incidence of errors, as evidenced by the significant increase in the volume of unit construction [5].

Forcada et al. [29] have highlighted that the Spanish housing industry experienced a boom in the late 1990s and early 2000s that led to substantial inexperience in the industry, resulting in declining quality and increased defects. Chong and Low [30] assessed defects in apartment building construction and occupancy stages and found that construction-stage defects were related to workmanship and protection issues during construction. Material defects were more likely to be observed during occupancy due to development time, and maintenance issues were mainly related to floor defects post-occupation. Chong and Low [31] investigated the causes of latent building defects and reported that a lack of design feedback and reluctance to adopt new methods contributed to defects. Zalejska Jonsson and Hungria Gunnelin [32] captured the defects in newly constructed residential buildings from the owners' perspective and reported waterproofing and weatherproofing as the key issues, followed by HVAC.

Similarly, Crommelin et al. [10] have observed that the construction and delivery methods for apartment developments can lead to the creation of defects. The key issue identified is that buyers of apartments have minimal input or oversight during the construction process. Instead, they must rely on government agencies, private certifiers, and subcontractors to ensure that the work is completed to the required standards. The study also emphasized that buyers have limited access to information, making it challenging to identify quality issues within the property. Table 1 summarizes the primary causes of defects in apartment buildings identified from selected studies.

Table 1. Key causes of defects in apartment buildings identified from selected studies.

Causes	[22]	[21]	[33]	[28]	[29]	[10]	[31]	[34]	[24]	[35]	[30]	[32]
Project environment	X											
Organizational culture										X		
Commercial Pressures									X			
Exposure (environmental)			X								X	
Design and Constructability							X					X
Material quality					X					X		
Motivation	X				X			X				
Management Strategy		X		X				X				
Workmanship								X		X	X	
Time Pressures		X			X				X			
Human error	X		X						X	X		
Limited Information Sharing					X	X		X				X
Poor Communication		X			X	X		X				X

The summary of defect causes identified poor communication, limited information sharing, and human error as the primary causes of apartment defects, as evidenced by Table 1. This is because these defects are reported by a majority of the reviewed studies. The literature review extensively covers the issues of limited information sharing and management within the industry. Poor communication is often linked with these issues and can be observed at all levels of a project—local, managerial, or within the broader environment in which the project is undertaken. Human error as a cause is primarily analyzed at the local level, where the defect physically manifests. However, human error can also occur within the project and company structure. Other common defect causes identified were time pressures, workmanship, management strategy, and motivation. In the

apartment sector, time pressures are a factor, given the high proportion built by developers for profit and the high levels of repeatability in work. Work is priced on small margins, and time savings across large numbers of apartments can be the difference in a subcontractor making or losing money on a project. This issue can also impact workmanship, which is further exacerbated by the apartment boom and the strain it has put on the available skills and experience in the industry. The limited oversight from the industry itself, regulators, and eventual owners also contributes to this issue. Furthermore, the high volume of work and time pressures can lead to reduced motivation for project team members, while the high demand for staff in the sector can allow staff with lower motivation or poorer workmanship to maintain work more readily or to change employers if required.

2.2. Recent Cases of Defective Multi-Unit Dwellings in Australia and Governments' Response

In recent times, high-rise residential apartment buildings in Australia have faced incidents of defects, including major structural issues in Opal Tower and Mascot Towers in Sydney. Crommelin et al. [10] note that while the New South Wales government was aware of issues within the apartment building sector, noteworthy regulatory change was not initiated until after the Opal and Mascot Tower incidents occurred.

Mascot Towers, a 10-story residential tower located in the Sydney suburb of Mascot, was constructed in 2009. In 2019, during an engineering inspection, significant safety concerns for residents were identified due to structural defects within the building, including cracking in the structural elements [8]. As a result, the building was evacuated and remains vacant to date. While technical reports commissioned to investigate the cause of the defects at Mascot Towers have not been made public, it has been reported that cracking occurred in the building's key supports [10]. The building was outside of the statutory warranty period, which typically covers such buildings for up to 10 years, due to its age.

Furthermore, the developer had already declared bankruptcy due to financial issues before discovering the major defects in Mascot Towers. As a result, residents had limited options for addressing the building's defects and were unable to occupy the property. To assist the owners and residents of the tower, the NSW Government implemented an assistance package that covered emergency accommodation costs until the building's rectification works could be completed. However, legal issues related to the development have slowed down the resolution of the defects and the reoccupation of the building.

Opal Tower, a 36-story residential building located in Sydney's Olympic Park, was completed in August 2018. In December 2018, a loud cracking noise was heard by residents, and a subsequent inspection revealed a significant structural defect in the building [7]. As a result, nearly 3000 residents were evacuated due to fears of a potential collapse. This event prompted the NSW Government to commission an independent report to investigate the cause of the issue and recommend ways to prevent similar incidents in the future.

The government-commissioned report revealed that the major structural defects were caused by design and construction issues [7]. Specifically, hob beams in the building were under-designed, shortcuts were made in construction processes, and material deficiencies were also found to contribute to the failure. The report [7] recommended five key actions to prevent future incidents, including registering engineers through a government database, conducting third-party checks of designs and design changes, ensuring that construction adheres to design specifications, creating an online system to detail building certifications, and establishing a review board to investigate and report on any structural damage caused by design and construction.

The Australian government has produced numerous reports on quality issues in the construction industry since compliance and enforcement problems were brought to light by the Grenfell Tower fire in the UK in June 2017. The fire was partly attributed to the use of flammable cladding, which allowed the fire to spread [9], leading to an investigation into similar cladding products used in commercial and residential buildings across Australia. The second phase of reports was commissioned after the Opal Tower and Mascot Towers in Sydney experienced significant structural issues. A review and summary

of these government reports, which were produced over the previous five-year period, are discussed below. One such report was commissioned by the Australian Senate in June 2015 to investigate issues of non-conforming building products. The Economic References Committee updated the report requirements in August 2017 to include an interim report on issues of flammable cladding. The report made eight recommendations, including bans on specific cladding products, the creation of a national licensing scheme, and making Australian standards and codes available free of charge [36].

Additionally, several state government reports were commissioned on non-compliant flammable cladding issues. These included the 2017 Victorian cladding task force report [37], the 2018 Tasmanian aluminum composite panel audit [38], and the 2018 Queensland non-conforming building products audit taskforce status report [39]. These reports provided recommendations on establishing registers of buildings with flammable cladding issues and helped create regulatory frameworks to facilitate and deliver the remediation works required for government and private buildings.

In June 2017, the Building Ministers Forum (BMF) commissioned a report to review the implementation of the National Construction Code, with a particular focus on compliance and enforcement issues. The BMF oversees matters related to regulation and policy creation for the Australian construction and building sector. The report consulted federal and state governments and other stakeholders, and it provided twenty-four recommendations across ten themes. The themes included improving accessibility and sharing of building information, enhancing training and registration of building professionals, and strengthening regulatory oversight [40].

Another report was jointly undertaken by the NSW State Government and the Strata Community Association of NSW in late 2021 [41], which aimed to review serious defects in strata buildings completed within the last six years and over four stories in height. The report found that 39% of the surveyed buildings had some serious defect, with waterproofing issues being the most common at 34%, followed by fire safety systems at 20% and structural-related issues at 14%. The report also revealed that 51% of the defects were identified through independent inspections, while 37% were reported directly by residents. The report highlighted the significant financial and emotional impacts of defects and the resolution process for residents, as well as the challenges faced by strata agencies in responding to defects, such as obtaining consensus among owners and dealing with legal challenges. The overall summary of reports looking into building quality issues in Australia since 2017 is presented in Table 2.

In addition to the state government reports responding to the growing issues in the sector, several reports have been completed by researchers, research groups, and industry groups. One such report was commissioned by the Construction, Forestry, Maritime, Mining, and Energy Union (CFMEU) in 2019 [42]. The research identified the cost of rectifying defects in apartments constructed between 2009 and 2019 as $6.2 billion and highlighted that rising insurance costs, cost overruns, and delays related to defects would impede industry activity and growth without immediate action. The report emphasized the role of poor regulatory oversight as a key driver in reducing apartment standards. Additionally, the lack of oversight and prevalence of private certification contribute to outcomes of poor-quality apartments for eventual owners. Other reports, such as those undertaken by Johnston and Reid [24] and Crommelin et al. [10], were also motivated by the observation of these issues in the industry.

Table 2. Summary of Reports on Building Quality Issues in Australia Since 2017.

Report Title	Commissioned by	Date	Aims
Non-conforming building products Interim report: Aluminum composite cladding	Australian Federal Government	September 2017	Investigate non-conforming building products, flammable cladding
2017 Victorian cladding taskforce report	Victorian State Government	November 2017	Investigate non-conforming cladding products on buildings
2018 Tasmanian Aluminum Composite Panel audit	Tasmanian State Government	January 2018	Audit of all aluminum composite cladding in Tasmania
Building Confidence: Improving the effectiveness of compliance and enforcement systems for the building and construction industry across Australia	Building Ministers' Forum (BMF)	February 2018	Compliance and enforcement in construction
Queensland Non-Conforming Building Products Audit Taskforce Status Report	Queensland Government	April 2018	Review potential non-conforming combustible cladding
Regulation of building standards, building quality, and building disputes	NSW Government	April 2020	Flammable cladding, defects response, building certification
Research report on serious defects in recently completed strata buildings across New South Wales	NSW Government, Strata Community Association NSW	September 2021	Review serious defects, buildings >4 stories

3. Research Design and Methodology

The step-wise methodology of the current study is shown in Figure 2. There were three key steps, as shown in Figure 2 and subsequently explained. The first step, the literature review, has been discussed in Section 2 where different data sources, including published articles, government reports, and surveys, were reviewed, whereas the other two steps are presented below.

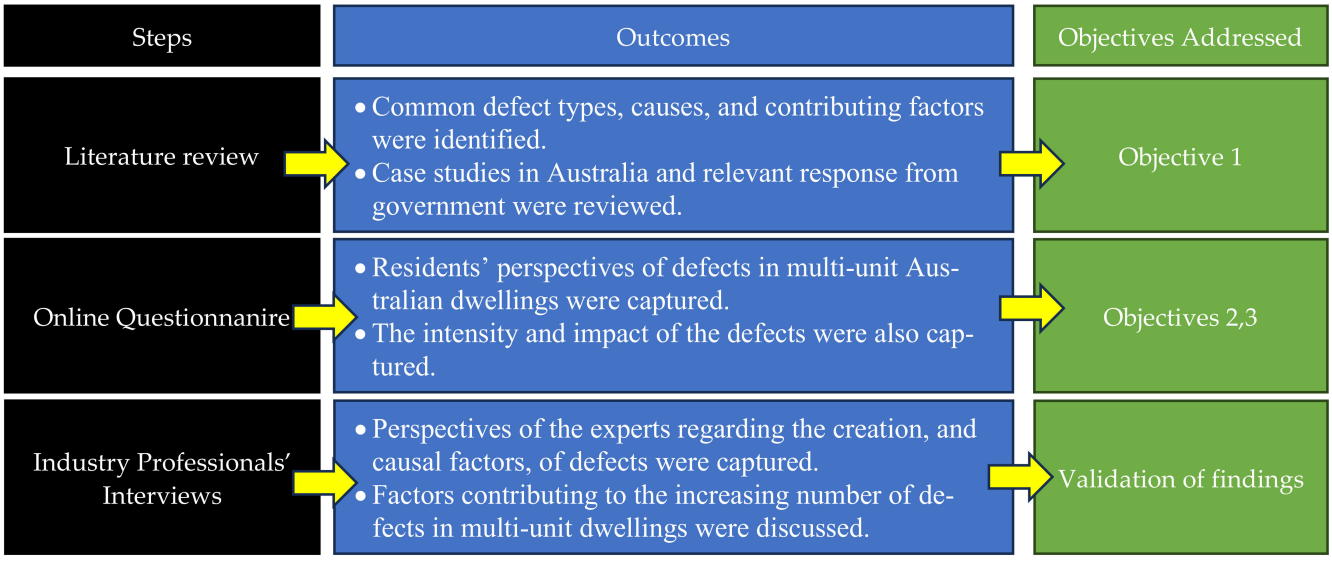


Figure 2. Research steps.

This research employed a combination of quantitative and qualitative methods. An online questionnaire was designed and distributed to increase response rates and accessibility for participants. The quantitative data collected included information about the type, frequency, and severity of defects, which was supplemented with experiential data from the respondents. Additionally, qualitative data were collected from industry experts through interviews, providing additional insights into the complex factors surrounding defects. Mintzberg [43] and Shah and Corley [44] noted that collecting only quantitative data can make it difficult to explain results without additional context, which is why this study also collected qualitative information from industry members involved in the construction and management of the investigated apartment buildings.

3.1. Data Collection through the Online Questionnaire

Various sources were considered for gathering the defect data, recognizing the fact that there is no single repository for collecting information on apartment defects. This information is distributed among construction companies, body corporates, insurers, building inspectors, government agencies, and others. Therefore, this study aimed to obtain access to defect information from all available sources, including previous research papers, apartment residents, and service providers.

Several data collection methods were reviewed for their suitability in obtaining additional defect data, including interviews, case studies, surveys, and observations. The primary objective of data collection was to verify and reinforce any existing defect data to add integrity to the reviewed defects. This review also helped rule out methods such as case studies for the current study and highlight the desired sample size. Additionally, the level of detail required was low, only requiring basic details of each defect, including type and severity. Speed and ease of data collection were also considered, resulting in the selection of a self-completion online questionnaire as the primary data collection component. The outline of the questionnaire is presented in Table 3. The online questionnaire allows easy access and submission of data, as well as the transfer of data back to the investigator, encouraging greater participation. It also allows for the distribution of links to the questionnaire easily through a link or QR code and the collation and extraction of data, promoting ease of analysis.

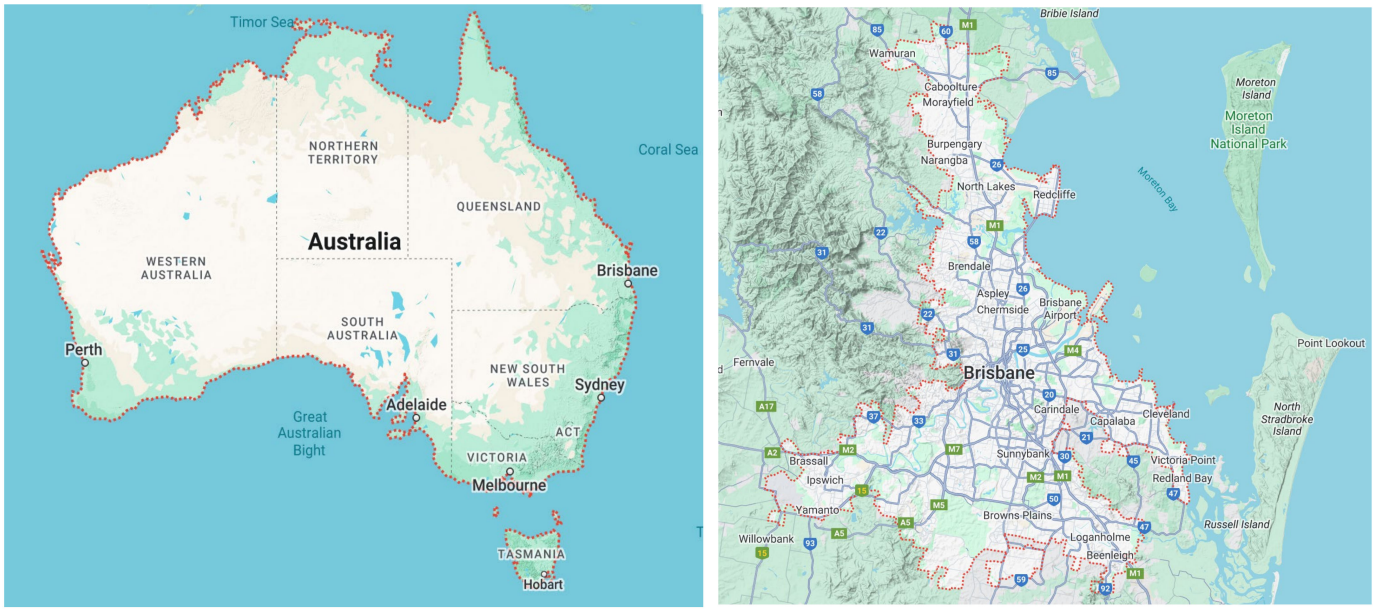
The questionnaire developed in the current study aimed to capture information on the types, frequency, and severity of defects present in apartments. The data were directly acquired from apartment occupants. Since it was assumed that most respondents might lack technical knowledge or understanding of defect types, the questionnaire design included significant guidance regarding defect types and examples with each question to help guide participants. Moreover, open-ended answers were allowed for questions related to defect types, which allowed for greater levels of description from the respondent. The responses were then reviewed and classified using the defect types identified from the literature to categorize the responses received. The lead author conducted the process manually in consultation with other authors.

The main purpose of the questionnaire was to gather information about defects, which made up most of the content and data collected. For each defect reported, seven questions were asked, including a description of the defect, how it was identified, its severity, the impact it had, whether it had been rectified, and if so, the timeframe for rectification. To prioritize future quality assurance and defect prevention efforts, severity-related questions were included in ranking each reported defect. A scoring system was developed based on risk management principles to identify key defect types that require additional focus and quality assurance activities. The scoring system multiplies the likelihood (scale of 0–30) and severity of the risk to provide an overall risk score using the Project Management Body of Knowledge Book (PMBOK) risk management procedures [45,46]. The frequency scores were determined by the reported percentage of defects for each defect type from the questionnaire. The severity of each defect was ranked from negligible (1) to extreme (9), with other options including minor (3), moderate (5), and severe (7). The severity score

is the weighted average of the values assigned by respondents. A linear scale is used to map the severities. The total risk score for each construction system was calculated by averaging the defect risk scores for each type. The likelihood was captured on a scale of 1 to 6, translated to multiples of 5 (5, 10, 15, . . ., 30). Where 1 (or 5 in subsequent graphs) represents the least likelihood and 6 (or 30 in subsequent graphs) represents the highest likelihood. The final likelihood was the average of the values assigned by respondents to each defect.

The remaining questions were designed to provide sufficient insight while keeping the questionnaire concise. Participants were also prompted to report up to three additional defects. Other questions focused on ensuring that the respondents were suitable for the study, that the building was of the correct height and age, and that the participants provided informed consent. Data were also collected on the defect reporting mechanisms and how the owners or managers responded to these defect reports. Therefore, questions were added to determine if the defect had been reported, to whom, whether it had been rectified, and if so, the timeframe for rectification.

Regarding the distribution of the survey, it was crucial to ensure that invitations were targeted to the appropriate demographic to achieve the highest response rate. The literature review highlighted the growth of apartments and its impact on the incidence of defects over the last 15–20 years. Therefore, this study targeted buildings constructed after 2005 and with more than three stories. The Australian Taxation Office (ATO) provided data that showed most new apartments built in Australia during this period were located in the three largest cities—Sydney, Melbourne, and Brisbane (See map in Figure 3a) [3]. Consequently, this study focused on Brisbane (See map in Figure 3b) due to its accessibility, convenience for researchers, and lack of prior investigations compared to Sydney and Melbourne.



(**a**) (**b**)

Figure 3. (**a**) Australian map showing states and major cities, (**b**) Brisbane city (Source: Google Maps, 2024).

Data on apartment buildings meeting the construction date and height criteria were obtained from the development map from Brisbane Development [47]. The map is collaboratively created by a broad user base and provides details for approximately 120 buildings meeting the criteria, totaling almost 16,000 apartments. The data were then extensively cleaned to ensure accurate and consistent information on the type of development, height, number of apartments, completion year, and other critical data.

Table 3. Questionnaire Outline.

Section #	Section Title	Questions
1	Overview and Informed Consent	Questionnaire Overview Informed Consent information
		Do you wish to participate?
2	Apartment Defect Questionnaire—Resident	Do you live in an apartment/unit in a building four stories or higher?
		Have you identified any defects in the property?
		Please provide the approximate age of the building, if known
3	Defect #1	Please select the type of defect.
		How was the defect identified?
		Please describe the severity of the defect.
		Select the impacts the defect has had on you and your occupation of the property.
		Has the defect been fully rectified?
4	Rectified Defect #1	Approximately how long did the defect take to get rectified?
5	Unrectified Defect #1	Have you taken any action regarding the defect?
6	Reported Defect #1	Approximately how long ago was the defect reported?
		What prevented the defect from being rectified?
7	Report Additional Defect?	Would you like to report an additional defect?

In terms of sample size and selection, nonprobability sampling was utilized to limit the potential for selection bias and improve the reliability of any findings [48]. A sampling frame was created using the development data, with each building allocated a number for selection. Simple random sampling was then used to create a list of buildings to be surveyed from the sampling frame. Random numbers were generated using the RAND function in Microsoft Excel Version 2302, which employs a linear congruent generator to create pseudorandom numbers. The sample size was determined using the guidelines outlined by Dillman [49] and Grembowski [50]. With a population size of over 5000 and a +/− sampling error of 10%, a total sample size of 96 was desired. Thus, the online questionnaire, therefore, aimed to exceed 100 respondents.

The respondents of the questionnaire were residents of selected buildings in Brisbane Australia. To qualify as a respondent, it was ensured that the respondents were

- Residents of the selected buildings and not visitors or guests staying temporarily with the main residents.
- Well-versed in the English Language to apprehend the questionnaire.
- Sane adults of 18 years and above age.
- The lead researcher distributed the questionnaire online through the university data collection systems and in person. A list of emails was collected from the building service providers or directly from the residents. Data through the questionnaire were collected from 24 June to 30 September 2022.

3.2. Industry Professional Interviews

While data collection from apartment residents provided information on observed defects, obtaining greater context from those involved in the construction and operation of mid and high-rise buildings can provide insights necessary for interpreting and evaluating the collected data. To obtain this insight, interviews were conducted with six industry experts. This was necessary because the process of building a structure from its initial

concept to its completion and operation involves numerous stakeholders, all of whom have the potential to influence the building's quality.

The purpose of conducting the interviews was to obtain insights into the experiences and perspectives of the experts regarding the creation and causal factors of defects, as well as the broader industry factors contributing to the increasing number of defects and declining apartment quality in recent years. The experts were chosen based on their involvement and knowledge in the design and construction of apartment buildings, allowing them to provide valuable insights into potential issues and factors that may lead to defects during different phases of the building lifecycle.

The interview questions were developed to capture the interviewees' perception regarding the existence of defects, their roles in the development of concerned dwellings, the key reasons for these defects, factors responsible for the defects and their impact on their businesses, and how to reduce the severity and occurrence frequency of these defects as presented in Table 4. The questions were carefully crafted to validate the defects identified from the literature and through the questionnaire survey. The interviewees were allowed to discuss any additional topics not covered by the questions, given the varying roles of the interviewees. All interviewees had direct experience in designing, constructing, or handing over the selected building types and were required to have at least five years of experience in Brisbane-based locations. A total of six questions were asked of six industry professionals who met the selection criteria.

Table 4. Industry Expert Interview Questions.

Number	Questions
1	Do you believe there is a major issue regarding defects in residential apartments?
2	What is your involvement in the development of these buildings?
3	What are the issues you are involved in or aware of that you believe contribute to the creation of defects?
4	What other factors influence the creation of defects?
5	What impact do defects have on your company?
6	What could be done to reduce the frequency or severity of defects observed?

Table 5 provides details of these interviewed professionals, including their designations and project phases in which they were primarily involved. The interviews were conducted remotely, using phone and video conferencing platforms such as Microsoft Teams and Zoom. Conducting interviews in this way minimized issues related to timing, travel, and protocols surrounding access to construction sites. The typical interview time frame was between 20 and 40 min, depending on the interviewee's availability and the depth of response they provided. The interviews were conducted during September and early October 2022. The questions acted as prompts and a rough guide where required, and respondents were allowed to deviate and explore their own topics and themes as desired.

Table 5. Details of interviewed professionals.

Number	Code	Designation	Project Phase
1	INT1	Engineer	Design
2	INT2	Estimator	Tendering
3	INT3	Consulting Engineer	Various stages
4	INT4	Engineer	Design and Construction
5	INT5	Consulting Engineer	Design
6	INT6	Project Engineer	Construction

4. Results and Discussions

4.1. Results of Questionnaire-Based Data

In accordance with the methodology of this study, 104 participants who fulfilled the criteria for the questionnaire were included in the study. This required them to reside in an apartment located in a building with more than three stories and to have identified at least one defect in the property.

In response to the question regarding property defects, 84 out of 104 respondents (81%) reported that they had identified defects in their property. This high rate of defect incidence reinforces the need for the study and provides sufficient data for further stages of the questionnaire. The next question focused on the age of the buildings. This question aimed to analyze whether apartments were more likely to have defects based on age and whether different types of defects were more likely to affect properties of differing ages. The responses provided a good mix of building ages, allowing for analysis between the identified defects for each building age, as shown in Figure 4. The age of the building was assessed, keeping September 2022 as the date of assessment, and the respondents were asked to select the relevant age bracket from the provided options. For some buildings, the age data were obtained from the building service providers; hence the option was disabled for the pertinent respondents. Similarly, where some respondents in the same buildings were unsure of the building's age, the data from other respondents in the same building were used and cross-compared with the data from building service providers. Of the respondents, 32% lived in buildings 20+ years old, which represents those constructed before the apartment boom in Australia; 23% lived in buildings 10–20 years old; and 38% lived in buildings 0–10 years old, representing those built during the boom. However, 7% of respondents were unsure of the age of their building.

The next question of the survey aimed to collect information on the types of defects reported by the participants. Based on the information provided by respondents, 11 defect types were ultimately used to categorize the data. The questionnaire asked respondents to report defects in order of severity, and the section repeated to allow up to three defects to be reported. This was a functional requirement of the platform for the online questionnaire, and thus, the results of all reported defects were combined in this section to facilitate analysis.

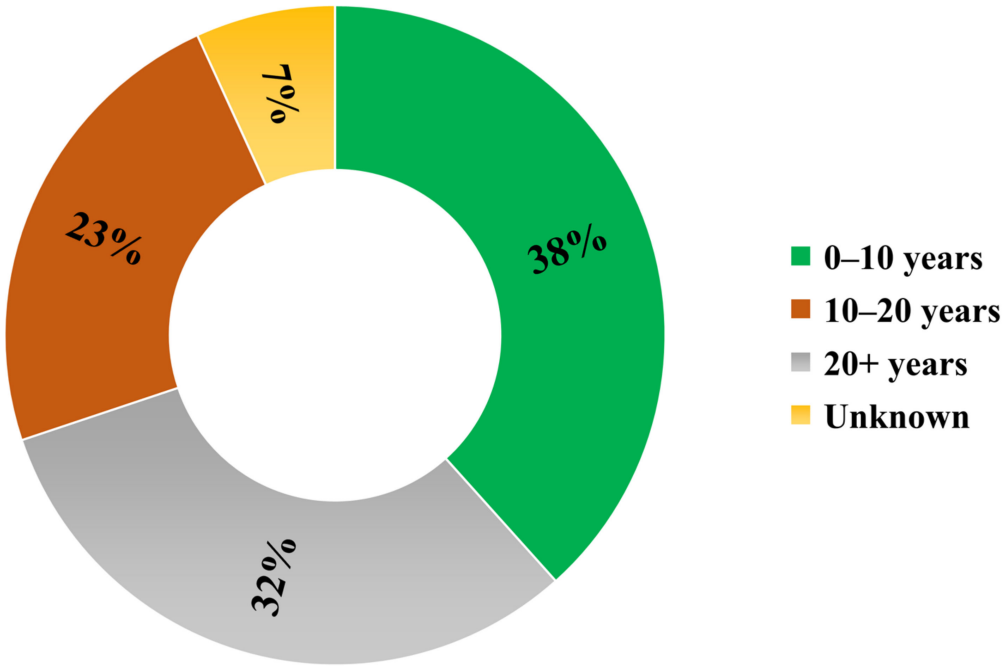


Figure 4. Building's Age.

Figure 5 presents a breakdown of defect types by frequency within each building age category. For most defect types, the variance in frequency by age falls within reasonable expectations. However, HVAC system defects were found to be much more common in newer buildings (0–10 years) reported by five respondents compared to older buildings, i.e., 10–20 years (1) and 20+ years (2). The top three reported issues were waterproofing (reported by 20 respondents), followed by internal finishes (19), and structural issues (17) across all types of buildings. In addition to these, Electrical (14), Hydraulics (12), and Corrosion (11) were also commonly reported, creating a second tier of defect types that require additional analysis. The frequency analysis is used in conjunction with the severity analysis to detail the expected risk from each defect category.

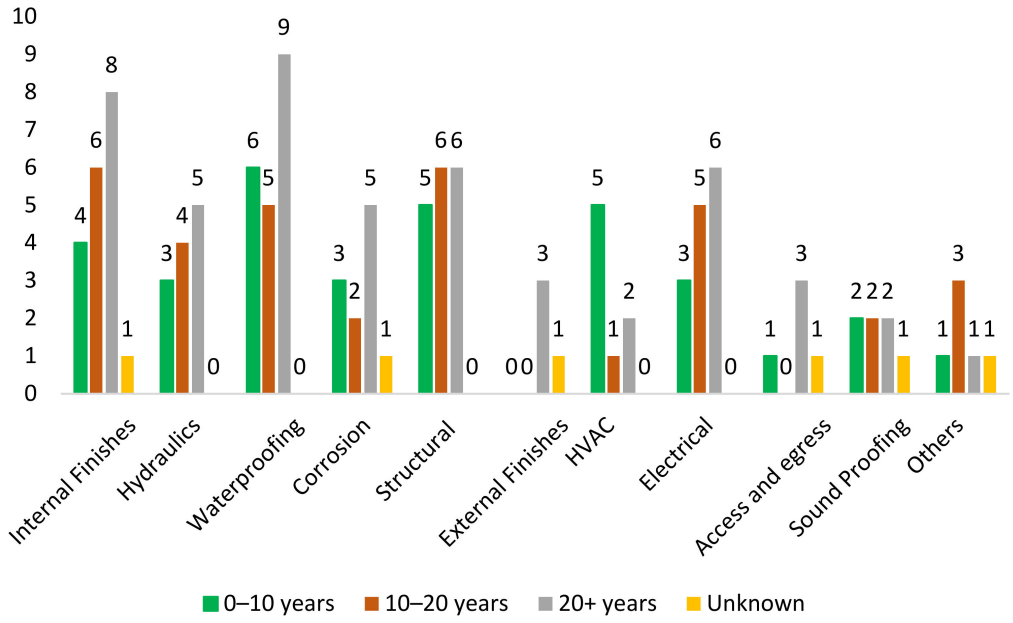


Figure 5. Defect Type by Building Age.

A multiple-choice question was provided to assign severity to each defect, with five severity categories available: negligible, minor, moderate, severe, and extreme. Figure 6 shows the severity reported for each defect type. Common defect types, such as waterproofing and structural issues, had a high proportion of defects identified as moderate or severe, 17 and 16 respondents, respectively. As such, these areas must be targeted for improving the quality of multi-unit dwellings in Australia. While frequently observed, internal finishes did not have a high severity, with ten respondents reporting the defects as negligible or minor. Among the second tier of frequently reported defects identified in the frequency analysis, electrical and corrosion defects had a moderate average severity, while hydraulics defects had just below moderate average severity.

Another question inquired about how defects are typically identified. The method of identifying the defects contributes to further analysis of the actions taken and whether the defect has been rectified. It also demonstrates the typical defect reporting method, which can inform future analysis of the defect lifecycle from identification to rectification. As shown in Figure 7, most of the known defects (89%) were reported by the apartment owners or residents. While it is reasonable to assume that residents and owners are more aware of defects they have reported, this does not eliminate the need for building committees to proactively conduct inspections in buildings and common areas and report their findings.

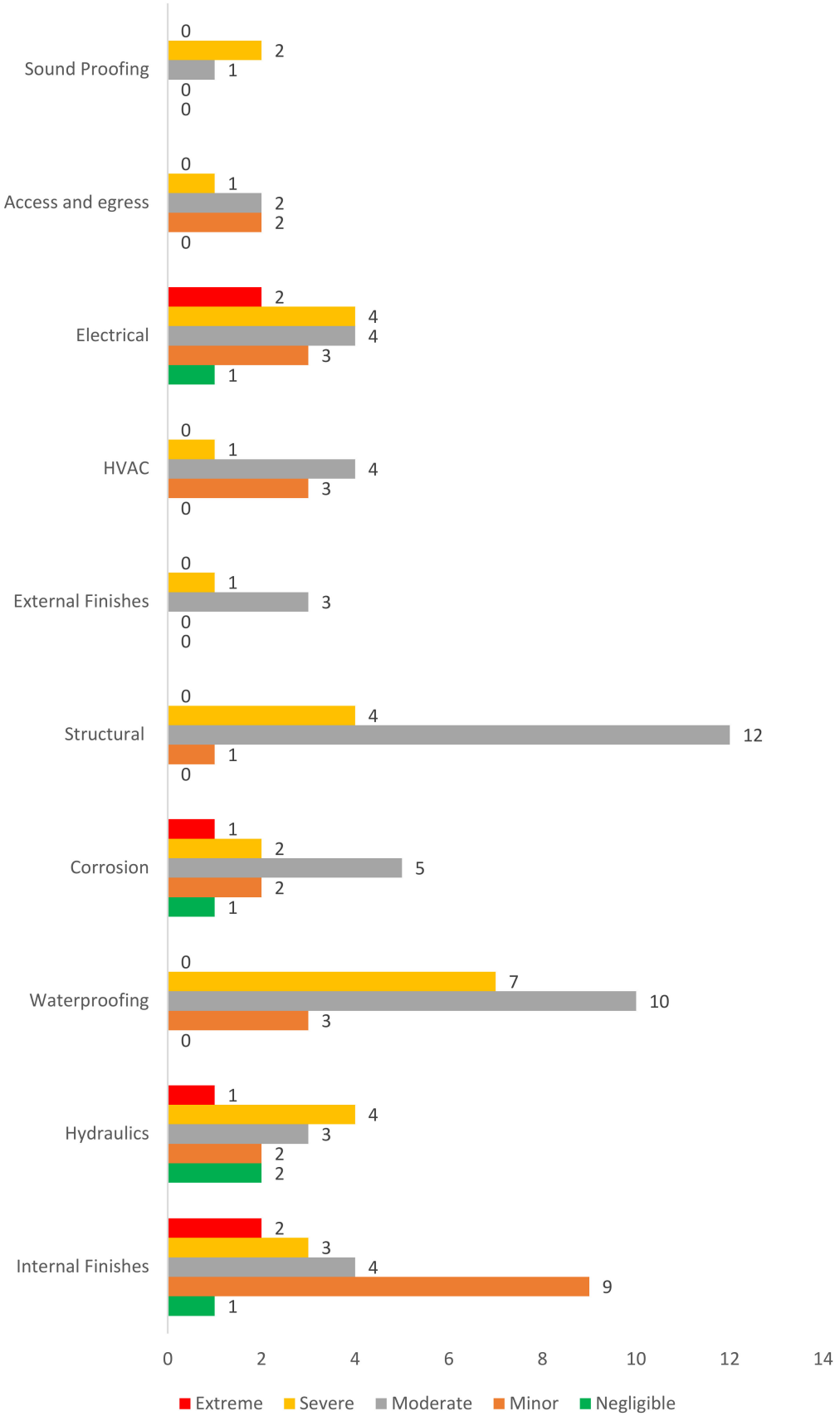


Figure 6. Severity of defects.

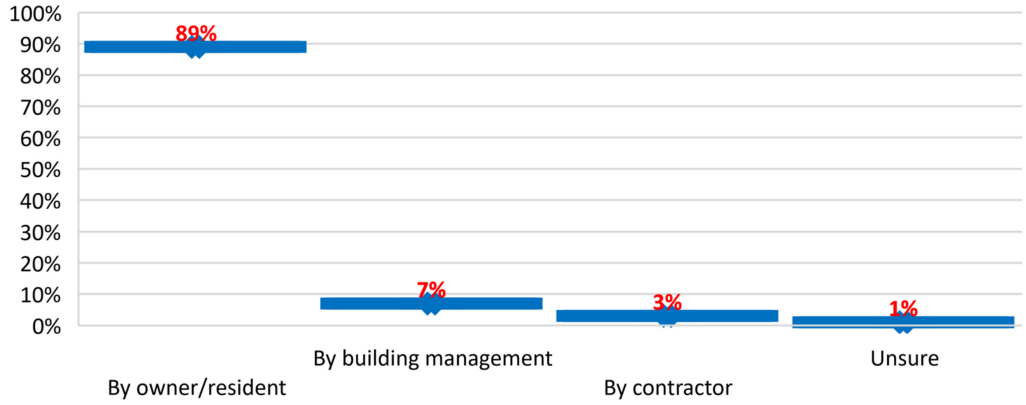


Figure 7. Who identified the defect?

Another question investigated the impact of defects on occupants, taking into account that defects can have not only cost, and property use impacts but also psychological impacts. Respondents were given an opportunity to provide free-form responses to describe other types of impacts. The purpose of the question was to determine how the occupant perceived the presence of the defect and its associated impacts. Multiple selections were permitted, but most respondents noted two types of impacts, as shown in Table 6.

The most frequently reported impact types were property use and psychological, with 50 respondents each. Cost impacts were also reported by 44 respondents. A more in-depth analysis of the subtypes of each impact and their magnitude would be beneficial and should be considered as an area for future research.

The questionnaire also captured information on whether the reported defects had been fully rectified. This information is important as it provides insight into the severity and impacts of the defect as reported by the occupant. Additionally, it allows the questionnaire to be divided into two streams based on the response received. If the defect had not been rectified, the subsequent questions aimed to determine the reasons behind this. On the other hand, if the defect had been rectified, the questionnaire aimed to determine the timeframe within which the rectification works were completed. The purpose of this question was to determine what proportion of defects were being fully rectified. The responses showed that only 26% of reported defects had been fully rectified, while 74% had not been addressed. The high volume of unrectified defects provides an opportunity to gather data on the barriers or issues that prevented their rectification.

Table 6. Types of impacts and their share.

Type of Impact	Count	Percentage
Cost	44	29.30%
Intended Property Use	50	33.30%
Psychological	50	33.30%
Health and Safety	5	3.30%
Time	1	0.70%

The respondents who reported rectification of the defects were asked additional questions to provide the timeframe for rectification works. The timeframes were divided into five categories ranging from within one week to over one year. This question aimed to review the typical rectification timeframes for defects and to analyze whether there were notable variations in this timeframe for different defect categories. The results shown in Figure 8 highlight that electrical and hydraulics issues were typically rectified within one month. However, issues related to waterproofing, and HVAC typically took over three months to rectify. This can likely be attributed to the nature of these defects, with electrical

and hydraulic issues often confined to a single apartment or issue location and thus being readily identified and repaired. Waterproofing and HVAC issues can more frequently relate to issues outside of the apartment reporting the problem, where increased complexity and issues determining responsibility and costs can delay repair works.

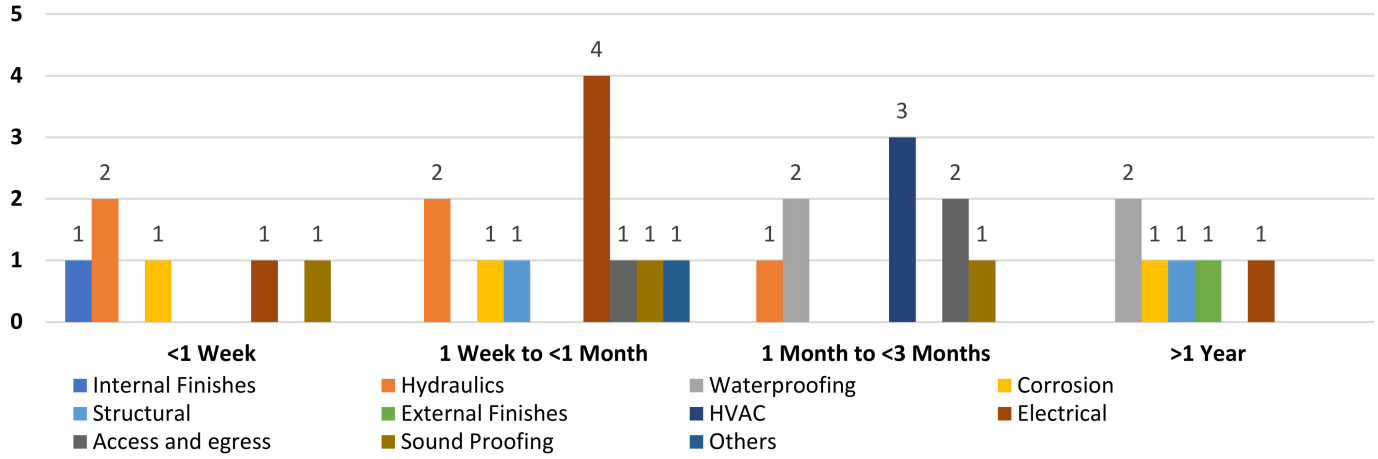


Figure 8. Rectified Defects—By Type and Timeframe.

As previously highlighted, most respondents indicated that the defects had not been corrected. This provided an opportunity to investigate what may have prevented the defects from being repaired. Accordingly, multiple questions were asked to find the underlying reasons. One such question investigated if the reporter had taken any action after reporting the defect. Options were given that the defect had been reported to either building management or a real estate agent, that an attempt had been made to rectify the defect, or that no action had been taken. The question aimed to determine the typical course of action for an apartment occupant upon discovering a defect. Most respondents had reported the defect, with 43% reporting to building management and 19% reporting to their real estate agent. Unusually, 21% had not taken any action regarding the defect, which may be related to defects with insignificant or minor severity. Finally, 17% had attempted to repair the defect themselves.

Furthermore, respondents who indicated that no action was taken were asked to specify how long ago the defect had been reported. Figure 9 presents several timeframe options ranging from less than 1 week to over three months. The responses showed that 71% of the respondents had reported the defect over three months prior. This highlights that potentially greater detail could have been sought in longer timeframes, for example, greater than six months and greater than 12 months, to gain a more comprehensive understanding of the situation.

To provide additional insight, a crosstabs analysis was undertaken to examine how long the defect had been reported against its severity. The purpose was to identify the typical severity of the defects not rectified for over three months. Further investigations into the severity of the defects revealed that more than 82% of the defects reported over three months ago were classified as moderate to extreme. The overall portion of issues reported over three months ago was more than 70%. These findings suggest that most reported issues face delayed rectification, exacerbating the impacts on the residents.

Once it was revealed that most of the reported issues faced delayed rectification, it was natural to inquire about the reasons for such delays. Figure 10 provides the potential causes of inaction reported by the respondents.

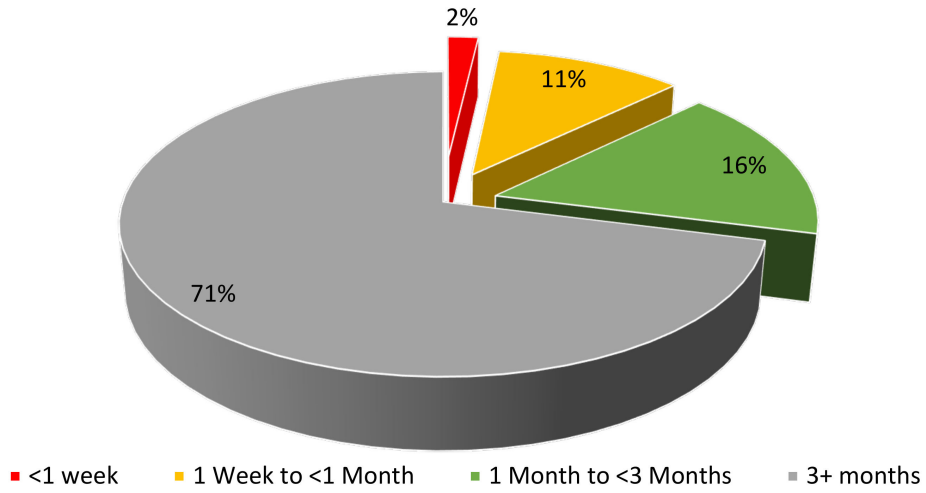


Figure 9. Approximately how long ago was the defect reported?

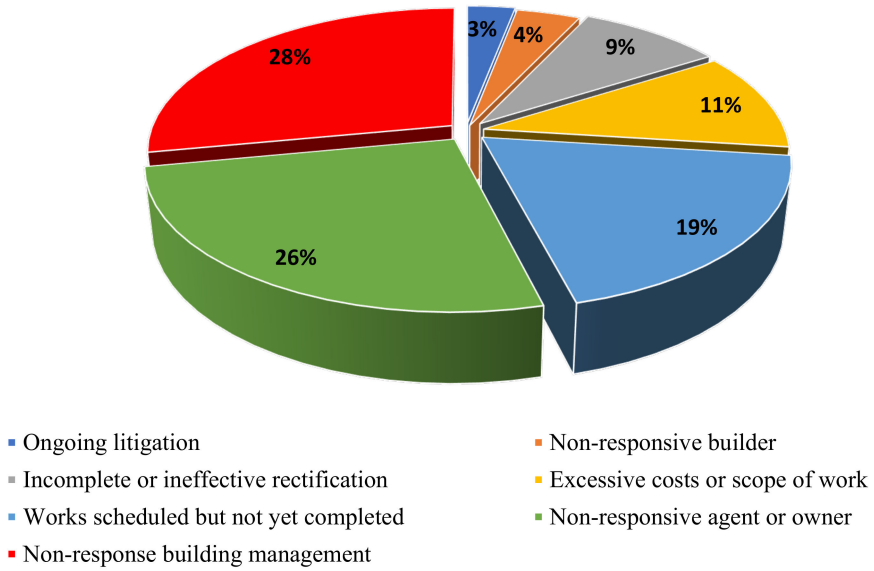


Figure 10. What prevented the defect from being rectified?

Most responses indicated that a lack of response prevented the defect from being rectified, with 28% of respondents pointing to building management and 26% pointing to the property owner or agent as the party not responding. Additionally, 19% noted that works had been scheduled but not completed, which could be considered defects that will be rectified. Finally, 11% of respondents reported that works had been refused due to costs or scope, and future work could delve more deeply into the types of issues that parties refuse to rectify. Other issues can also be seen in Figure 10, including ineffective rectifications, non-responsive builders, and legal issues.

4.2. Risk Analysis of Defects

Table 7 indicates that there are two main tiers of defects. These tiers require targeted focus to reduce their impacts. Given the total possible risk score of 150 (30 for likelihood and 5 for severity, i.e., $30 \times 5 = 150$), the defects can be categorized into three tiers. The first tier with a high score (>100) consists of waterproofing, with a risk score of 108. The second tier, with low medium to upper-medium scores (50–100), consists of structural issues, with a risk score of 77.35, and internal finishes, with a risk score of 56.55. Considering their high frequency and moderate to high average severity, these three defect types ranked

significantly higher than all other defect types. Other defects had lower risk scores, such as hydraulics, with a risk score of 24, followed by electrical, with a score of 22.5, and corrosion, with 20.35. Other categories such as external finishes, sound proofing and access and egress, had very low risk scores. Table 7 highlights the significant risk presented by waterproofing and structural issues, indicating the need for targeted focus and quality assurance activities in these areas. Additionally, internal finishes, hydraulics, electrical, and corrosion issues also present a moderate level of risk, and efforts should be made to address them appropriately to prevent further impacts on residents.

Table 7. Total Defect Risk Scores.

Defect Type	Severity Score	Likelihood Score	Total Risk Score
Internal Finishes	3.48	16.25	56.55
Hydraulics	2.40	10	24
Waterproofing	4.32	25	108
Structural	3.64	21.25	77.35
External finishes	0.88	2.5	2.2
HVAC	1.44	10	14.4
Electrical	3.04	7.50	22.8
Corrosion	2.20	9.25	20.35
Access and egress	0.92	6.25	5.75
Soundproofing	0.76	3.75	2.85

Z-scores are used to determine how far a data point is from the mean in standard deviation units and are a useful tool for identifying significant outliers. A Z-score of 0 indicates a data point is exactly at the mean, while a positive Z-score indicates the data point is above the mean, and a negative Z-score indicates the data point is below the mean. In this case, the Z-scores were calculated for the defect risk scores of each defect relative to the mean risk score for all defects. The results are shown in Figure 11, which highlights that the waterproofing defect had a Z-score of 1.7. Sound proofing had a Z-score of 1.3, indicating they were over one standard deviation above the mean. These results suggest that these two defect types are significant outliers and require targeted focus to reduce their impacts.

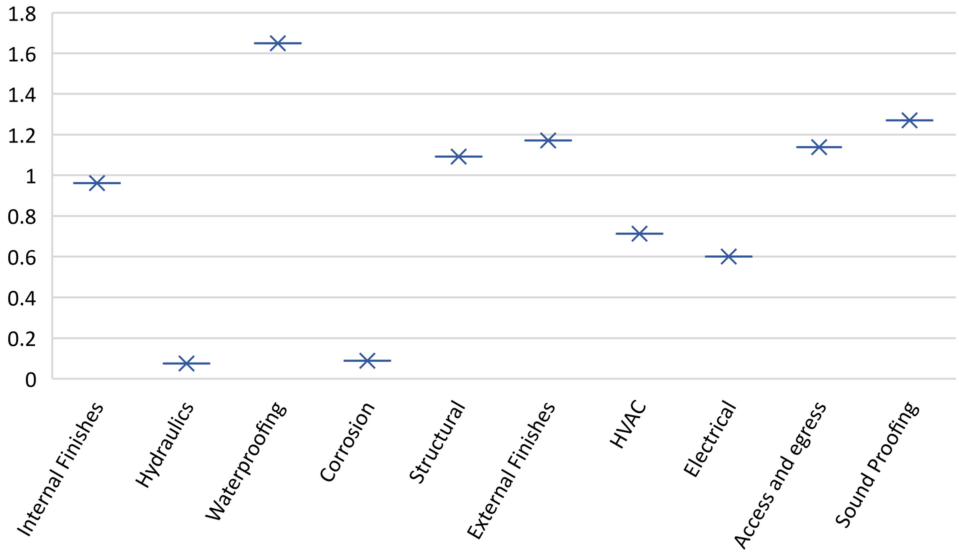


Figure 11. Defect Risk Z-Scores.

In summary, the questionnaire provided insight into the types of defects occurring in apartment buildings and the associated activities involved in reporting and rectifying them. Firstly, the reported defect rate from the respondents of 81% is consistent with previous research conducted by Johnston and Reid [24], who identified a defect rate of 85%, and Judd et al. [25], who reported a defect rate of 72%. This builds confidence in the representativeness of the responses and highlights the significant number of apartments affected by defects.

Regarding building age, a good mix of building ages was represented by the pre- and post-apartment building boom from around 2009. Little correlation was found between apartment age and defect type, with the most common defect types, waterproofing, and structural issues being frequently observed in buildings of all ages. However, the exception to this was electrical defects, which were observed in a much larger proportion of buildings that were 0–10 years old.

The analysis of defect types and frequencies revealed that the most reported types were related to waterproofing, internal finishes, and structure. These findings strongly correlate with previous research conducted by the NSW State Government and Strata Community Association NSW [41], which found the most frequent defect types to be waterproofing (34%), fire safety (20%), and structural issues (14%). A review of the severity of defects found that most waterproofing and structural defects were identified as moderate or severe risks. Given their high frequency and severity, these defects pose significant risks to apartment occupants.

Furthermore, the most common method for identifying and reporting defects was through the apartment's occupants. However, residents should also be aware of defects within their building through their building management committee, as inspections and committee activities have limitations in identifying defects. Regarding the impacts of these issues on building occupants, the most reported types were psychological and property use, with most respondents identifying more than one impact type.

Regarding defect rectification, most respondents reported that their defect had not been fully rectified. However, for defects that had been rectified, the majority were completed within three months. Electrical and hydraulic issues were typically dealt with in less than one month, as these defects can significantly impact apartment usability (e.g., taps, lights, etc.) and may be low-cost and straightforward, affecting only individual apartments. More complex defects that may involve multiple apartments and higher costs, such as waterproofing and HVAC, typically take over three months to rectify.

An analysis of unrectified defects found that most defects had been reported to building management or real estate agents; however, no action had been taken in most cases. This is concerning, given that most of the reported defects (>82%) were moderate, severe, or extreme. Higher severity defects with long rectification timeframes present significant risks to residents, and the delay in addressing these issues warrants further research. The main reasons for the lack of action included a lack of response from either building management or the real estate agent or owner, costs, and other factors.

In terms of the risks associated with these defects, waterproofing and structural defects carry the highest risks, as indicated by their Z-scores. These defects were significant outliers compared to all the other defects studied. Therefore, defect prevention activities and future research should prioritize addressing these issues.

4.3. Results of the Interviews

A total of six interviewees were included in the current study. The key points from each interview are presented below.

Interviewee one (INT1) acknowledged that there is a significant issue with quality and defects in the building industry, particularly in the case study area. They also mentioned that private certifiers are often blamed for these issues, but in their opinion, this blame is misdirected. INT1 argued that these types of buildings are highly complex, and it is unrealistic to expect certifiers to oversee all elements with the required level of knowledge.

Instead, the certifiers they have worked with have tended to be risk-averse and adopt a conservative view of building standards and codes. INT1 also noted that Queensland has more stringent regulations than other states. INT1 went on to explain that poor quality outcomes can be observed at all levels of projects. Since the early 2000s, there has been a growing trend in the industry to procure buildings through Design and Construct (D&C) contracts. Under these contracts, buildings are tendered using the minimum amount of design documents, and contractors are expected to complete the design and construction of the building at a fixed price. This approach can lead to discrepancies, oversights, and other issues. Furthermore, there is a lack of oversight, as the design, which was previously completed by a separate team of architects and engineers who oversaw the construction of their design, is now performed by the contractor. This can result in design anomalies and shortcuts that are not identified or rectified. To address these issues, INT1 suggested a return to more traditional forms of building procurement, where a separate design team is engaged to complete a high-quality design and oversee its implementation.

Interviewee two (INT2)'s perspective on the issue of quality issues and defects in the industry is similar to INT1's. They also expressed concerns about the D&C method, which has become the dominant procurement method in recent years, leading to lower quality work, as much of the design and associated risks are now in the hands of contractors. INT2 highlighted that this has resulted in overworked and inexperienced teams completing work quickly and at low cost, which inevitably leads to lower-quality outcomes. They also discussed that clients often do not appreciate the importance of quality work and that tendering on slim margins does not encourage the right attitudes, leading to the view that corners must be cut to maintain profits. INT2 also highlighted the issue of lack of oversight, which can contribute to poor outcomes.

Interviewee three (INT3) highlighted the importance of considering whole-of-life costs and reputational costs, particularly for Tier 1 contractors, who are more considerate of these factors. However, they noted that the quality systems and practices of Tier 2 and 3 contractors are more hit-and-miss, and it is crucial to choose a reputable company at this level. They also emphasized the need for consumer power to incentivize good developer behaviors, as the public often knows little about the company building their home or investment. Furthermore, INT3 discussed the downward pressure on prices for consulting engineers, driven by increasing numbers of smaller companies and reliance on graduate or overseas offshoring to reduce costs. This has led to a decrease in the quality of documentation produced due to reduced expertise and time spent on each project.

Interviewee four (INT4) also agreed that there is a major issue surrounding quality issues and defects in the industry. According to INT4, who has spent almost two decades working with a Tier 1 builder across various projects and locations, an increasing reliance on D&C contracts has allowed contractors to deviate from design documentation, which has become a growing concern. INT4 believes that the issue lies in the fact that little is known to the public about the reputation of the builder of their apartment. This is particularly relevant when smaller contractors are involved, as they may have little reputation to protect. However, bigger players have the necessary resources and systems to support proper quality management. They also have more concern over reputation and wish to keep operating in markets for long periods, so maintaining this business and obtaining repeat customers is a goal. INT4 does not agree with the common narrative that suggests not buying apartments built in the last 20 years due to quality concerns. He believes that there is a lot of blame directed at certifiers, and developers often deflect and defer blame toward them.

Interviewee five (INT5) also acknowledged the major issues surrounding quality and defects in the industry. They highlighted the failure of regulation at various levels of government as the primary reason for the demonstrated issues with poor quality and non-conforming products used in the industry, such as flammable cladding. INT5 noted that other building components also face compliance issues, which are now typically packaged into various subcontractor packages. The subcontractors are then relied upon

to undertake their quality assurance and certification of work, with the certifier merely collecting the various certificates. However, this issue is often put onto private certifiers, who cannot inspect all the works firsthand and cannot be expected to be experts in all elements of complex buildings. INT5 further suggested that there is an incentive for some less scrupulous subcontractors to push areas of shortcuts with lower quality work and materials, as these work packages for subcontractors are typically fixed prices. Therefore, all facets of the industry need increased oversight, and material compliance issues took major fires to get the necessary review. Now, this attention needs to be directed at the broader quality issues in these apartments to ensure that they are safe for residents.

Interviewee six (INT6) agreed that there is a major issue surrounding quality and defects in the industry. According to INT6, they have experience working with a mid-tier construction company delivering higher-end apartment buildings, mostly in mid-rise projects in South-East Queensland. As their clients have high expectations regarding the quality of their apartments, part of INT6's role is reviewing apartments pre-handover and arranging rectification works as required. Typically, these fixes are cosmetic or related to installation or design errors, such as installing the wrong type of showerhead or door. These are usually straightforward fixes, but issues with subcontractors can arise, and their company closely monitors subcontractors and develops long-term relationships to incentivize quality work. However, perception issues also impact their company, as clients are warier, with many choosing to engage independent inspectors as part of the handover process. INT6 suggested that it would be better to focus on identifying and fixing defects during the build rather than finding and rectifying them post-construction.

Overall, all interviewees agreed that there are significant issues with quality and defects in the apartment construction industry in Australia, particularly in Brisbane and Queensland. Certifiers have been blamed for these problems, but interviewees suggested that they are not solely responsible and that there are wider issues at play. The increasing reliance on D&C contracts, fixed-price contracts, and incomplete design documentation has led to contractors deviating from design documentation, resulting in growing concerns about the quality of buildings. Furthermore, buyers often do not know who is building their property, which means that smaller developers have little incentive to build or protect their reputation. To address these issues, there needs to be increased public awareness about the importance of reputation and more oversight of the industry to ensure that quality is maintained throughout the building process. Design work and documentation are also declining due to a lack of experts or experienced engineers, which needs to be addressed. Finally, subcontractors are relied upon to inspect and verify their work, which has the potential for negative exploitation and non-recording of quality issues.

5. Conclusions

This study examined key defects in multi-unit Australian dwellings. The increasing number of these buildings being constructed and occupied in Australia and the corresponding rise in defects within them made this study necessary. The study aimed to shed light on the causes and extent of defects within this type of building.

The pertinent literature was reviewed to understand the existing apartment defects. The review revealed that the study was necessary because of the increasing number of mid-rise and higher residential apartment buildings being constructed in Australia and the rising number of defects occurring in these buildings. The review also highlighted the challenges and limitations faced by previous research in this area, including the lack of access to information about defects. Furthermore, the literature review identified specific defect types, such as waterproofing and structural defects, as major concerns in the industry. These findings were reinforced during the latter phases of the study.

Based on a comprehensive questionnaire, data on 11 key defects were collected from 104 building residents. The top three reported defects were waterproofing, internal finishes, and structural issues. Overall, at least 84% of respondents deemed waterproofing and structural issues to be moderate to severe. Most defects (89%) were identified by residents,

who reported them to building owners, real estate agents, managers, and strata services. Furthermore, 71% of the reported defects had been first reported three months or more prior, and 74% of them had not been fully rectified. The defects had various impacts on residents, with the highest reported impacts being on the intended use of the property, psychological issues, and costs. Reasons for not rectifying the issues included non-responsive owners, building management or agents, scheduling difficulties for incomplete works, high costs, and litigation. Waterproofing and structural defects were highlighted as the top risky defects in terms of their potential impact on apartment buildings, and they must be taken seriously to avoid serious damage.

Finally, six industry professionals were interviewed to shed light on the reasons for the prevalence of defects in Australian apartment buildings, and all agreed that there are major issues and defects in the apartment construction industry in Australia. The key themes highlighted by the interviewed professionals included the reliance on and push for D&C and fixed-price contracts, the absence of the builder's reputation in local systems, the lack of public awareness, the reliance on less experienced workers and engineers, and self-inspection of works without proper quality checks. These issues are resulting in quality issues and defects in Australian apartment buildings, with the potential for inspection results to be manipulated.

This study has certain limitations that need to be acknowledged. First, there is a limited amount of data on local Australian apartment defects. This issue was addressed by reviewing local reports and obtaining the opinions of building residents, but the study's case study area is limited to Brisbane, Queensland, and data from other states are not included. Additionally, the study only examines post-construction defects, and data were collected from a sample of 104 respondents, which may not be representative of the population. Future studies could benefit from collecting data on all types of defects and obtaining more comprehensive opinions from residents and industry professionals across Queensland and the rest of Australia. Finally, while the study interviewed six industry professionals, a larger sample size of professionals could be beneficial for gaining a more diverse perspective on the issue.

Future follow-up studies could investigate the defects occurring in Australian apartment buildings on a country-wide scale and collect data from all states. The sample size could be increased, and different procurement types could be investigated to address and minimize defects in apartment buildings throughout Australia. Another potential area of research is examining the causes of and solutions for avoiding delayed rectification of apartment defects. Finally, developing a public rating system for apartment buildings could be an important focus of follow-up studies.

Author Contributions: Conceptualization, M.D. and F.U.; methodology, M.D. and F.U.; software, M.D.; validation, M.D. and F.U.; formal analysis, M.D.; investigation, M.D.; resources, F.U.; data curation, M.D.; writing—original draft preparation, M.D.; writing—review and editing, M.D., F.U., S.Q. and O.O.; visualization, M.D.; supervision, F.U.; project administration, F.U., S.Q. and O.O.; funding acquisition, F.U., S.Q. and O.O. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The ethics for this study is approved under application number H22REA112 by UniSQ as of 23 June 2022. Data has been collected as per the approved protocols.

Data Availability Statement: The data used in this study are available upon reasonable request from the first author in accordance with the University of Southern Queensland (UniSQ) data sharing policy.

Acknowledgments: The authors are grateful to UniSQ for providing an enabling research environment.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Foster, S.; Hooper, P.; Easthope, H. Cracking up? Associations between building defects and mental health in new Australian apartment buildings. *Cities Health* **2022**, *6*, 1152–1163. [CrossRef]
2. Shoory, M. *The Growth of Apartment Construction in Australia, Bulletin—June 2016*; Reserve Bank of Australia: Brisbane, Australia, 2016. Available online: https://www.rba.gov.au/publications/bulletin/2016/jun/pdf/bu-0616-3.pdf (accessed on 9 January 2024).
3. Australian Bureau of Statistics. *Telling Storeys—Apartment Building Heights*; Australian Bureau of Statistics: Canberra, Australia, 2020. Available online: https://www.abs.gov.au/articles/telling-storeys-apartment-building-heights (accessed on 9 January 2024).
4. Australian Bureau of Statistics. *Australian National Accounts: National Income, Expenditure and Product*; Australian Bureau of Statistics: Canberra, Australia, 2019.
5. Paton-Cole, V.P.; Aibinu, A.A. Construction defects and disputes in low-rise residential buildings. *J. Leg. Aff. Disput. Resolut. Eng. Constr.* **2021**, *13*, 05020016. [CrossRef]
6. Paton-Cole, V. Assessment of defects and disputes in residential buildings. In Proceedings of the 43rd Australasian Universities Building Education Association Conference, Built to Thrive: Creating Buildings and Cities that Support Individual Well-Being and Community Prosperity, RACV, Noosa, QLD, Australia, 6–8 November 2019; Zhao, X., Kalutara, P., Webber, R., Eds.; Central Queensland University: Norman Gardens, QLD, Australia, 2019; pp. 160–169.
7. Hoffman, M.; Carter, J.; Foster, S. *Opal Tower Investigation: Final Report*; Department of Planning and Environment (NSW). UniSearch NSW Minister for Planning and Housing: Parramatta, NSW, Australia, 2019. Available online: https://apo.org.au/sites/default/files/resource-files/2019-02/apo-nid221431.pdf (accessed on 9 January 2024).
8. McIlroy, J. Mascot Towers Debacle a Sign of Deep Housing Crisis. *Green Left Wkly.* 2019, p. 1226. Available online: https://www.greenleft.org.au/content/mascot-towers-debacle-sign-deep-housing-crisis (accessed on 9 January 2024).
9. McKenna, S.T.; Jones, N.; Peck, G.; Dickens, K.; Pawelec, W.; Oradei, S.; Harris, S.; Stec, A.A.; Hull, T.R. Fire behaviour of modern façade materials–Understanding the Grenfell Tower fire. *J. Hazard. Mater.* **2019**, *368*, 115–123. [CrossRef] [PubMed]
10. Crommelin, L.; Thompson, S.; Easthope, H.; Loosemore, M.; Yang, H.; Buckle, C.; Randolph, B. *Cracks in the Compact City: Tackling Defects in Multi-Unit Strata Housing*; City Futures Research Centre, UNSW: Sydney, Australia, 2021. Available online: https://apo.org.au/sites/default/files/resource-files/2021-10/apo-nid315107.pdf (accessed on 9 January 2024).
11. Morrell, P. The Rise of Apartment Living: Why Australian Families Are Choosing Apartments. Available online: https://morrellproperty.com.au/the-rise-of-apartment-living-why-australian-families-are-choosing-apartments/ (accessed on 5 January 2024).
12. Kohler, A. The Dirty Little Secret That Keeps Australian Housing Wildly Unaffordable. Available online: https://www.smh.com.au/national/the-dirty-little-secret-that-keeps-australian-housing-wildly-unaffordable-20231121-p5elo7.html (accessed on 5 January 2024).
13. Ullah, F.; Sepasgozar, S.M.; Thaheem, M.J.; Wang, C.C.; Imran, M. It's all about perceptions: A DEMATEL approach to exploring user perceptions of real estate online platforms. *Ain Shams Eng. J.* **2021**, *12*, 4297–4317. [CrossRef]
14. Ahmed, S.I.N.; Pasquire, C.; Manu, E. Key factors affecting commercial actors in collaborative working within the UK construction industry. *J. Financ. Manag. Prop. Constr.* **2022**, *27*, 323–347. [CrossRef]
15. Ullah, F.; Sepasgozar, S.M.; Shirowzhan, S.; Davis, S. Modelling users' perception of the online real estate platforms in a digitally disruptive environment: An integrated KANO-SISQual approach. *Telemat. Inform.* **2021**, *63*, 101660. [CrossRef]
16. Watt, D. *Building Pathology: Introduction and Practice*; Wiley-Blackwell: Hoboken, NJ, USA, 1999.
17. Yacob, S.; Ali, A.S.; Au-Yong, C.P.; Yacob, S.; Ali, A.S.; Au-Yong, C.P. Factors Contributing to Building Defects. In *Managing Building Deterioration: Prediction Model for Public Schools in Developing Countries*; Springer: Berlin/Heidelberg, Germany, 2022; pp. 41–63.
18. Australian Bureau of Statistics. *Census of Population and Housing: Census Dictionary*; Australian Bureau of Statistics: Canberra, Australia, 2016.
19. Atkinson, A.R. The role of human error in construction defects. *Struct. Surv.* **1999**, *17*, 231–236. [CrossRef]
20. Qin, H.; Stewart, M.G. Construction defects and wind fragility assessment for metal roof failure: A Bayesian approach. *Reliab. Eng. Syst. Saf.* **2020**, *197*, 106777. [CrossRef]
21. Atkinson, A.R. The pathology of building defects: A human error approach. *Eng. Constr. Archit. Manag.* **2002**, *9*, 53–61. [CrossRef]
22. Josephson, P.-E.; Hammarlund, Y. The causes and costs of defects in construction: A study of seven building projects. *Autom. Constr.* **1999**, *8*, 681–687. [CrossRef]
23. Aljassmi, H.; Han, S.; Davis, S. Project pathogens network: New approach to analyzing construction-defects-generation mechanisms. *J. Constr. Eng. Manag.* **2014**, *140*, 04013028. [CrossRef]
24. Johnston, N.; Reid, S. An Examination of Building Defects in Residential Multi-Owned Properties. Deakin Univeristy and Griffith Univeristy Australia. 2019. Available online: https://www.griffith.edu.au/data/assets/pdf_file/0022/831217/Examining-Building-Defects-Research-Report-S-Reid-N-Johnston.pdf (accessed on 9 January 2024).
25. Judd, S.; Randolph, B.; Easthope, H. *Governing the Compact City: The Role and Effectiveness of Strata Management*; City Futures Research Centre, UNSW: Sydney, Australia, 2012.
26. Georgiou, J.; Love, P.; Smith, J. A comparison of defects in houses constructed by owners and registered builders in the Australian State of Victoria. *Struct. Surv.* **1999**, *17*, 160–169. [CrossRef]
27. Yoon, S.; Son, S.; Kim, S. Design, Construction, and curing integrated management of defects in finishing works of apartment buildings. *Sustainability* **2021**, *13*, 5382. [CrossRef]

28. Jingmond, M.; Ågren, R. Unravelling causes of defects in construction. *Constr. Innov.* **2015**, *15*, 198–218. [CrossRef]
29. Forcada, N.; Macarulla, M.; Fuertes, A.; Casals, M.; Gangolells, M.; Roca, X. Influence of building type on post-handover defects in housing. *J. Perform. Constr. Facil.* **2012**, *26*, 433–440. [CrossRef]
30. Chong, W.-K.; Low, S.-P. Assessment of defects at construction and occupancy stages. *J. Perform. Constr. Facil.* **2005**, *19*, 283–289. [CrossRef]
31. Chong, W.-K.; Low, S.-P. Latent building defects: Causes and design strategies to prevent them. *J. Perform. Constr. Facil.* **2006**, *20*, 213–221. [CrossRef]
32. Zalejska Jonsson, A.; Hungria Gunnelin, R. Defects in newly constructed residential buildings: Owners' perspective. *Int. J. Build. Pathol. Adapt.* **2019**, *37*, 163–185. [CrossRef]
33. Porteous, W. Classifying building failure by cause: New approach to identifying the causes of building failure avoiding involvement with issues of blame. *Build. Res. Inf.* **1992**, *20*, 350–356. [CrossRef]
34. Karim, K.; Marosszeky, M.; Davis, S. Managing subcontractor supply chain for quality in construction. *Eng. Constr. Archit. Manag.* **2006**, *13*, 27–42. [CrossRef]
35. Aljassmi, H.; Han, S.; Davis, S. Analysis of the complex mechanisms of defect generation in construction projects. *J. Constr. Eng. Manag.* **2016**, *142*, 04015063. [CrossRef]
36. Economics References Committees—Society for Ecological Restoration. *Non-Conforming Building Products-Interim Report: Aluminium Composite Cladding*; Parliament of Australia: Canberra, Australia, 2017. Available online: https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Economics/Non-conforming45th/~/media/Committees/economics_ctte/Non-conforming45th/Interim_report_cladding/report.pdf (accessed on 9 January 2024).
37. Victorian Cladding Taskforce. *Victorian Cladding Taskforce: Interim Report*; Department of Environment, Land, Water and Planning: Melbourne, Australia, 2017.
38. Consumer, Building and Occupational Services (CBOS). *Tasmanian Aluminum Composite Panel Audit Summary*; Tasnmanian Government: Hobart, Australia, 2018.
39. Queensland Government. *Queensland Non-Conforming Building Products Audit Taskforce*; Queensland Government: Brisbane, Australia, 2018.
40. Shergold, P.; Weir, B. Building Confidence: Improving the Effectiveness of Compliance and Enforcement Systems for the Building and Construction Industry across Australia. 2018. Available online: https://apo.org.au/sites/default/files/resource-files/2018-02/apo-nid314175.pdf (accessed on 9 January 2024).
41. Government of New South Wales. *Research Report on Serious Defects in Recently Completed Strata Buildings across New South Wales September 2021*; Office of the New South Wales Building Commissioner, Strata Community Association (NSW): Sydney, Australia, 2021. Available online: https://apo.org.au/sites/default/files/resource-files/2021-12/apo-nid315099.pdf (accessed on 9 January 2024).
42. Construction, Forestry, Maritime, Mining, and Energy Union (CFMEU). *Shaky Foundations—The National Crisis in Contruction*; Construction, Forestry, Maritime, Mining, and Energy Union (CFMEU): Canberra, Australia, 2019.
43. Mintzberg, H. An emerging strategy of "direct" research. *Adm. Sci. Q.* **1979**, *24*, 582–589. [CrossRef]
44. Shah, S.K.; Corley, K.G. Building better theory by bridging the quantitative–qualitative divide. *J. Manag. Stud.* **2006**, *43*, 1821–1835. [CrossRef]
45. Reich, B.H.; Wee, S.Y. Searching for Knowledge in the PMBOK®Guide. *Proj. Manag. J.* **2006**, *37*, 11–26. [CrossRef]
46. Ullah, F.; Qayyum, S.; Thaheem, M.J.; Al-Turjman, F.; Sepasgozar, S.M. Risk management in sustainable smart cities governance: A TOE framework. *Technol. Forecast. Soc. Change* **2021**, *167*, 120743. [CrossRef]
47. Brisbane Development. Interactive Brisbane Map. Available online: https://brisbanedevelopment.com/brisbane-development-map/ (accessed on 9 January 2024).
48. Bickman, L.; Rog, D.J. *The SAGE Handbook of Applied Social Research Methods*; Sage Publications: Thousand Oaks, CA, USA, 2008.
49. Dillman, D.A. *Mail and Internet Surveys: The Tailored Design Method—2007 Update with New Internet, Visual, and Mixed-Mode Guide*; John Wiley & Sons: Hoboken, NJ, USA, 2011.
50. Grembowski, D. *The Practice of Health Program Evaluation*; Sage Publications: Thousand Oaks, CA, USA, 2015.