Dora Oravecz

From:	Sara Wilkinson <Sara.Wilkinson@uts.edu.au>
Sent:	Friday, 22 October 2021 2:06 PM
To:	CommunityServices
Subject:	Evidence to NSW parliamentary hearing tomorrow - STAR
Attachments:	Armstrong et al 2021 1-s20-S0264275121001189-main.pdf

Dear Dora,

Thank you again for hearing our submission today.

Re measuring office vacancy, please see Gill's attached paper in *Cities*.

And also Gill's PhD Chapter 7 (p.211-293) on vacancy, which is available via:
https://hdl.handle.net/2440/129492

The references are:

Armstrong, G., Soebarto, V., & Zuo, J. (2021). Vacancy Visual Analytics Method: Evaluating adaptive reuse as an urban regeneration strategy through understanding vacancy. *Cities*, *115*. Doi.org/10.1016/j.cities.2021.103220

Armstrong, G. (2020) *The adaptive reuse predicament: an investigation into whether building regulation is a key barrier to adaptive reuse of vacant office buildings*. Doctoral thesis, University of Adelaide. Available from http://hdl.handle.net/2440/129492

If we can provide any further information, please let us know.

Best wishes, Sara

Sara J. Wilkinson. BSc MA MPhil PhD FRICS AAPI
Professor of Sustainable Property

Faculty of Design Architecture & Building
School of Built Environment
Room 06.05.023.
University of Technology Sydney

Cities 115 (2021) 103220

Contents lists available at ScienceDirect

Cities

journal homepage: www.elsevier.com/locate/cities

Vacancy Visual Analytics Method: Evaluating adaptive reuse as an urban regeneration strategy through understanding vacancy

Gill Armstrong [*], Veronica Soebarto, Jian Zuo

School of Architecture and Built Environment, University of Adelaide, Australia

ARTICLE INFO

Keywords:
Vacancy
Obsolescence
Adaptive reuse
Urban regeneration

ABSTRACT

Premature obsolescence of existing buildings is a significant challenge for sustainable regeneration in cities internationally. Adaptive reuse is one approach to address obsolescence in cities globally. High vacancy can be a crucial predictor of obsolescence, but vacancy is poorly understood and can be 'hidden'. This paper presents a novel quantitative method, called Vacancy Visual Analytics Method (VVAM), to identify vacancy in city populations. VVAM permits detailed visualisation of the location and quantity of vacancy, including Greyspace, a form of hitherto undetectable vacancy. To test VVAM, this paper reports its application to a population of office buildings (n=118) in Adelaide, an Australian city reporting high office building vacancy. VVAM revealed the vacancy distribution did not lend itself to whole building adaptive reuse, despite the universal advocacy for greater adaptive reuse globally. This finding implies whole building adaptive reuse may not be appropriate to address vacancy in all cities. This study recommends policy formation should involve a thorough examination of vacancy across building populations to ensure policy efficacy. VVAM presents a useful tool to critically understand vacancy and inform policy to address urban vacancy, including cities affected by COVID-19 office building vacancy.

1. Introduction

Advocacy for adaptive reuse, as a strategy for economic and urban revitalisation, has its early roots in heritage conservation and as a reaction to sterile brownfield redevelopments (Saniga, 2012). Adaptive reuse is now synonymous with sustainable development through better deployment of resources and avoidance of renovation and replacement, which are resource-intensive (Conejos et al., 2015). However, it is commonly assumed that buildings and old sites are abandoned for long periods before stakeholders decide to adapt and reuse. Abramson (2016) describes adaptive reuse as the 'architecture of obsolescence' (p. 127), which encapsulates the premise that buildings are redundant before adaptive reuse occurs. Obsolescence is defined in ISO 15686 as 'the loss of ability of an item to perform satisfactorily due to changes in performance requirements' (ISO/IEC, 2011: 3.14), which according to Muldoon-Smith (2016), can be indicated by high levels of vacancy. There is a gap in the existing body of knowledge to understand the process of vacancy and how vacancy occurs in an existing building before the building enters a final state of obsolescence with whole-building vacancy and derelict sites. A reliance on assumptions about vacancy as a driver of adaptive reuse is problematic, and risks lost opportunities for sustainable and resilient urban regeneration.

Increasingly, non-heritage buildings, perceived to be obsolete, vacant or underused, are connected with adaptive reuse, including commercial offices (Bullen, 2007; Muldoon-Smith & Greenhalgh, 2016; Remøy & van der Voordt, 2014) and industrial buildings (Shen & Langston, 2010; Tan et al., 2018; Vardopoulos, 2019). Urban policy, which levers private investment to adapt existing building stocks, offers low-cost solutions to address economic decline (Cardullo et al., 2018). However, Ikiz Kaya et al. (2021) identify a literature gap to outline the policy-related instruments surrounding adaptive reuse and provide a holistic overview of different adaptive reuse policy contexts. They suggest further research is needed to evaluate adaptive reuse policy.

Adaptive reuse is a commonly cited strategy to address urban decline (Wilkinson & Remøy, 2018). New unforeseen urban threats have recently emerged, with the COVID-19 pandemic generating a rapid shift in working patterns in commercial buildings and dispersal of urban core activities into residential suburbs and online stores (Elliot, 2020; Green, 2020). It remains unclear if the dispersal of commercial activities is temporary or will have more permanent impacts on the demand for

* Corresponding author.
E-mail address: Gillian.armstrong@adelaide.edu.au (G. Armstrong).

https://doi.org/10.1016/j.cities.2021.103220
Received 2 July 2020; Received in revised form 10 March 2021; Accepted 11 April 2021
Available online 24 April 2021

commercial space in urban cores, leaving the need for strategy and policy to address perceived vacancy.

The objective of this paper is to present a reproducible technique, the *Visual Analytic Method* (*VVAM*), to support the evaluation of adaptive reuse as an urban regeneration strategy for inclusion in sustainable development policies and for a range of building uses. VVAM aims to help urban planners, policy, and decision-makers when designing, understanding and promoting strategies to mitigate obsolescence in building populations to ensure urban resilience and revitalisation. VVAM also permits an independent assessment of vacancy when lobby groups cite high vacancy when calling for urban policy reform, such as 'red-tape reduction' to streamline development assessment through planning approval and building regulation compliance.

This paper uses the building populations in the Central Business District (CBD) of Adelaide, South Australia, to demonstrate a real-world application of VVAM. Adelaide is one of four Australian state capitals perceived to have a high vacancy problem in the office building market. Australia also currently has no independent database to verify vacancy rates published by commercial organisations directly involved in commercial building property transactions. VVAM is an exploratory approach using cross-sectional data and analysis to examine the distribution of vacancy to evaluate adaptive reuse as a city-wide urban regeneration strategy or where a rapid, unforeseen change has occurred impacting commercial space demand, such as COVID-19.

2. Literature review

This review comprises two components. One is to highlight how literature connects adaptive reuse to vacancy. This section of the review used keyword searches in the Scopus database to identify the most recent literature sources published in English in the last five years. The second part seeks to highlight the gap in vacancy knowledge to outline the need to develop VVAM to evaluate sustainable adaptive reuse. A search of recent grey literature (e.g., unpublished doctoral thesis) also produced several results. Sources were garnered via searches using combinations of the following keywords: adaptive reuse, rehabilitation, change of use, vacan*, 'vacancy rate', 'underutilised existing buildings', 'building stocks', and obsolescen*.

Shahi et al. (2020) offer a definitional framework for building adaption designed to overcome the lack of consistency in common terms used to describe the process of change in existing buildings. This paper adopts several characteristics, identified by Shahi et al. (2020), to define adaptive reuse. These characteristics are 'the process of extending the useful life' to 'maximise the reuse and retention of existing structures and fabric' intended to improve economic, environmental, and social performance of existing buildings' through 'a change of use of either part or whole of a building' (p. 19–20).

2.1. Motivators for adaptive reuse

Wilkinson and Remøy (2018) suggest, 'the original land-use of the building is no longer economically or socially viable or desirable and a change [of use] is required' (p. 7). High levels of vacancy in a building can be a crucial predictor of premature obsolescence in existing buildings (Muldoon-Smith, 2016). Vacancy is described as both a motivator of adaptive reuse and as a 'problem' that adaptive reuse can help offset through managing asset depreciation (Bokhari & Geltner, 2018). Literature infers under-used buildings dilapidate faster than buildings that are continuously occupied and return higher yields, as they do not have sufficient investment to upgrade or maintain quality (Remøy & van der Voordt, 2014; Zheng, Shen, & Wang, 2014; Langston et al., 2013; Ho, Yau, Poon, & Liusman, 2011; Ho et al., 2011). This idea connects adaptive reuse with environmental sustainability and circular economy principles as adaptive reuse can extend a building's useful life and reduce construction waste as a consequence of premature obsolescence and demolition (Foster & Kreinin, 2020; Wilkinson & Remøy, 2018; Wynne & Riedy, 2018; Conejos et al., 2016). Adaptive reuse is also poised to provide continuity for the more social aspects of urban renewal, including maintaining urban character (Loli & Bertolin, 2018), and as a key strategy in heritage conservation (Mısırlısoy & Günçe, 2016; Rodrigues & Freire, 2017; Yazdani Mehr, 2019).

Numerous actors are involved in decisions to adapt buildings (Loli & Bertolin, 2018). They include designers, surveyors and constructors; planners and building code compliance certifiers; heritage officers and local council officers; legal representatives; estate agents, property valuers and insurers; investors and banking financiers; building owners and developers; and end-users (Aigwi, Ingham, et al., 2020; Pinder et al., 2013). It is worth noting additional actors who advocate for adaptive reuse but are not identified in scholarly literature, specifically emergency service professionals. These actors are affected by building vacancy, including dilapidation and incidents caused by unauthorised occupants in empty buildings. The identification of these actors emerged during qualitative interviews during adaptive reuse research. Fire personnel advocate for adaptive reuse as they receive call outs for events in disused buildings, and there are additional risks for emergency service personnel when accessing dilapidating buildings.

2.2. Shades of adaptive reuse

Published articles predominately describe adaptive reuse on a whole building basis with a permanent use change for the building (Galdini, 2019). Adaptive reuse, however, can refer to a broad scope of projects in practice, including the criticised practice of adaptive reuse facadism, which retains only a thin veneer of the existing structure (Gaskin, 2020; Yung & Chan, 2012). Sustainable adaptive reuse occurs by maximising the existing building's retention, which can occur on a temporary or permanent basis (Wilkinson & Remøy, 2018). O'Callaghan and Lawton (2016) highlight growth in temporary adaptive reuse with 'pop-up' events and businesses partially occupying accessible street-level floors of commercial buildings. Mixed-use multi-level (MUML) or Pocket Adaptive Reuse (PAR) are useful ways of addressing partial vacancy in buildings that still have some occupancy (Armstrong, 2020). Non-permanent adaptive reuse is also beneficial in emergency or disaster management (Shahi et al., 2020).

The adaptive reuse process can apply to development at all scales and all buildings, not only historic and culturally valuable ones, as shown in models to deliver aged and dementia care residential facilities through adaptive reuse of non-heritage retail malls affected by recent societal shifts to online shopping (Roberts & Carter, 2020). This application of adaptive reuse can sustainably solve societal problems through a creative coupling of over and undersupply building types with compatible uses. Compatible use can make adaptive reuse an economical alternative to demolition and site redevelopment (Della Spina, 2020). One further interesting variation on adaptive reuse is 'top-up' development to extend the economic life of existing buildings through adding additional floors of new uses, such as vertical residential extensions to commercial buildings in city centres (Holden, 2018).

2.3. Critical insights of adaptive reuse

While most of the literature on adaptive reuse advocates greater uptake, voices critical of adaptive reuse as a regeneration strategy are emerging. These voices suggest adaptive reuse may have unintended consequences. Adaptive reuse is criticised for dissonance and displacing communities through gentrification (Abramson, 2016; Galdini, 2020; Yung et al., 2014). The displacement risk is present if occupancy and vacancy are unknown before changes in land uses are granted, and conversion occurs (Grodach et al., 2017). This framing highlights the importance of quantifying the distribution of existing building vacancy in cities considered to be in distress to evaluate the efficacy of adaptive reuse as an urban regeneration strategy. O'Callaghan and Lawton (2016) call for a robust analysis of the potential and unintended negative impacts of temporary adaptive reuse in cities with transitional economies such as Dublin. Permanent but low-quality adaptive reuse is an emerging problem across London's stocks of older office buildings (Clifford et al., 2018). The review highlights the need for a more critical interrogation of adaptive reuse (Armstrong, 2020; Clifford et al., 2018).

Greenhalgh and Muldoon-Smith (2017) consider adaptive reuse to be a high-level intervention and only one of several obsolescence mitigation strategies for office buildings. Other less invasive strategies should be considered first to address vacancy when it first appears, including brand repositioning, tenant consolidation, maintenance and energy efficiency upgrades (Greenhalgh & Muldoon-Smith, 2017; Muldoon-Smith & Greenhalgh, 2019). These criticisms highlight the need for a nuanced understanding of vacancy distribution in buildings, using vacancy data to evaluate the sustainability of available options and the possible unintended negative consequences of adaptive reuse.

2.4. Frameworks for adaptive reuse regeneration

Few studies focus on adaptive reuse beyond the single building scale as a broader urban regeneration strategy. Two recent studies have put forward frameworks for supporting adaptive reuse of existing buildings as replicable tools for policymakers. Ferretti and Grosso (2019) present an integrative approach to understanding the reuse of landscapes considered disused or vacant landscapes. Aigwi, Phipps, et al. (2020) develop parameters for a performance-based framework for evaluating adaptive reuse of underutilised historical buildings. While these two studies are commendable in providing tools for evaluating adaptive reuse as a regeneration strategy, their frameworks focus on encouraging reuse without discussing vacancy. The absence of vacancy in frameworks is a gap in the field because vacancy is a driver of adaptive reuse, as mentioned at the start of this review.

A study by Huuhka & Kolkwitz, 2021 demonstrates that demolition and redevelopment patterns vary significantly between building use categories. They highlight the need for policymaking to acknowledge how urban planning shapes the flow of demolition and redevelopment decision frameworks in which adaptive reuse also sits (Huuhka & Kolkwitz, 2021; Greenhalgh & Muldoon-Smith, 2017). Studies by Aksozen et al. (2017) and Kohler and Yang (2007) connect vacancy with a threat of unsustainable premature demolition and economic loss. Aksozen et al. (2017) develop their Mortality Analysis method, which allows analysis of existing building demolition at three levels: city, district and at a granular individual building scale. A further model to specifically aid policy development seeking to rehabilitate existing building stocks is put forward by Sing et al. (2019). However, these useful tools do not examine vacancy as an indicator of the need for rehabilitation intervention.

2.5. Vacancy to evaluate urban planning solutions

Vacancy connects to policy development when managing competing demands upon metropolitan land-uses (Buitelaar, Moroni, & De Franco, 2021; Lee & Newman, 2017; Brouwer, 2014). Burkholder (2012) identified that city-wide vacancy analysis is useful to strategic planning, highlighting planning must consider the larger picture of what vacancy provides as fodder for its own future development (p. 1166). Wolff and Wiechmann's (2014) framework of urban shrinkage indicators suggests vacancy rates can offer insightful perspectives on a city's urban growth and contraction. However, Wolff and Wiechmann (2014) also flag vacancy data as not the 'easiest form of information to obtain' (p. 8).

In a study on vacant office buildings in The Netherlands, Remøy (2010) interrogates office building adaptive reuse using vacancy data published by commercial organisations. The study itself did not include a critical interrogation of the commercial vacancy data on which it relied. Muldoon-Smith (2016) uses vacancy data (m^2) and rental losses (£) to compare secondary grade office markets in English regional cities. These doctoral theses focus upon ameliorating and quantifying vacancy in office buildings markets made up of secondary grade or older buildings (Muldoon-Smith, 2016; Remøy, 2010). Neither study appears to go as far as locating and visualising the distribution and size of vacancy types on a floor-by-floor, building-by-building or granular basis necessary to evaluate adaptive reuse policy. There exists a need for a deeper and more nuanced understanding of vacancy in existing building populations to assist policy decisions in addressing obsolescence in the built environment, including adaptive reuse (Muldoon-Smith, 2016: 17). At present, urban vacancy is typically addressed through ad hoc public policies (Buitelaar et al., 2021). The problem of vacancy data availability and lack of discussion needs addressing in research and policy to move toward a more anticipative policy framework for sustainable management of buildings, as recommended by Buitelaar et al. (2021).

2.6. Vacancy understanding

Difficulties exist for policymakers to estimate the extent of vacancy problems in office building markets (Muldoon-Smith, 2016) and calls for identifying a 'crucial need for a reliable estimate of the extent of the [vacancy] problem' (Keeris & Koppels, 2006: 3). One barrier to deepening understanding of vacancy problems is that vacancy can be 'hidden' when using accepted industry methods to calculate occupancy and vacancy rates (Muldoon-Smith, 2016; Wolff & Wiechmann, 2014). Arguably, access to disaggregated vacancy datasets is needed by policymakers when they are considering agile ways to manage and address obsolescence and vacancy. To add further complexity when understanding vacancy, some literature suggests not all vacancy is considered problematic. Indeed, some vacancy is an indicator of a functional commercial building market (Crone, 1989; Wilkinson & Remøy, 2018).

An 'indigestible lump' is a striking image used to describe vacancy in Australian office building markets (Ness, 2002: 112). This metaphor suggests vacancy is 'bad' when it cannot be resolved during periods of positive economic growth and where there is also a rising demand for office space (Ness, 2002). The 'indigestible lump' aligns with the 'sinking stack' theory offered in research to describe the seemingly inevitable downward trajectory of vacancy, moving from premium office buildings to secondary grade office stocks. Unresolved vacancy is put forward as an indicator of obsolescence in office buildings (Atkinson, 1988; Bryson, 1997; Hassler, 2009; Remøy, 2010). Collectively these representations project the idea that shrinking cities are prone to indigestible bulges of unwanted commercial space manifesting as high structural vacancy in secondary grade office buildings in cities globally. There are also suggestions that declining real estate markets do not always support short-term or long-term reuse (Kim et al., 2020). However, without a critical examination of vacancy data, this narrative is problematic as it remains unsubstantiated.

Concepts of vacancy sub-types (Muldoon-Smith & Greenhalgh, 2017) and the process of adaptive reuse have a multitude of applications, making both vacancy and adaptive reuse broad in scope (Armstrong, 2020). Vacancy sub-types include natural, untenanted, and 'greyspace' vacancy (Couch & Cocks, 2013; Keeris & Koppels, 2006; Muldoon-Smith & Greenhalgh, 2017). Natural vacancy is the concept used to describe a 'healthy' vacancy rate, conducive to market growth, presented as an indicator of a balanced relationship between supply and demand (Couch & Cocks, 2013). Several sources suggest a beneficial natural vacancy rate ranges between 3% and 10% (Geraedts et al., 2018: 123; Muldoon-Smith & Greenhalgh, 2017: 480; Remøy, 2010: 32). These vacancy types are time dependant and, therefore, can only be detected through longitudinal data gathering and analysis of several years of vacancy data (Muldoon-Smith, 2016).

Untenanted vacancy is a vacancy type often used by industry groups such as the Property Council of Australia (PCA) to calculate aggregated office building vacancy rates, such as those detailed in bi-annual Office Market Reports (PCA, n.d.). The PCA also guides office building grading (PCA, 2012), and vacancy discussion often focuses on lower-quality or secondary grade buildings (Bullen & Love, 2009; Sing et al., 2019). This vacancy type can be quantified and analysed using longitudinal and cross-sectional research approaches. The PCA undertakes data gathering to quantify untenanted vacancy data, with aggregated vacancy rates calculated using data from office space advertised for lease by real-estate listings. Industry professionals confirm the listings before rates and office market forecasts are published (PCA, n.d.). When considering office building adaptive reuse, untenanted vacancy is potentially ready to convert as there are fewer legal barriers and processes to restrict the commencement of adaptive reuse development.

Greyspace is described as a 'hidden' vacancy type as it is concealed in space already leased, but it is surplus to tenants' requirements. Greyspace can affect a considerable floor area within buildings and mask the true extent of obsolescence with a building or across a market (Muldoon-Smith, 2016: 115; Hammond, 2013). This vacancy type is challenging to locate and therefore quantify (Muldoon-Smith & Greenhalgh, 2017). Vacancy rates published by the PCA do not include greyspace. Unless greyspace becomes part of a formal and advertised sublease, its presence does not readily convert to collectable data and remains tacit knowledge. Greyspace is not a longitudinal category of vacancy and is therefore wholly suitable for quantification via methods dependant on a cross-sectional research design.

3. The Vacancy Visual Analytics Method

VVAM is a solution to the lack of available data collected and critical investigation to independently quantify and understand commercial building vacancy beyond real-estate groups with invested interests and potential bias. It is also capable of quantifying both untenanted and greyspace vacancy as it facilitates cross-sectional analysis.

VVAM uses a cross-sectional research design to quantify and visualise the distribution of vacancy types across a building population or city based on secondary data. A key advantage of cross-sectional studies is that they can be 'generally quick, easy, and cheap to perform' (Sedgwick, 2014: 2). This efficiency is one benefit of cross-sectional analysis because results can be quick to produce to aid policy development and further research compared to data collection in longitudinal research designs. Cross-sectional studies are suitable for providing an understanding of vacancy in a particular 'snapshot in time', such as when vacancy rates are perceived as being problematically high or low and affecting future urban growth. Two types of vacancy are suitable for cross-sectional studies: untenanted vacancy and greyspace vacancy, as both types are not time-dependent. This study is also the first of its kind to measure greyspace in buildings, previously considered to be hard to detect (Muldoon-Smith, 2016; Wolff & Wiechmann, 2014).

The method consists of 3 stages before evaluating urban policy mechanisms. Stage one evaluates the secondary dataset against the research inquiry objectives before constructing a building population sample in stage two. Vacancy types are then quantified and visualised across the sample in the third stage. Fig. 1 represents the VVAM framework. This paper describes stages 1–3 before the detail of Adelaide's case study is given to demonstrate how VVAM can provide a rich source of insight for urban planning policymakers. The case study highlights how the distribution of vacancy relates to policy development.

3.1. *Stage 01 repurposing secondary data*

The systematic framework, provided by Johnston (2017), is adopted to repurpose secondary data for VVAM. Johnston's framework details the need for three considerations before data analysis: developing the questions of inquiry, identifying the dataset, and evaluating the dataset.

3.1.1. *Developing inquiry questions*

A critical review of current urban regeneration policy initiatives to ameliorate vacancy is helpful to set research questions for interrogation by VVAM. For instance, a review of local government policy action to encourage building owners to reactivate vacant buildings. In addition, a review of published research could further inform any research

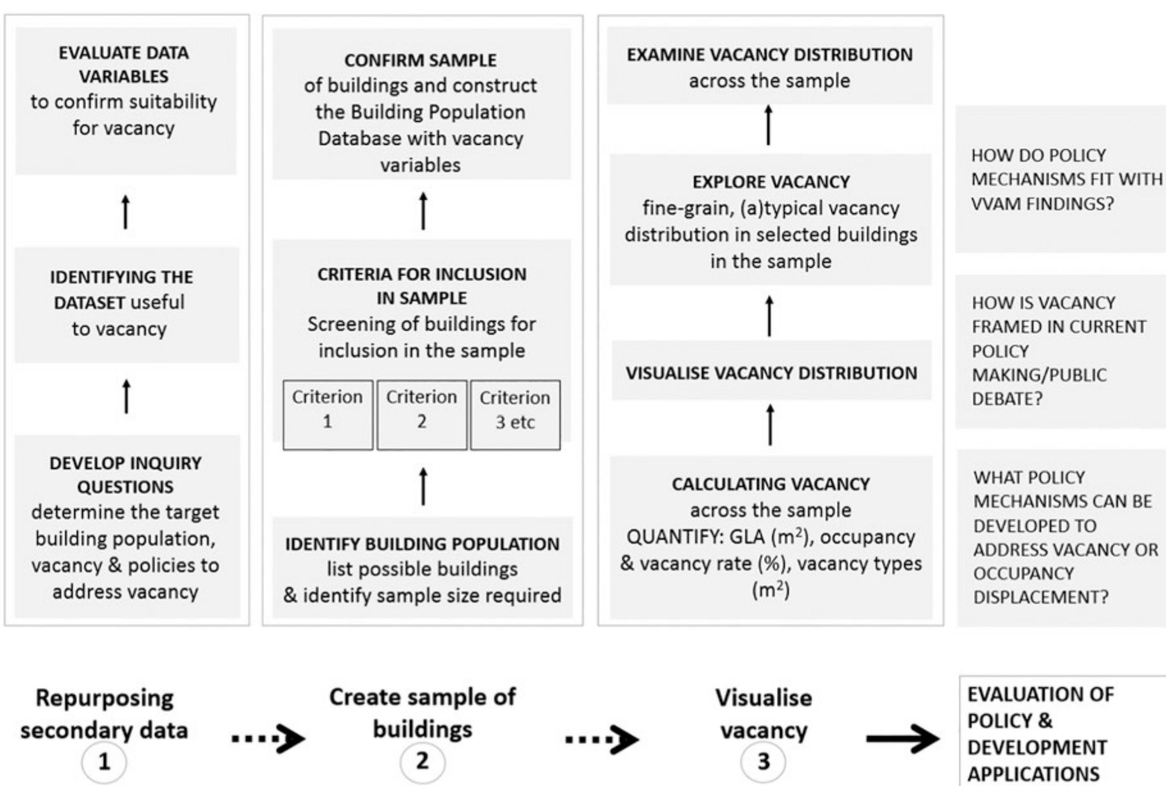

Fig. 1. VVAM framework, incorporating Johnston (2017) model for repurposing secondary data.

questions to be investigated by VVAM and refine how scholarly literature frames vacancy in particular building populations such as retail or office buildings.

3.1.2. Identifying the dataset

Two sound data sources for quantifying vacancy are (1) secondary data collected by local and national governments for environmental rating schemes and (2) taxation data. Mandatory disclosures are most promising as they will potentially permit the inclusion of a larger sample of buildings when compared with voluntary disclosure schemes. Data, however, is patchy when schemes are relatively new, as is the case for mandatory environmental rating schemes for commercial buildings in Australia, which were only introduced in 2017 (Australian Government, 2019). However, new energy efficiency ratings are a possible source for future research once enough time has elapsed since their introduction (Australian Government, 2019). Data collected by local and national government taxation purposes is another most likely source for vacancy research, in the absence of immediately available and publicly accessible databases of all buildings in a given location. A study by Muldoon-Smith (2016) also identifies taxation data as the most comprehensive and readily available for examining vacancy in commercial buildings within the UK. This paper details the application of VVAM using local council taxation data.

3.1.3. Evaluate data variables

Once a suitable dataset is sourced, a review of the variables can determine the vacancy types permissible by the dataset. The review needs to examine:

- Variables useful to investigate vacancy
- Variables to aid efficient construction of each building's dataset, for example, locational information (e.g. GIS references, building number, street name);
- The smallest unit of data to be analysed
- If any further work is required to identify the units of data according to storey level location
- Classification of functional use, e.g., office use, retail use

Secondary data for existing buildings can be published according to the scale and size of the space or business it serves. Therefore it is likely to be built up of smaller units of accommodation than on a whole-building basis. For instance, there will typically be many individual tenancy leases or businesses within a subdivided multistorey commercial building. These smaller units are referred to in this paper as Single Ownership Areas (SOAs) and are defined by their gross lettable area (GLA). The GLA is a broadly accepted method of measurement for transactional purposes used in property valuations (API, 2017a,b). The total GLA only includes area which is exclusively available for occupation, to the exclusion of another owner(s) or tenant(s). Therefore, one SOA can encompass the whole building under single ownership or tenancy, or only part of the available floor area. Each building's vacancy data will likely need compiling from smaller units of SOA data.

The accuracy and trustworthiness of secondary data are a potential limitation of reusing existing data. A comparative check of GLA (m^2) can be undertaken to address this potential limitation and aid confidence before undertaking more extensive work to calculate vacancy using VVAM. A reliable source of floor area values is needed to undertake a comparative check, such as mandatory building energy efficiency programs controlled and audited by government organisations. The comparative check of GLA data for Adelaide is detailed later by Fig. 3 in the case study.

3.2. Stage 02 create sample of buildings

Before VVAM can be applied, a building sample or population database is needed. Decisions need to be taken about variables to categorise the buildings and the inclusion criteria used to select the building population sample. The criteria may include space use categories, heritage status, and physical attributes such as storey height or minimum floor areas.

VVAM offers flexibility as a practical tool for policymakers as it can accommodate different building typologies and uses and is not limited by storey levels or average floor plate areas. VVAM can also incorporate other variables essential to other research inquiries, such as ownership structures using certificates of land titles. Ownership structure refers to the number of owners and their legal status affecting any future decisions to manage a building, as documented in a building's titles or deeds. Ownership structures, therefore, have the potential to impact building management, particularly adaptations to address vacancy. The use of MS Excel for vacancy analysis using VVAM permits convenient integration of other statistical analysis software if the research inquiry requires further investigation. Exporting a building population database from Excel format to SPSS for statistical analysis is a convenient and efficient extension of VVAM. The method also permits the integration of references to allow GIS mapping, if required by the research inquiry.

3.3. Stage 03: visualise vacancy

VVAM is relatively straightforward as it uses simple calculations using floor area data. First, GLAs need to be calculated, then areas occupied and vacant can be established, before vacancy types can be quantified. This vacancy data can then be visualised. The calculations needed to quantify vacancy before visualisation are detailed below.

3.3.1. Calculating vacancy

The construction of a database enables the calculation of GLA ($GLA_{BUILDING}$, in m^2) for each building using the formula on a building-by-building basis:

$$\text{Total } GLA_{BUILDING} \quad \sum GLA_{SOA1} + GLA_{SOA2} + \ldots\ldots + GLA_{SOA\ldots}$$

Space within existing buildings can be further separated into different use-classes. Often existing buildings contain more than one functional use, e.g. commercial buildings can include a combination of office-use, education or training-use, childcare provision and retail or restaurants. This preparatory work enables VVAM to be applied for a range of different building populations and evaluate urban planning policy for a multitude of policy initiatives, such as adaptive reuse to address commercial building vacancy or policy to target heritage building reactivation.

Identifying and coding different class-uses within a building can accommodate different development types within a building population. Mixed-use development is an increasingly popular design strategy internationally, and therefore mixed-use buildings need to be accommodated in studies to develop effective policy action. Typical mixed-use developments comprise ground-floor retail, car parking, commercial and residential accommodation, all within the same building envelope. Areas for different space uses can be accommodated within VVAM if GLAs for different class-uses are given prefixes to denote where space categorisation is needed. To examine only office-use space, for example, the use of the prefix 'o' for office space use, or 'r' for retail space use:

$$\text{Total } oGLA \quad \sum oGLA_{SOA1} + oGLA_{SOA20} + \ldots\ldots + oGLA_{SOA150}$$

$$\text{Total } rGLA \quad \sum rGLA_{SOA1} + rGLA_{SOA20} + \ldots\ldots + rGLA_{SOA150}$$

Prefixes enable the isolation of SOA data for separate space uses within buildings in a population sample.

An Occupancy Rate (OR) needs to be calculated for each building before vacancy rates (VR %) can be determined. Data variables to quantify the occupied floor areas are referred to as Component of Gross Lettable Area (CGLA) in this paper. A vacancy rate (VR) is then calculated for each building by finding the inverse of OR (%). In addition to VR (%), it is also useful to understand vacancy in terms of area (m^2) by calculating Vacant Area (VA). Vacancy rates (%) can be converted to areas (m^2) easily as follows:

$$OR \quad \text{Total } CGLA_{BUILDING}/\text{Total } GLA_{BUILDING} \times 100\%(\%)$$

$$VR \quad 100\% \quad OR\ (\%)$$

$$VA \quad \text{Total } GLA_{BUILDING} \quad \text{Total } CGLA_{BUILDING}\ (m^2)$$

On this basis, vacancy rate (%) and area (m^2) can be quantified within a building population across and filters can be applied to map vacancy across different building locations, construction ages, building height and other variables relevant to research inquiry.

GLA, which is Untenanted (GLAU) and vacant greyspace (VG), are two types of vacancy suitable for quantification using cross-sectional datasets. It is important to quantify greyspace to enable a more nuanced and useful understanding of space usage and demand within a city. Data from space advertised 'for lease' is only one component of urban vacancies. To identify Untenanted (GLAU) and Greyspace vacancy (VG), data needs to be collected which determines not only values of GLA (m^2) but also the Component of GLA (CGLA) used by the current tenants or owner-occupiers. For illustration, in the case of Adelaide, data collected for local council rates valuation of commercial buildings included variables that could be combined to deduce which SOAs are: vacant and unleased (GLAU); leased and occupied; and leased but under-occupied – greyspace (VG). Untenanted vacancy (GLAU) can be calculated when the Component of GLA (CGLA) is equal to 0 m^2, meaning the SOA has 0 m^2 occupation. Likewise, Greyspace (VG) can be derived from SOA data when CGLA is greater than 0 m^2. If the CGLA is equal to GLA, space is considered to have no greyspace vacancy and is fully occupied. The formula for calculating Untenanted and greyspace vacancy on a building by building basis are as follows:

$$\text{If } CGLA \quad 0\ m^2,\ \textit{untenanted vacancy}\ GLAU_{BUILDING}$$
$$\sum GLA_{SOA1} + GLA_{SOA2} + \ldots\ldots + GLA_{SOA150}\ (m^2)$$

$$\text{If } CGLA > 0\ m^2,\ \textit{greyspace vacancy}\ VG_{BUILDING}$$
$$\sum (GLA_{SOA1} \quad CGLA_{SOA1}) + (GLA_{SOA2} \quad CGLA_{SOA2}) + \ldots\ldots (m^2)$$

If space use categories are also used, vacancy for specific space uses in each building can also be investigated. For example: *untenanted vacancy* in office use space: $oGLAU \quad \sum oGLA_{SOA1} + oGLA_{SOA2} + \ldots\ (m^2)$, and for *greyspace vacancy* in office use space: $oVG \quad \sum (oGLA_{SOA1} \quad oCGLA_{SOA1}) + (oGLA_{SOA2} \quad oCGLA_{SOA2}) + \ldots\ (m^2)$. The data generated through the above formula can then be visualised, and its distribution examined.

3.3.2. *Visualise vacancy distribution*

VVAM enables the visualisation of vacancy and occupancy as part of a critical investigation of vacancy distribution within a building and across a building population to evaluate urban planning policy mechanisms to address perceived high vacancy rates. While aggregated vacancy rates can identify vacancy problems within a city, aggregated rates cannot offer insights into the distribution, scale and location of vacancy clusters and types.

VVAM uses stacked bar-charts to represent vacancy and occupancy within each building to undertake analysis of the 'shape' and approximate location of vacant space. This representation of data is similar to architectural section drawings. Sectional drawings differ from horizontal plans as they are used to communicate vertical dimensional information and can, therefore, visualise occupancy and vacancy on a level-by-level basis. Microsoft Excel is used to create stacked bar charts because MS Excel software licences are typically standard software and often used by local government and real-estate industry groups for collating property data. The stacked bar charts visualise area (m^2) data, which can also be classified according to its functional use (office, retail, or other). VVAM visualises the distribution of occupied space, greyspace and vacant space floor areas. Examples of the visualisations for two buildings are given in Fig. 2.

The areas represented in the stacked bar charts are the GLA (m^2) assumed to be calculated using the International Property Measurement Standard 3 Office Method of Measurement (API, 2017a,b). Each bar on the stacked bar charts does not represent the actual floor area but a total of the GLA (m^2) for each level within a building. Therefore, there can be some variation in the total floor area's representation compared to the expected total floor area on a floor-by-floor basis. An example of this can be seen on the 6th and 9th levels of building A, and the ground and 5th levels of building B. This feature of the visualisations can be explained by exclusions for calculating GLA due to variations in architectural design, location of services, lifts and common stairs (API, 2017a,b).

4. Application of VVAM to explore vacancy

4.1. *Case study: City of Adelaide*

Adelaide is the capital of South Australia (SA) but currently has a low predicted growth rate compared to the other Australian state capital cities. South Australia's population growth is predicted to be between 0.1% and 0.9% p.a. up to 2027 (ABS, 2018). SA also had a net loss in interstate migration in 2016–17 (ABS, 2018). In 2017, published vacancy rates for the CBD's commercial buildings hovered around 16.1% (Knight Frank, 2017). This average was above the historic vacancy rate of 12.4% (PCA, 2018). Media attention to the high vacancy average rate described the problem as the 'adaptive reuse predicament' (Evans, 2015) and called for policy action to increase adaptive reuse uptake to address vacancy. Despite the problem of perceived high vacancy in Adelaide, senior policymakers at both local and state government departments communicated to the researcher that they did not have access to vacancy data beyond aggregated office building vacancy rates published by industry groups representing office building owners and investors.

A range of policy initiatives exist for Adelaide and adopted through extensive public consultation, including draft State *Planning Policy 03 (SPP03) Adaptive Reuse* (GovSA, 2018) and SA's Minister's specification for *Upgrading health and safety in existing buildings* (GovSA, 2017). These policies call upon *Postcode 3000*, a successful and influential urban planning policy developed in the 1990s for the neighbouring state of Victoria (GovSA, 2017, 2018; McNeill, 2011; Tassone, 2010; Wilkinson, 2018). *Postcode 3000* sought to attract dwellers back into Melbourne CBD through adaptive reuse of vacant buildings affected by Melbourne's economic recession (Baird, 1994; Spiller, 2018).

4.2. *Applying VVAM to the City of Adelaide*

The method detailed in this paper is applied to the office building population for commercial buildings i) located within Adelaide CBD, ii) with non-heritage status, iii) multistorey – 4 storeys and above, and iv) for office-use. The research design uses the largest possible sample of buildings to ensure the sample is representative of the office building population for the case of Adelaide.

Adelaide City Council (ACC) collects data to set local council rates for non-residential buildings. This dataset was identified and deemed most appropriate for the research inquiry, which sought to investigate regulatory barriers preventing adaptive reuse of vacant CBD office buildings. The evaluation found useful variables in the data to examine vacancy in office buildings. ACC shared the data following the drafting of a confidentiality agreement with the researcher.

An evaluation of the secondary data found buildings are often subdivided into varying numbers of commercial suites, referred to as SOA.

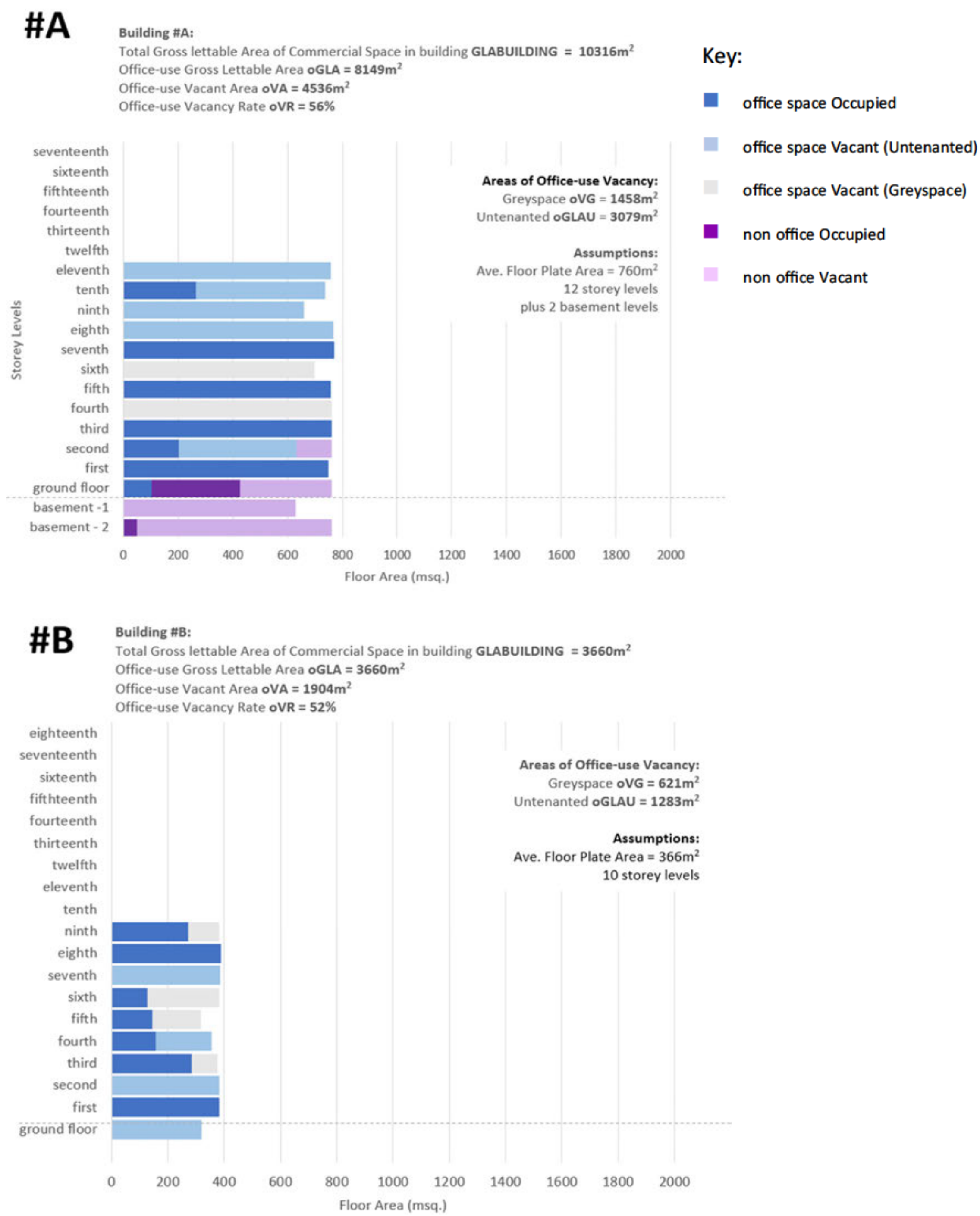

Fig. 2. Example visualisations of vacancy and occupancy generated by VVAM.

In the sample, buildings contained as little as 1 SOA unit were up to a maximum of 193 SOA units. During the stage 01 data evaluation, it was also noted that some buildings were known under several building addresses, particularly on corner sites which abut two or more streets. Further investigative work established the range of addresses each building was known under, including using GIS references, electronic CAD site plans and maps within databases such as Core Logic's Cityscope Adelaide (RP Data, 2012).

Initial values of $GLA_{BUILDING}$ for each building were evaluated against what was known about each building's design to aid confidence in the data and method. The evaluation included storey level totals, site areas, and building footprint areas. Fig. 3 provides an example of a comparative check undertaken in stage 01 review of the dataset using GLA values. The comparative check reveals $GLA_{BUILDING}$ values in the dataset chosen for VVAM interrogation for Adelaide closely matched floor areas (m^2) extracted from Building Energy Efficiency Certificates (BEEC) data, published online via Australia's national mandatory Commercial Building Disclosure Program. BEEC data is selected as it has inbuilt quality-assurance checks of BEEC data via a CBD Auditing Program by the Department of the Environment and Energy on behalf of the Australian Government (CIE, 2019). This is important as audited data, produced and submitted by independent assessors, can be considered to be reliable.

Unexpectedly high or low values for $GLA_{BUILDING}$ were investigated,

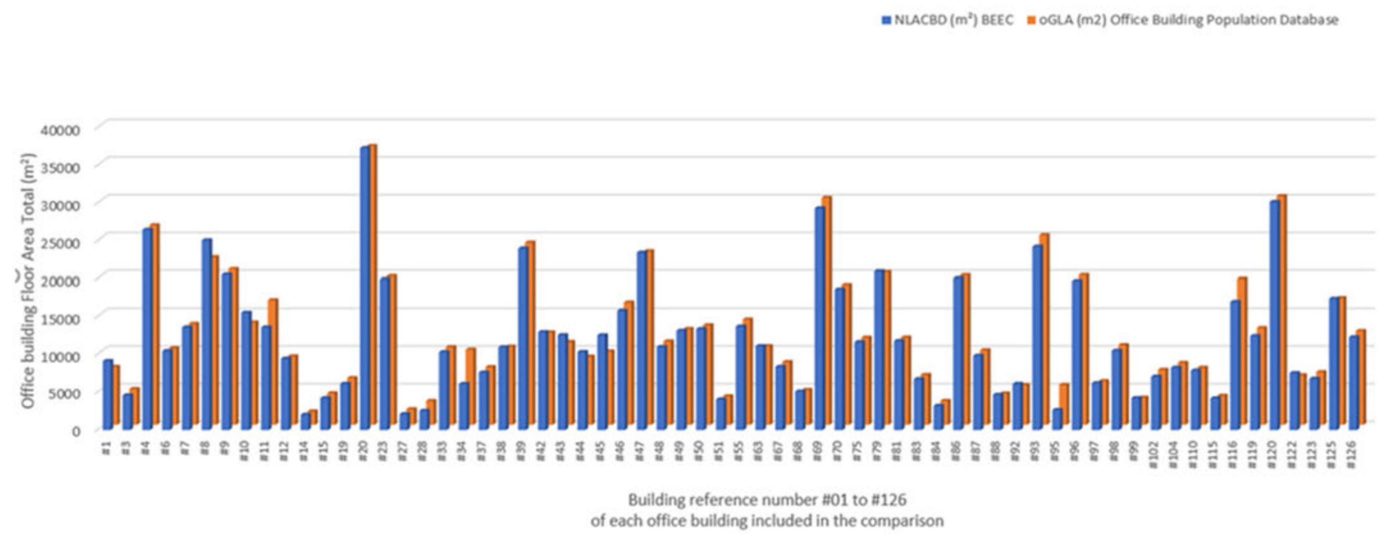

Fig. 3. Comparison of total floor area for each building using ACC data extracted by VVAM and data published in Building Energy Efficiency Certificates published by the Commercial Building Disclosure Program.

and any buildings with unexplained $GLA_{BUILDING}$ values were removed as outliers. A limitation in the ACC dataset was due to some buildings being occupied by local and state government departments. Such buildings revealed a dramatically lower $GLA_{BUILDING}$ value than expected. One possible explanation is that these organisations are exempt from local council rates for non-residential property. This exemption generates no legal requirement or little financial incentive to declare accurate occupancy information in the local council Tenancy Information Survey (TIS), the mechanism for collecting this data. These buildings were considered outliers and removed from further research, leaving a final total of 118 office buildings in the sample (n 118).

For the case of VVAM, a recalibration of some SOA data was necessary to enable the visualisations. In some cases, only one floor level was recorded against an SOA, which equated to a multistorey building. In other instances, data for mid-level floors appeared to be missing. It was necessary to recalibrate the SOA data to visualise the 'shape' and approximate location of vacant space for each building on a level-by-level basis. This recalibration is a limitation of VVAM as some assumptions had to be made about the location of floor areas when SOAs spanned more than one floor plate. Comparisons with other data sources or investigative site visits can help evaluate data accuracy. However, these visits are time-consuming, and tenants or owner-occupants may not wish to disclose floor area information nor permit access.

4.3. *Findings from applying VVAM to Adelaide*

The application of VVAM to Adelaide CBD office building population was fruitful and produced some surprising findings which challenge perceptions of vacancy promoted by commercial property stakeholders. These findings and insights could not be deduced from the simplistic aggregated vacancy rates reported by property groups.

4.3.1. *Distribution of vacancy types*

For Adelaide's case, VVAM revealed no secondary grade buildings standing empty in the sample despite vacancy is found across both primary and secondary building grades in Adelaide CBD, as shown in Table 1. Mean vacancy rates ($VR_{BUILDING}$, %), shown in Table 1, were found to be high at around 50%, which is higher than aggregated rates published by real estate groups representing the property market. This increase was expected as $VR_{BUILDING}$ (%) quantified using VVAM, included both Untenanted and Greyspace vacancy, rather than just space available for lease which met PCA threshold for inclusion of vacant tenancies of area > 1000 m^2.

Table 1
Area vacant by building grade (n = 118), including Untenanted and Greyspace vacancy.

Building by grade	No. of buildings	Total oGLA (m^2)	Total oVA (m^2)	Mean oVR (%)
All grades	118	972,528	552,794	48.9%
Primary grade only	46	596,084	349,228	51.6%
Secondary grade only	72	376,444	203,566	48.2%

Adelaide's data suggests the vacancy problem is due to low demand rather than a specific regulatory problem within secondary buildings, as the vacancy is spread across both primary grade buildings and the lower-quality stock. Another key finding is that no single secondary grade building stood empty, questioning whether whole building adaptive reuse is a suitable urban regeneration strategy for Adelaide CBD. If the demand for office space is low across all office grades, there is also a potential economic risk for adaptive reuse developers. For instance, if a city is undergoing shrinkage, there may be little or no demand for other proposed new uses compatible with the vacant office buildings in CBD locations. Compatible uses are identified as residential, education or health uses (City of Perth, 2017).

4.3.2. *Tenant fit with commercial building design*

Further analysis was conducted to establish whether building grade, size, ownership structure, and occupancy configuration had a relationship with the presence of untenanted and greyspace vacancy. A statistical analysis has been performed to calculate the association between the above factors with vacancy, using the chi-square test. The size of a building, ownership structure and occupancy configuration were all found to be a significant factor of the presence of vacancy ($p < 0.005$), disclosing buildings with larger office-use floor areas, with lower subdivision and fewer groups of owners groups, tended to have a higher vacancy rate (oVR).

This finding contradicted perceptions, disclosed in stakeholder interviews, that commercial building tenants predominantly seek large scale, uninterrupted floorplates in premium grade buildings. Instead, it offers an alternative view, one that highlights an equal or perhaps more demand for lower grade, smaller-scaled office-use space in the case of Adelaide as large-scale buildings tend to have a higher vacancy rate. This finding questions the market need for a continued supply of commercial offices with design briefs specifying large scale, uninterrupted floorplates and signals that the market needs more diversity in accommodation in new commercial architecture in cities.

4.3.3. Visualisations revealed the hidden vacancy

By visualising vacancy types and occupancy, the vacancy location and the relative size of the vacant spaces became apparent, as shown in Fig. 4. Office buildings with over 50% vacancy tended to have a complex mix of greyspace and untenanted vacancy. The distribution of greyspace pockets has implications for adaptive reuse viability in the short-term because space cannot be adaptively reused if it is contracted as leased, even if underused. The analysis also reveals that untenanted vacancy is overwhelmingly distributed in small pockets of single or partial floor plates. Only two large scale buildings with oVR > 50% contain multiple floorplates of untenanted vacancy in office use space (oGLAU) stacked together.

While the study expected to find some vacancy as greyspace, it was still surprising to find greyspace was 3.2 times greater than the area of untenanted vacancy in buildings reporting vacancy rates of over 50%. This finding supports literature examining vacancy in the UK, which suggests greyspace can have a substantial presence in office buildings (Hammond, 2013; Muldoon-Smith, 2016). Hammond (2013) predicts

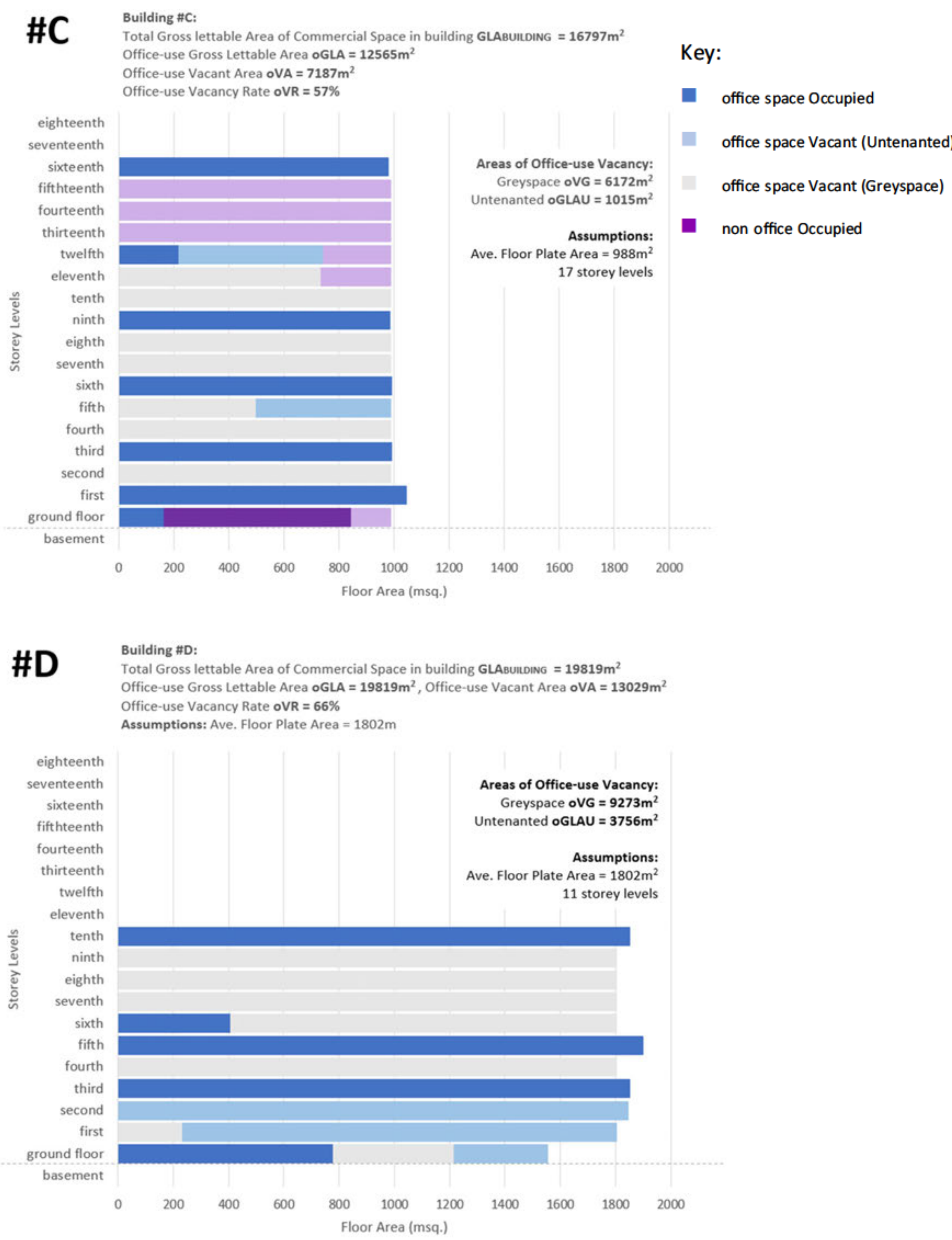

Fig. 4. Visualisations of vacancy and occupancy for Adelaide's office building population.

greyspace vacancy equates to '20% of all property leased by the private sector, which has a total rental commitment of £382bn' (p. 1). Muldoon-Smith (2016) suggests, 'greyspace could equate to 50% of a building's floor space' (p. 115).

Untenanted vacancy is distributed in small pockets peppered throughout the building population, in and amongst occupied commercial suites. Analysis of vacancy distribution using VVAM also highlights landlords had not yet adopted strategies to consolidate vacant space, which is one low intervention obsolescence mitigation strategy (Greenhalgh & Muldoon-Smith, 2017). Consolidation is arguably, a precursor to higher cost interventions such as adaptive reuse.

5. Discussion

The revitalisation of transitioning or stagnating cities and their underutilised buildings is often recognised as a key priority in terms of economic, social and environmental agendas in Australia and internationally (Sing et al., 2019; Wilkinson & Remøy, 2018). VVVAM uses vacancy to indirectly examine the potential cause and effect relationships between perceived drivers of urban decline, which are often the focus of public debate and lobbying. Without access to fine-grain transparent vacancy data, policy mechanisms are limited to corrective initiatives rather than anticipative mechanisms proposed by Buitelaar et al. (2021). In addition, applying policy initiatives from elsewhere runs the risk of ineffective policy if the local and specific vacancy issues are not generalisable and policymakers do not fully understand vacancy drivers.

VVAM generates useful data to bridge the different stakeholder groups crucial to facilitating urban revitalisation through adaption, including urban planners and designers, property owner investors and managers, tenant user groups, and building surveyors and certifiers. Vacancy and occupancy levels are two key influencers that shape decisions and actions by these different stakeholder groups to mitigate changing demand and obsolescence. This approach offers a critical understanding of vacancy types, so policy mechanisms and stakeholder actions can be evaluated and shaped to align better with local property markets and sustainable urban regeneration. VVAM offers useful insight for developing anticipative urban policy development to address the risks of existing building obsolescence early.

Local and state government departments in Australia have already shown interest in VVAM. In August 2018, the researchers were approached by the SA State Government heritage unit with the Department of Environment and Water to quantify and examine the distribution of vacancy across state heritage-listed buildings. VVAM was applied to a sample of 85 heritage buildings, and analysis completed in 2019 informed heritage conservation policy initiatives. This project also disclosed building owners believed it was not likely that further policy initiatives to relax building code compliance would encourage greater adaptive reuse and increased occupancy of Adelaide's heritage-listed building population.

This paper responds to the increasing recognition that vacancy understanding can inform sustainable policy action in response to both urban shrinkage and uncontrolled growth (Buitelaar et al., 2021; Burkholder, 2012). This recognition aligns with criticisms of adaptive reuse published in two recent studies from opposite sides of the world. In Australia, Grodach et al. (2017) are critical of small manufacturing displacement from the inner city due to land-use zoning redesignation. Similarly, Clifford et al. (2018) are critical of the extension of permitted development rights in England and Wales, which encourage adaptive reuse of existing office buildings, highlighting a lack of consideration of vacancy has led to "some places of occupied office space being converted, leading to a potential loss of business activity" in London (p. 10). An understanding of vacancy and how it is distributed within buildings and across cities can avoid the unintended economic and social consequences highlighted by Clifford et al. (2018) and Grodach et al. (2017).

This paper aligns with longstanding calls from policymakers for practical but research-based tools to address public policy decision making (Lavis et al., 2004). VVAM makes a unique contribution for local government joining the drive to adopt data-informed policy in Australia (ACELG, 2013; CoM, 2013; Petit et al., 2020) and internationally (Goldsmith & Crawford, 2014).

VVAM contributes to emerging research offering tools to aid policy development seeking to rehabilitate existing buildings, called for by Sing et al. (2019), and for effective, sustainable management of existing building stocks. Researchers have made systematic attempts to offer helpful tools to aid adaptive reuse uptake, notably: the *Conversion Meter* by Geraedts et al. (2018: 126–149); the fuzzy adaptive reuse selection model by Tan et al. (2014); the ARP model by Langston et al. (2013); and *adaptSTAR* by Conejos et al. (2013). VVAM seeks to quantify vacancy and visualise its distribution rather than evaluate each building's physical attributes.

6. Conclusion

VVAM is the first known study to visualise vacancy on a level by level, building by building basis and the first study to quantify greyspace vacancy. The distribution of vacancy, enabled by VVAM, can be used to critically evaluate adaptive reuse as a go-to strategy to mitigate premature obsolescence. In the case of Adelaide CBD, due to the distribution of vacancy revealed by VVAM, it is unlikely current state and local government policy initiatives will increase the uptake of adaptive reuse to solve the vacancy problem. Despite high average vacancy rates published by property groups, the distribution of vacancy does not lend itself to whole-building adaptive reuse in a city with arguably low demand for buildings converted to new uses. On a broader level, the application of VVAM challenges accepted narratives often offered by stakeholder groups about vacancy. The findings raise questions about the viability of adaptive reuse as an urban regeneration solution in all cities and the need for adaptive reuse policy development for different vacancy problems. Insights gained from applying VVAM to a real-world case highlight the method's relevance for other cities internationally, seeking to address high vacancy rates sustainably.

VVAM is replicable to any city or building population and can therefore provide data-rich, transparent, and objective insight into vacancy types and their distribution to inform strategic policymaking decisions. As with all studies, replication is, of course, dependant on the availability of suitable data. The availability of data to quantify vacancy is a potential limitation of VVAM and should be acknowledged. In the case of Adelaide, taxation data could be repurposed for vacancy because the local council links the rateable value for commercial buildings to "occupancy across the city", commenting "property valuations for the purpose of calculating rates payable are prepared on the basis of Annual Value, which is ACC's 'preferred valuation method'" (ACC, 2017: 2). Other jurisdictions may not link commercial building rates with occupancy, and other data sources will need to be sought. A recommendation from this research is for the development of local councils to collect and publish vacancy data for all building populations important for economic and regeneration activity.

The method can enhance the quality of future research studies that rely on vacancy data to contextualise their research inquiry. For example, VVAM analysis can triangulate qualitative data, which gathers opinions from stakeholders about urban regeneration options to address existing building vacancy and obsolescence. A range of state and local policy levers can offer financial gain for stakeholders, particularly building owners and developers. These policy levers include regulation dispensations, tax concessions, planning approval exemptions, and grants or loans to upgrade existing buildings. Triangulation of qualitative data can limit the bias from stakeholders who seek to financially benefit from encouraging policy action around reducing the economic costs of building regulation. It is hopeful that VVAM can help quantify the impact of policy mechanisms seeking to target vacancy by applying VVAM before and after implementing any policy actions.

Through VVAM, the spread and location of vacancy in any given city can be quantified and tracked, akin to how epidemiology tracks and controls the spread of disease in human populations. VVAM can be valuable to understanding the impact of sudden shocks to property markets, such as the global pandemic of COVID-19. While the impact of COVID-19 upon demand for commercial space in urban cores is yet to be determined, a quantitative approach to understanding vacancy distribution will enable effective policy decision-making to mitigate COVID-19 impacts. Resolving high levels of vacancy is also a vital means to address social and environmental agendas such as reducing premature demolition, construction waste and increasing energy efficiency in existing buildings.

CRediT authorship contribution statement

Gill Armstrong: Conceptualization, Methodology, Formal analysis, Investigation, Writing – Original draft, Visualization, Project administration.

Veronica Soebarto: Writing – Review & Editing, Supervision.

Jian Zuo: Writing – Review & Editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abramson, D. M. (2016). *Obsolescence: An architectural history*. University of Chicago Press.

Adelaide City Council. (2017). City of Adelaide 2017–18 integrated business plan. Retrieved from: https://www.cityofadelaide.com.au/assets/documents/BROCHURE-rates.pdf.

Aigwi, I. E., Ingham, J., Phipps, R., & Filippova, O. (2020). Identifying parameters for a performance-based framework: Towards prioritising underutilised historical buildings for adaptive reuse in New Zealand. *Cities, 102*, 102756.

Aigwi, I. E., Phipps, R., Ingham, J., & Filippova, O. (2020). Characterisation of adaptive reuse stakeholders and the effectiveness of collaborative rationality towards building resilient urban areas. *Systemic Practice and Action Research*, 1–11. https://doi.org/10.1007/s11213-020-09521-0.

Aksozen, M., Hassler, U., Rivallain, M., & Kohler, N. (2017). Mortality analysis of an urban building stock. *Building Research and Information, 45*(3), 259–277.

Armstrong, G. (2020). *The adaptive reuse predicament: An investigation into whether building regulation is a key barrier to adaptive reuse of vacant office buildings*. Doctoral thesis. University of Adelaide. Available from http://hdl.handle.net/2440/129492.

Atkinson, B. (1988). Urban ideals and the mechanism of renewal. In *RAIA conference*. Sydney: RAIA.

Australian Bureau of Statistics (ABS) (2018) Summary for South Australia. In: 3222.0 - Population Projections, Australia, 2017–2066. Last accessed 22.11.2019 from: https://www.abs.gov.au/ausstats/abs@.nsf/7d12b0f6763c78caca257061001cc588/fd938fe1fe00d597ca257c2e001724b5!OpenDocument.

Australian Centre of Excellence for Local Government (ACELG). (2013). Knowledge City. Available at: https://apo.org.au/node/33925.

Australian Government (2019) Commercial building disclosure legal framework. Last accessed 25.11.2019 from: http://cbd.gov.au/overview-of-the-program/legal-framework.

Australian Property Institute (API) (2017a) Technical Paper Information – Methods of Measurement. Last accessed 26/03/2019, available from: https://www.api.org.au.

Australian Property Institute (API). (2017, April). Investor insight: Office market outlook. Available at: https://www.investa.com.au/WWW_Investa/media/Resources/April-2017-Office-Market-Report.pdf?ext .pdf&alt &fpl &fpt &fpr &fpb &guid 0fd9d529-0db5-471f-9dbc-a3ee38ad8bf0&lgW 0&lgH 0&mdW 680&mdH 0&smW 480&smH 0.

Baird, M. (1994). Postcode 3000. *Australian Planner, 31*(3), 153–158.

Bokhari, S., & Geltner, D. (2018). Characteristics of depreciation in commercial and multifamily property: An investment perspective. *Real Estate Economics, 46*(4), 745–782.

Brouwer, H. J. (2014) Land policy and vacancies in the metropolitan Amsterdam office market. In: Nozeman E., Van der Vlist A. (eds) European metropolitan commercial real estate markets. Advances in spatial science (the regional science series). Springer, Berlin, Heidelberg.

Bryson, J. (1997). Obsolescence and the process of creative reconstruction. *Urban Studies, 34*(9), 1439–1458.

Buitelaar, E., Moroni, S., & De Franco, A. (2021). Building obsolescence in the evolving city. Reframing property vacancy and abandonment in the light of urban dynamics and complexity. *Cities, 108*, Article 102964.

Bullen, P. A. (2007). Adaptive reuse and sustainability of commercial buildings. *Facilities, 25*(1/2), 20–31.

Bullen, P. A., & Love, P. E. (2009). Residential regeneration and adaptive reuse: Learning from the experiences of Los Angeles. *Structural Survey, 27*(5), 351–360.

Burkholder, S. (2012). The new ecology of vacancy: Rethinking land use in shrinking cities. *Sustainability, 4*(6), 1154–1172.

Cardullo, P., Kitchin, R., & Di Feliciantonio, C. (2018). Living labs and vacancy in the neoliberal city. *Cities, 73*, 44–50.

Centre for International Economics (CIE) (2019). Review of the Commercial Buildings Disclosure Programme. Retrieved on 29/06/2020 from: http://cbd.gov.au/overview-of-the-program/cbd-review/cbd-2019-program-review.

City of Melbourne (CoM). (2013). Knowledge city strategy 2014–2018. Available at: https://www.melbourne.vic.gov.au/about-council/vision-goals/knowledge-city/Pages/knowledge-city-strategy.aspx.

City of Perth. (2017). *C-grade office case study: Exploring options for adaptive reuse in the Central City*. Unpublished report. Economic Development Unit, Perth City Council.

Clifford, B., Ferm, J., Livingstone, N., & Canelas, P. (2018). *Assessing the impacts of extending permitted development rights to office-to-residential change of use in England*. London: Royal Institute of Chartered Surveyors.

Conejos, S., Langston, C., & Smith, J. (2013). AdaptSTAR model: A climate-friendly strategy to promote built environment sustainability. *Habitat International, 37*, 95–103.

Conejos, S., Langston, C., & Smith, J. (2015). Enhancing sustainability through designing for adaptive reuse from the outset. *Facilities, 33*(9/10), 531–552.

Conejos, S., Langston, C., Chan, E. H., & Chew, M. Y. (2016). Governance of heritage buildings: Australian regulatory barriers to adaptive reuse. *Building Research & Information*, 1–13.

Couch, C., & Cocks, M. (2013). Housing vacancy and the shrinking city: Trends and policies in the UK and the City of Liverpool. *Housing Studies, 28*(3), 499–519.

Crone, T. M. (1989). *Office vacancy rates: How should we interpret them? Business Review, (May), 3–12*.

Della Spina, L. (2020). Adaptive sustainable reuse for cultural heritage: A multiple criteria decision aiding approach supporting urban development processes. *Sustainability, 12*(4), 1363.

Elliot, L. (2020, June 07). *After Covid we're going to need a serious urban regeneration plan*. The Guardian. Available at: https://www.theguardian.com/business/2020/jun/07/after-covid-were-going-to-need-a-serious-urban-regeneration-plan.

Evans, R. (2015, August 18). *Code red over city office space* (p. 45). The Advertiser.

Ferretti, V., & Grosso, R. (2019). Designing successful urban regeneration strategies through a behavioral decision aiding approach. *Cities, 95*, 102386.

Foster, G., & Kreinin, H. (2020). A review of environmental impact indicators of cultural heritage buildings: A circular economy perspective. *Environmental Research Letters, 15*(4), 043003.

Galdini, R. (2019). Urban reuse practices in contemporary cities: Experiences in Europe. *Cities, 87*, 103–105.

Galdini, R. (2020). Temporary uses in contemporary spaces. A European project in Rome. *Cities, 96*, 102445.

Gaskin, M. (2020). Design in context (2020). In A. Orbaşlı, & M. Vellinga (Eds.), *Architectural regeneration* (pp. 291–305). John Wiley & Sons. https://doi.org/10.1002/9781119340379.

Geraedts, R., van der Voordt, T., & Remøy, H. (2018). Conversion potential assessment tool. Building urban resilience through change of use. In S. J. Wilkinson, & H. Remøy (Eds.), *Building urban resilience through change of use* (pp. 121–151). John Wiley & Sons (2018).

Goldsmith, S., & Crawford, S. (2014). *The responsive city: Engaging communities through data-smart governance*. John Wiley & Sons.

Government of South Australia (GovSA) (2017). Minister's Specification: Upgrading health and safety in existing buildings, Including Amendment 01. Last accessed: 20.12.17 from website: https://www.sa.gov.au/topics/planning-and-property/land-and-property-development/building-rules-regulations-and-information/the-south-australian-housing-code-and-minister-s-specifications.

Government of South Australia (GovSA). (2018). Summary of the draft state planning policies for South Australia. Available from: https://www.saplanningportal.sa.gov.au. (Accessed August 2018).

Green, B. (2020, May 20). Covid-19 blurs home and workplace boundaries. *The RIBA Journal*. Available at: https://www.ribaj.com/intelligence/covid-19-rise-in-home working-home-workplace-design-brian-green.

Greenhalgh, P., & Muldoon-Smith, K. (2017). *Mitigating office obsolescence: The agile future*. London: British Council for Offices. Available at: http://www.bco.org.uk/Research/Publications/Mitigating_Office_Obsolescence_The_Agile_Future.aspx.

Grodach, C., O'Connor, J., & Gibson, C. (2017). Manufacturing and cultural production: Towards a progressive policy agenda for the cultural economy. *City, Culture and Society, 10*, 17–25.

Hammond E (2013) Surplus Commercial Property Leases Worth up to £75bn. Financial Times July 25 2013. Last accessed 04/11/2019. Available from: https://www.ft.com/content/d25b515e-f38b-11e2-b25a-00144feabdc0.

Hassler, U. (2009). Long-term building stock survival and intergenerational management: The role of institutional regimes. *Building Research and Information, 37*(5–6), 552–568.

Ho, D. C. W., Yau, Y., Poon, S. W., Liusman, E., et al. (2011). Achieving sustainable urban renewal in Hong Kong: Strategy for dilapidation assessment of high rises. *Journal of Urban Planning and Development, 138*(2), 153–165.

Holden, G. (2018). Top-up: Urban resilience through additions to the tops of city buildings. Building urban resilience through change of use, 105–120 (2018). In S. J. Wilkinson, & H. Remøy (Eds.), *Building urban resilience through change of use (105–130)*. John Wiley & Sons.

Huuhka, S., & Kolkwitz, M. (2021). Stocks and flows of buildings: Analysis of existing, demolished, and constructed buildings in Tampere, Finland, 2000–2018. *Journal of Industrial Ecology*, 1–13. https://doi.org/10.1111/jiec.13107.

Ikiz Kaya, D., Pintossi, N., & Dane, G. (2021). An empirical analysis of driving factors and policy enablers of heritage adaptive reuse within the circular economy framework. *Sustainability, 13*(5), 2479.

International Organization for Standardization (ISO). (2011). Buildings and constructed assets — Service life planning — Part 5: Life-cycle costing. ISO Standard No. 15686. Retrieved from https://www.iso.org.

Johnston, M. P. (2017). Secondary data analysis: A method of which the time has come. *Qualitative and Quantitative Methods in Libraries, 3*(3), 619–626.

Keeris, W. G., & Koppels, P. W. (2006). Uncertainty about the vacancy rate in the Dutch office market, due to the different vacancy types and stratified structure (No. eres2006_235). European Real Estate Society (ERES). Available at: https://docs.google.com/file/d/0B2-Sf44-ZfMFVTlHM3pKa25zRnM/edit.

Kim, G., Newman, G., & Jiang, B. (2020). Urban regeneration: Community engagement process for vacant land in declining cities. *Cities, 102*, 102730.

Knight Frank (Aug. 2017) Office market overview. Accessed 22/11/2019. Available from: https://www.knightfrank.com.au/research/adelaide-office-market-overview-august-2017-4912.aspx.

Kohler, N., & Yang, W. (2007). Long-term management of building stocks. *Building Research and Information, 35*(4), 351–362.

Langston, C., Yung, E. H. K., & Chan, E. H. W. (2013). The application of ARP modelling to adaptive reuse projects in Hong Kong. *Habitat International, 40*, 233–243.

Lavis, J. N., Posada, F. B., Haines, A., & Osei, E. (2004). Use of research to inform public policymaking. *The Lancet, 364*(9445), 1615–1621.

Lee, J., & Newman, G. (2017). Forecasting urban vacancy dynamics in a shrinking city: A land transformation model. *ISPRS International Journal of Geo-Information, 6*(4), 124.

Loli, A., & Bertolin, C. (2018). Towards zero-emission refurbishment of historic buildings: A literature review. *Buildings, 8*(2), 22. https://doi.org/10.3390/buildings8020022.

McNeill, D. (2011). Fine grain, global city: Jan Gehl, public space and commercial culture in central Sydney. *Journal of Urban Design, 16*(2), 161–178.

Mısırlısoy, D., & Günçe, K. (2016). Adaptive reuse strategies for heritage buildings: A holistic approach. *Sustainable Cities and Society, 26*, 91–98.

Muldoon-Smith, K. (2016). *Taking stock: An investigation into the nature, scale and location of secondary commercial office vacancy in the UK and an appraisal of the various strategies and opportunities for its management and amelioration*. Doctoral thesis. Northumbria University.

Muldoon-Smith, K., & Greenhalgh, P. (2016). Greasing the wheels, or a spanner in the works? Permitting the adaptive reuse of redundant office buildings into residential use in England. *Planning Theory & Practice, 17*(2), 175–191.

Muldoon-Smith, K., & Greenhalgh, P. (2017). Situations vacant: A conceptual framework for commercial real estate vacancy (no. eres2017_341). European Real Estate Society (ERES).

Muldoon-Smith, K., & Greenhalgh, P. (2019). Suspect foundations: Developing an understanding of climate-related stranded assets in the global real estate sector. *Energy Research & Social Science, 54*, 60–67.

Ness, D. A. (2002). *Accounting for the effects of oversupply of commercial property*. Doctoral dissertation. University of South Australia.

O'Callaghan, C., & Lawton, P. (2016). Temporary solutions? Vacant space policy and strategies for re-use in Dublin. *Irish Geography, 48*(1), 69–87.

Petit, C., Wentz, E., Randolph, B., Sanderson, D., Kelly, F., Beevers, S., & Reades, J. (2020). Tackling the challenge of growing cities: An informed urbanisation approach. In *In open cities|open data (pp. 197–219)*. Singapore: Palgrave Macmillan.

Pinder, J., Schmidt, R., III, & Saker, J. (2013). Stakeholder perspectives on developing more adaptable buildings. *Construction Management and Economics, 31*(5), 440–459.

Property Council of Australia (PCA). (2012). *Guide to office building quality*. The Property Council of Australia Ltd.

Property Council of Australia (PCA). (2018, July). *Office market report 2018*. The Property Council of Australia Ltd.

Property Council of Australia (PCA) (n.d.) About the OMR. Last accessed 28.03.19, available at https://www.propertycouncil.com.au/Web/Events__Services/Research_Services/OMR_About.aspx.

Remøy, H., & van der Voordt, T. (2014). Adaptive reuse of office buildings into housing: Opportunities and risks. *Building Research and Information, 42*(3), 381–390.

Remøy, H. T. (2010). *Out of office: A study on the cause of office vacancy and transformation as a means to cope and prevent*. IOS Press.

Roberts, E., & Carter, H. C. (2020). Making the Case for Centralized Dementia Care Through Adaptive Reuse in the Time of COVID-19. *Inquiry: a Journal of Medical Care Organization, Provision and Financing, 57*. https://doi.org/10.1177/0046958020969305.

Rodrigues, C., & Freire, F. (2017). Adaptive reuse of buildings: Eco-efficiency assessment of retrofit strategies for alternative uses of an historic building. *Journal of Cleaner Production, 157*, 94–105.

RP Data. (2012). *Adelaide Cityscope*. Sydney: Cityscope Publications Pty.

Saniga, A. (2012). *Making landscape architecture in Australia*. UNSW Press.

Sedgwick, P. (2014). Cross sectional studies: Advantages and disadvantages. *BMJ, 348*, g2276.

Shahi, S., Esfahani, M. E., Bachmann, C., & Haas, C. (2020). A definition framework for building adaptation projects. *Sustainable Cities and Society, 102345*.

Shen, L. Y., & Langston, C. (2010). Adaptive reuse potential: An examination of differences between urban and non-urban projects. *Facilities, 28*(1/2), 6–16.

Sing, M. C., Love, P. E., & Liu, H. J. (2019). Rehabilitation of existing building stock: A system dynamics model to support policy development. *Cities, 87*, 142–152.

Spiller, M. (2018). Economic change and urban design. In K. Dovey, R. Adams, & R. Jones (Eds.), *Urban choreography: Central Melbourne 1985* (pp. 149–163). Carlton, Victoria: Melbourne University Press.

Tan, Y., Shen, L. Y., & Langston, C. (2014). A fuzzy approach for adaptive reuse selection of industrial buildings in Hong Kong. *International Journal of Strategic Property Management, 18*(1), 66–76.

Tan, Y., Shuai, C., & Wang, T. (2018). Critical Success Factors (CSFs) for the adaptive reuse of industrial buildings in Hong Kong. *International Journal of Environmental Research and Public Health, 15*(7), 1546.

Tassone, R. (2010, October 18). *Commercial conversions and shop top housing*. Adelaide City Council. Internal Memo. Unpublished.

Vardopoulos, I. (2019). Critical sustainable development factors in the adaptive reuse of urban industrial buildings. A fuzzy DEMATEL approach. *Sustainable Cities and Society, 50*, 101684.

Wilkinson, S. (2018). The context for building resilience through sustainable change of use adaptation (2018). In S. J. Wilkinson, & H. Remøy (Eds.), *Building urban resilience through change of use* (pp. 1–20). John Wiley & Sons.

Wilkinson, S. J., & Remøy, H. (Eds.). (2018). *Building urban resilience through change of use*. John Wiley & Sons.

Wolff, M., & Wiechmann, T. (2014). Indicators to measure shrinking cities. Martinez-Fernandez, Cristina; Fol, Sylvie; Weyman, Tamara; Musterd, Sako: A conceptual framework for shrinking cities. COST action TU0803: Cities re-growing smaller (CIRES).

Wynne, L., & Riedy, C. (2018). Precinct-scale innovation and the sharing paradigm (2018). In S. J. Wilkinson, & H. Remøy (Eds.), *Building urban resilience through change of use*. John Wiley & Sons.

Yazdani Mehr, S. (2019). Analysis of 19th and 20th century conservation key theories in relation to contemporary adaptive reuse of heritage buildings. *Heritage, 2*(1), 920–937.

Yung, E. H., & Chan, E. H. (2012). Implementation challenges to the adaptive reuse of heritage buildings: Towards the goals of sustainable, low carbon cities. *Habitat International, 36*(3), 352–361.

Yung, E. H., Langston, C., & Chan, E. H. (2014). Adaptive reuse of traditional Chinese shophouses in government-led urban renewal projects in Hong Kong. *Cities, 39*, 87–98.

Zheng, H., W., Shen, G., Q., & Wang, H (2014). Zheng, H. W., Shen, G. Q., & Wang, H. (2014). A review of recent studies on sustainable urban renewal. *Habitat International, 41*, 272-279. *Habitat International*, (41), 272–279.