Embedding Flexible design to endure long-term preservation of Industrial building in Australia

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Abstract: Obsolete industrial buildings often highlight the remains of an industrial culture, being the prominent part of the industrial heritage. Although they offer unsurpassed opportunities for reuse, abandoned industrial buildings are too often considered as obsolete brownfields by local authorities. The preservation of these buildings necessitates their conversion into new uses, a task requiring careful design and implementation. Standard criteria have been defined in the literature for ensuring the adaptive reuse of a built environment, which has minimal impact on heritage values. Nevertheless, little has been discussed about the impact modern social dynamics will have on the actual preservation of reused-adapted heritage buildings, as early obsolescence could jeopardize, and even negate, preservation efforts. This research is based upon detailed analysis of two successful case studies in the Australian context, and is aimed at revealing the need for a preservative approach which adopts multiple cycles of adaptive reuse, and gives priority to adaptive reuse as a proven strategy for salvaging significant buildings and ultimately contributing to community revitalization. The guiding philosophy is that the prominent, extensive, open-plan morphology of Australian industrial buildings could be profiteered to use flexible designs, capable of withstanding multiple cycles of adaptive reuse. The current research identifies the decision-making strategies to embed flexibility into the process of adaptive reuse, assisting in a long-term preservation paradigm for industrial structures.

Keywords: Industrial heritage, Flexible design, Long-term sustainable preservation, adaptive reuse.

1. Introduction

The characteristics of obsolete buildings within a city significantly impacts upon the conservation of cultural aspects of its history; in particular, the remnants of obsolete industrial heritage often present dramatic buildings, landscapes, sites and precincts that contribute to the distinct character of that city. The preservation of these buildings allows maintaining their intrinsic heritage and cultural values (Langston, 2008). A building could become obsolete for various reasons; changing economic and industrial practices, instigating demographic shifts or increasing the cost of upkeep or maintenance, but mostly because it is no longer suited for the original function (Günçe & Mısırlısoy, 2015). Adaptive reuse refers to the process of salvaging an existing building for a purpose other than which it was originally built. Therefore, successful adaptive reuse of obsolete buildings has been seen as project innovative

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opportunity for reusing the heritage asset (RAIA, 2004; Günçe & Mısırlısoy, 2015; Petković- Grozdanovića, et al., 2016; Mehr, et al., 2017). The loss of significant architectural structures will continue if adaptive reuse opportunities are not adopted successfully. This dynamic is well represented by the fate of Geelong's waterfront, in Victoria, Australia: Throughout the 1980's, most of Geelong's waterfront wool stores, which symbolized the significance of the nineteenth century wool industry of Australia, fell into a condition of disrepair (De Jong, 2007) and, regrettably, many iconic industrial buildings that shaped the landscape were lost. The last decades have seen one of the last remaining building, the Bow Truss Building, which formed part of the historic Dennys Lascelles Wool Stores (now National Wool Museum), pitilessly demolished and replaced as a wasteland for temporary car parking. Another local example is the iconic Geelong Power Station A Building, partially demolished to make way for Westfield Plaza Shopping Centre, whose remains now stand disfigured.

To date, adaptive reuse projects have been assessed in accordance with the triple bottom line theory: adaptive reuse of structures are considered a success if they are socially, economically and environmentally sustainable (Langston, 2008; RAIA, 2004; Petković-Grozdanovića, et al., 2016) . These ideas have been integrated into 'design criteria models' for helping in evaluating design performances for adaptive reuse management (Conejos, et al., 2011; Conejos, et al., 2014). Additionally, standard criteria have been defined to ensure that an adaptive reuse project has minimal impact on buildings' heritage values (RAIA, 2004). Nevertheless, little is said about the impact modern social dynamic will have on the actual preservation of reuse-adapted heritage buildings, as early obsolescence of adaptive reuse interventions could jeopardize preservation efforts. Researchers are stressing the need of considering flexible design strategies in the early design stage to maximize the adaptive reuse potential of new buildings (Andrade, et al., 2019), hence, it becomes apparent that the long-term preservation of a structure requires design for multiple cycles of reuse. Despite extensive research efforts being devoted to the reuse-salvage of obsolete buildings and the need for embedding flexibility to prevent, or delay obsolescence of new built, few authors have linked the two research fields: *How to prevent early obsolescence of adaptive reuse projects?*

This paper sought to reveal the need for multiple cycles of adaptive reuse, emphasizing the fact that the same societal dynamics producing large amounts of obsolete buildings can jeopardize preservation efforts by producing early obsolescence to adaptive-reused heritage buildings. Its main objective is to demonstrate the need to embed flexibility into adaptive-reuse design projects to maximize opportunities for long-term preservation. Of particular focus, was the aspect of long-term preservation of architecturally significant obsolete industrial build stock in Australia, this research proposed exploring design solutions suitable to reach the goal of successful, long-lasting preservation of significant architectural buildings. In this particular scenario, the prominent, extensive open-plan morphology of industrial buildings can be profited to produce flexible design strategies to be able to withstand several cycles of adaptive reuse (Martinez, 2020). Assimilating the synergies central to a successful integration of adaptive reuse and highlighting the integration of flexible design strategies, the authors propose a new term, '*Multiple re-use*', for signalling the aim of designing for multiple cycles of adaptive reuse.

2. Exploration of Flexibility in Adaptive reuse

In order to realize the paradigm of long-term preservation of significant industrial buildings, it becomes apparent it is imperative to integrate the ideas of flexibility and future adaptability into the design of adaptive reuse projects of such buildings; thus, aiming for a flexible architecture that is designed to easily respond to change throughout the lifetime of a structure. The benefits of this form of design are significant: it extends the life span of a structure, accommodates users' experiences and intervention, takes advantage of technical innovation more readily, and is economically and ecological more viable. It is worth mentioning that despite the terms 'flexible' and 'adaptable' are used interchangeably, 'adaptability', as defined by Steven Groák (1992), refers to being capable of different social uses, which means designing a particular space that can be used in a variety of different ways, whilst 'flexibility' refers to the provision of the capability of different physical arrangements; this can be achieved by altering the physical fabric, by joining, extending or through sliding or folding walls and furniture (Shuchi, et al., 2017). When pondering the question of flexibility in architecture, the issue of building's longevity arises. The main characteristics of flexible architecture, as defined by (Kronenburg, 2007), include a combination of adaptation, transformation, mobility and interaction in the structure.

Adaptability and transformability are showcased in Cedric Price's Fun Palace (Centre Canadien d'Architecture, n.d.); a proposition for an alternative educational leisure centre that designed to facilitate various programmatic and spatial reconfigurations initiated by its users. The concept was to make the design constantly under construction: users can rearrange wall panels to create new spaces as the program change and evolve, creating endless variation forms and flexibility (Özkoç, 2009). Another successful adaptive-reuse project integrating transformability (and adaptability) is the award-winning Ru Paré Community project (BETA, 2018).

3. Research Methodology

This research is based on a systematic analysis of two case-studies of adaptive reuse of industrial buildings in Australia: Tonsley's MAB (Adelaide) and Federal Mills (Geelong). The cases were analysed to recognize the design strategies and approaches adopted for the projects, aiming to understand how flexible design criteria can assist on long-lasting preservation. Both case-studies are architecturally significant and display a great value of adaptive reuse, however, the way the repurpose project was managed presents significant differences: Federals Woollen Mills was developed by a private company, without any involvement from the community, while Tonsley site was developed as a unique project, sponsored by the city of Adelaide, that promoted the participation of the community into project outlining and definition. Flexible design solutions were investigated, based upon available written and photographic documents and architectural drawings, to determine the strategies of flexible design that help in promoting long lasting preservation of these adaptive-reuse projects. Brand's model (1994) for building decomposition into '*Shearing Layers of Change*' was adopted in this research to help identifying how flexible design solution could be adopted for industrial heritage structures.

3.1 Case-Study 1: Tonsley, Former Mitsubishi Car factory, Adelaide, SA

3.1.1. Background

The site comprises most of the former Chrysler and Mitsubishi Motors Australia site, located in the suburb of Clovelly Park in the City of Marion, Adelaide, Australia. The Tonsley site represents the early settlement history of the Marion districts with mixed farming, market gardening and vineyards. Chrysler purchases the property in 1955 and builds a large complex of single-level sawtooth roofed assembly factory building (Tonsley, 2020).

3.1.2. Tonsley, Adaptive Reuse Innovation District, Adelaide.

When operations ceased at Tonsley vehicle assembly plant in 2008, planning began to transform the 64-hectare site into the Tonsley Innovation Precinct. During the transformation, the large steel frame structure remained, and corrugated asbestos cement sheets and the metallic roof has been replaced. Today, Tonsley is a vibrant knowledge precinct supporting clean technologies, sustainable industries, advanced manufacturing, education, and research. Whilst respecting the structure of the main building known as Tonsley's Main Assembly Building (MAB) in its current form, architects worked closely with community representatives and consultants to create a comprehensive design for the adaptive reuse, which celebrates the industrial heritage of the building and creates a unique destination and contemporary public space (Woods Bagot, 2018). Tonsley's MAB and associated Pods operate as an interconnected and intelligent mixed-use precinct. The masterplan recognised the importance of regional urban fabric and respected the manufacturing heritage of the site. The umbrella-like existing structure (Figure 1, left and right panels) celebrates the industrial heritage of the building, creates a unique public destination, and delivers a clear layout with a highly flexible work environment.

The tenancies use a 'pod' approach that is adaptable, flexible and highly functional. The Tonsley Pod can accommodate up to 40 people seated theatre-style and can easily transform from a training room to a networking space in minutes (Woods Bagot, n.d.). The Main Assembly Building has abundant natural sunlight and ventilation, thanks to skylights and open 'walls' and offers public areas such as the Town Square, two 'urban forests', plus cafés and meeting places that all create collision spaces to foster serendipitous networking for collaboration and innovation (RenewalSA, 2018). The re-use of the motor vehicle assembly building to create a framework within which individual 'pods' area developed and inserted and are able to be expanded, modified or re-placed is a clear example of how to be flexible.

Computer modelling was carried out to align appropriate daylight levels, thermal and acoustic performance, by allocating a specific ratio of solid panels, transparent panels and openings to each space typology. The project team also utilized computational fluid dynamics modelling to derive façade and roof permeability for optimal cross ventilation for user comfort throughout the year (Woods Bagot, n.d.). The aesthetic is industrial, with skeletal frames and raw, legible services. There is an awareness of the sun's path, of changing temperatures and wind patterns. Pockets of vegetation open to the sky provide a welcome respite from the surrounding urban landscape (Atkin, 2016). The grid layout and structures related to the existing build forms are maintained. All new structures do not interfere or connect to the existing building; organic lines are the soft element inside the rigid structure.

To adapt diverse needs, architectural space was designed to be flexible yet suitable to the functional requirements. Tonsley's proposed use of existing space morphology establishes basic systems configurations that allow expansion and contraction of different social uses providing different physical arrangements. Figure 1, central panel, shows examples of MAB's different spatial and functional arrangements, highlighting the flexibility of the design. Tonsley's project demonstrates the successful repurposing of the existing structural elements (hard system) combined with soft elements (organic and open plan) into flexible design arrangements.

The Tonsley model has produced innovative infrastructure features designed explicitly to nurture a collaborative community and to build a culture of innovation. This has meant combining the 'hard' infrastructure, the architecturally planned physical layout, with the 'soft' infrastructure that is supplied by the design of Tonsley's open spaces. The interaction of hard and soft infrastructure has helped to develop cosmopolitanism and a sense of place in the aesthetic transformation of a former manufacturing plant. One of the chief architects involved in developing Tonsley's master plan described the challenge of weaving together hard and soft elements of infrastructure (Mark Dean, 2018)

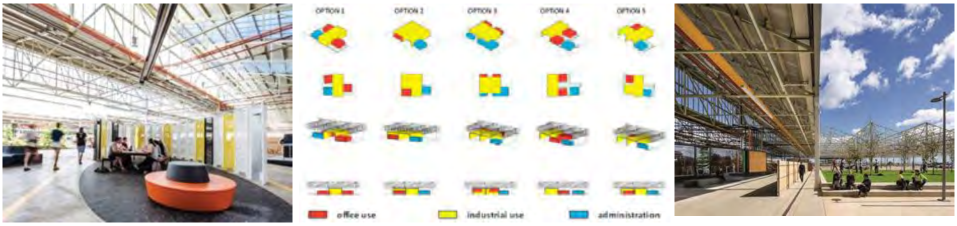


Figure 1: Left panel: MAB's original structure and today's interior (Source: Atkin (2016)), central panel: Examples of MAB's layout configurations (Source: Tonsley (2020)), right panel: MAB's Exterior and interior spaces (Source: Tonsley (2013))

3.2 Case-Study 2: The former Federal Woollen Mill, Geelong, VIC

3.2.1. Background

The Federal Woollen Mill played an important role in the production of army uniforms and blankets for Australian soldiers during the First World War, enabling Australia to produce its own essential military equipment without relying on assistance from overseas. The mill was vital to the economy of Geelong region, created stable employment for many local residents and was considered as a significant innovation of the times. The impressive brick structures of the former mill (Figure 2, left panel), completed in 1915 by Australia's first Labour Government, signal a time in Victoria's history where there was a move away from traditional factories (dark, poorly ventilated & multi-storeyed), towards a new approach focused on improving the working conditions of employees. Welfare programs for workers were also introduced, which was of great social significance (PIVOT CITY, n.d.).

The factory was regarded as revolutionary for its time in employing a logical and linear work-flow through all stages of the processes, which were housed in single storey "sheds" grouped around a central thoroughfare rather than in the usual multi-storeyed building. The buildings were particularly well designed to receive better day-light and ventilation. Another innovation of that time was that all processes were electrically powered from the mill's own power plant. This former Woollen Mill is the most intact in terms of its building stock and original design layout. The original fabric remains largely intact, despite the loss of plant and the addition of some modern envelope. The place is architecturally and scientifically important for its excellence in technology and layout, notably, the influential introduction of the shed principle of factory planning and the use of steam turbines and electric motors for machine driving (Victorian Heritage, 2020).

3.2.2. Federal Mills, Pivot City Innovation District

In 2013, David Hamilton Property Group purchased the Federal Woollen Mills in a derelict state and repurposed these historically significant buildings. Today, these Mills retain their imposing presence while hosting a vast diversity of activities (PIVOT CITY, n.d.). The site is defined by its free classical style in red brick, a material characteristic of much of Geelong, as well as the large windows that dominate its façade. This reinvention of the mill into a technologically creative start-up hub has helped Geelong to overcome its industrial decline, rising into a creative city.

The site located in North Geelong, within an Industrial 2 Zone has an area of approximately 54,000 m^2 with an existing floor space of 28,000 m^2. Original sketch plan, and structures related to original build form, are maintained (Figure 2, central panel). New internal structures, fixed to the existing fabric shed, propose new sub-spaces. The partition responded to the new uses: sub-areas- spaces for lease. This internal subdivision emphasis privacy and specific use spaces. The new proposal breaks-out the original conceptual design which followed a logical and linear workflow through the entire site (through all stages of the processes). This interconnection is lost, reducing flexibility and disfiguring the site.

The design features exposed historic steel beam structure, original polished concrete a unique red brick structure that combine to create a modern industrial interior (Figure 2, right panel). The "saw- tooth" system and large windows allow natural light to reflect throughout the space, this was essential in the manufacturing process that required large areas of enclosed space to house the machinery. The news workspaces were inserted into each industrial shed in a manner that kept the special qualities, structure and experiences of the original building.

Figure 2: Left panel: Federal Woollen Mills by 1975 (Source: Anon. (n.d.)), central panel: Present subdivision of spaces for lease (Source: Martinez (2020)), right panel: Today's Federal Mills' interior spaces (Source: Hamilton Group (2020))

The new tenancies spaces provide services that run under the roof structure. Federal Mill's infrastructural design enables sub-systems to be installed or changed with a minimum of interface problems. This is usually achieved by the separation of a 'base-building' and its interior 'fit-out'. All spaces are completely empty, and each tenancy needs to design his internal fit-out. Hamilton Group provides the service for fitting-out the space or offers some advice on how to use the space more efficiently.

Federal Mill's management plan focuses on how to use the space more efficiently; through detailed utilization studies prior to fit-out, in addition to real-time tracking during the occupation. If areas are underutilized, then they can be modified into more efficient space use. "There is a desire to fit-out highly flexible spaces that can be used for multiple purposes and/or business units or, alternatively, flex- form an office one week, with minor changes, to become a meeting room over the weekend" (Hamilton Group, 2020). The interior is subdivided into studios in a manner that respects the areas and volumes of the original spaces. The aim was to create flexible, adaptable interiors that would help extend the life of the building, while allowing the original plan to be easily read within the adapted building.

4. Identified Flexible Design Strategies for Adaptive Reuse

Adaptive reuse was unanimously signalled as one of the most valuable strategies to preserve these industrial buildings by largely retaining their structural integrity, therefore, the changes needed to alter the functionality appeared to be relatively minimal. The design analysis of the case-studies also revealed that the specific flexible strategies incorporated in the buildings increased the capacity to accommodate changes while preserving the industrial heritage. Case-study analysis portrayed how preservation of the structural clarity of industrial buildings principally influenced to retain their structural integrity, hence, the changes required to alter/enhance its functionality appear to be relatively minimal. Both projects demonstrated that fitting a newly constructed *shell* inside existing layouts is a bespoken way of offering industrial spaces a new purpose whilst maintaining the legacy.

Flexible designs appear as key factors for conveying sustainability of the projects. Tonsley's project took advantage of using the open space where flexible design is placed in a way that responds to the plan and spatial logic configuration. Federal Mill preserved the existing shed structure; unfortunately, the original plan, following the manufacture process, was lost to create privacy for the new tenants. The result degrades the flexibility of the site; however, this new subdivision could be an important factor for the economical sustainability of the project. Current research findings identified that, by adopting the shearing layers concept by Brand (1994), flexibility of industrial buildings can be categorized under the following design approaches.

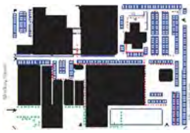
Structure: A process of retrofitting old industrial buildings for new uses should allow structures to retain their historic integrity while meeting the needs of the new occupants. Introduce flexible building concepts using existing industrial structure and combine whit de-mountable systems to extend the useful lives of existing.

Skin: A flexible skin must allow to be modified by means of easy and fast operations as occurs with enclosures formed by replaceable elements. The important additional aspect of transformable architecture is the ability of the building to interact with external environment and respond to climatic situations.

Services: Exposed services are treated as integrated expressive elements. Building management systems and solar panels are provided and adapting industrial buildings to balance modern heating, ventilation, and air conditioning (HVAC), point services must be located outside the building to have free access to repair, change or upgrade systems.

Spaces Plan: Flexibility of the possible layouts gives freedom for the users to create the desired space according to the client needs. Industrial building offer possibility to flexible design plan to increase multi-purpose space. Table 1 summarizes flexible design characteristics found to be common across the two case-studies, based upon Brand's model of decomposition of buildings.

Table 1: Summary of flexible design characteristics uncovered from the two case-studies.

Shearing Layers	Research Case Study 1 Tonsley's MAB, Geelong	Research Case Study 2 Federal Mills, Geelong
Structure	 Compact - Open	 Fragmented - Closed
	• Traces of the past are not erased, but integrated into the design.	• Old industrial structural elements emphasized: brick walls, columns and beams exposed, concrete surfaces are left untouched.
Skin	• Double glazed front façade + metallic cladding: strategic design adapted to a modular existent grid. • Roofs, wall and other parts of the facade are opened for light or closed for atmospheric reasons. • Modular skin: flexible and better insulated. • Ability of the building to interact with external environment	• Industrial building fabric conserved; artefacts, including signage, retained. Building's historic character preserved. • Conserved original building's brick façade and parts of the interior. • Replaced all damage metallic cladding + double glazing to improve building's performance.
Services	• Appropriate daylight levels, thermal and acoustic performance by allocating a specific ratio of solid panels, transparent panels and openings to each space typology. • Façade and roof permeability for optimal cross ventilation for user comfort. • All services running overhead, maintain original services point outside of envelope.	• All services running overhead, maintain original services point outside of envelope. • Free access to repair or change communications wiring, electrical wiring, plumbing, sprinkler system, HVAC. • Exposed services are treated as expressive integrated. • Addition of new 100KW solar system.
Spaces Plan	• Adaptable and flexible open plan. • Design provides future adaption and expansion capabilities through flexible arrangements, allows future adaptive reuse opportunities. • Internal circulation design strategy and existing building volume offers opportunities for the development of tenancies of different forms and scales. • Spatial flow-mobility, open plan, fluid and continuous. • Convertibility, divisibility, elasticity, multi-functionality.	• New use as offices has retained the building's spatial qualities and remnant artefacts. • The relationship between the original building groupings is cancelled to provide privacy in each sub-space. • All original access relating whit exterior have been carefully maintained. • The plan layout shows free circulation around external building, connecting areas through open pergolas: this connection is provided only for external circulation. • Independent structural grid: freedom to develop each space.
Stuff (Fit-out)	• Prefabricated components. • Uses a 'pod' approach that is adaptable, flexible and highly functional. • Able to be inserted, expanded, modified or replaced.	• Fit-out internal design is provided by tenants: the space to rent is empty and all services are provided under the roof. • Guidelines to fit out the space. • Separating the structural and infill elements.
	• Modular coordination system. • Separation of structural and infill elements. • Flexible layout: Open plan and partitioned office space, complemented with meeting rooms and utility spaces.	• Using accessible component. • Employing proper detailed design of fittings, fixtures, and joints that can be easily disassembled.

5. Discussion and Conclusion

Research has emphasised the importance of developing a flexible spatial configuration to meet the precipitously changing demands of the built environment. Despite extensive efforts devoted to the reuse-salvage of obsolete buildings, only a few authors successfully linked these two research fields to date. The current research primarily proposed the need for designing multiple cycles of adaptive reuse, emphasizing the fact that large amount of obsolete buildings would jeopardize the preservation efforts by creating early obsolescence of heritage structures. The importance of embedding flexibility into adaptive reuse projects expected to ease possible future cycles of adaptive reuse interventions, increasing the probabilities of attaining long-term preservation. The analysis of both case-studies revealed that architects and planners with a deliberate effort of producing design could accommodate changing uses of the spaces in order to realize the paradigm of long-term preservation. Therefore, the current paper posits that it is imperative to integrate the ideas of flexibility, and future adaptability, into the design of adaptive reuse projects. Despite the many threats obsolete industrial sites encounter, they have the advantage of presenting a morphology that results ideal for repurposing designs with embedded flexibility.

This research was proposed as an explorative study of existing adaptive reuse projects of obsolete industrial buildings and was part of a more extensive research study undertaken as a post graduate research thesis and presents findings two case study buildings located in Geelong as representative of a study undertaken to understand the Australian context. It does not offer any new tools or strategies for incorporating architectural flexibility into adaptive reuse projects. Designers are increasingly connecting the ideas of reuse-salvage of obsolete buildings and the paradigm of embedding flexibility to prevent future obsolescence. More inter-connected research into these fields, exploring design solutions suitable to reach the goal of successful; long lasting preservation of significant architectural buildings would be welcome.

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