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Zoning a productive city? A typology of clustering, diversity and specialisation in Melbourne's urban industrial areas

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Abstract

This research focuses on identifying the nuanced land use dynamics of urban industrial zones. Industrial lands in major Western cities have undergone significant change in the face of increasingly competitive property markets. At the same time, many countries seek to reshore manufacturing and support local industrial activity amid changes in production technologies, global supply chain shocks and geopolitical insecurity. Yet policymakers often fail to seriously consider the contemporary character of industrial zones and research has yet to analyse this in a systematic way. In response, we employ *k*-means cluster analysis to develop a typology of industrial zones in Melbourne, Australia. The typology captures a range of industrial zone clusters, which vary by industry mix, specialisation and spatial pattern. While some clusters represent traditional industrial areas, others are highly diverse in terms of firm and employment mix encompassing service sector activity and specialised manufacturing industries. These variations underscore the limitations of traditional zoning frameworks focused predominately on use separation and point towards the need for more responsive and context-specific urban economic development and industrial land use policies.

Keywords

economic development, industrial clusters, land use, urban planning, zoning

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摘要

本论文主要关注城市工业区土地利用细微动态的确认。面对竞争日益激烈的房地产市场，西方主要城市的工业用地发生了重大变化。与此同时，在生产技术变化、全球供应链冲击和地缘政治不安全的情况下，许多国家寻求回迁制造业，并支持本地工业活动。然而，政策制定者往往没有认真考虑工业区的当代特征，研究也尚未系统地分析这一点。有鉴于此，我们采用 K 均值聚类分析来制定澳大利亚墨尔本工业区的分类法。该分类法涵盖了一系列工业区集群，这些集群因产业结构、专业化和空间格局而异。虽然一些集群代表传统工业领域，但其他集群在企业和就业结构方面高度多样化，包括服务业活动和专业制造业。这些变化突显了主要侧重于用途分离的传统分区框架的局限性，并指出需要制定更具响应性的，并且适合具体情况的城市经济发展和工业用地政策。

关键词

经济发展、产业集群、土地利用、城市规划、分区

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Introduction

Cities around the globe are reassessing the value of urban manufacturing and industrial activity. Digital production technologies, pandemic-era supply chain disruptions and geopolitical security concerns have engendered efforts to reshore manufacturing and grow local production. For example, the European Commission (2020) Productive City agenda seeks to promote specialised, green and high-tech forms of manufacturing reintegrated into the city. In Australia, where this research takes place, federal government wants 'to be a country that makes things' while addressing climate change through investment in advanced and clean manufacturing (Albanese, 2022).

While these national and supranational agendas are significant, they do not provide meaningful attention to urban industrial land. Over the last 30 years, there have been significant changes to industrial land uses, which have not been captured in detail. The conventional focus of industrial zoning on land use separation and amenity impacts is no longer relevant in many instances where industrial activity is smaller and cleaner. Further, protected industrial zones have had mixed results in terms of stopping the incursion of residential and commercial activity and the subsequent land use conflicts that arise (Davis and Renski, 2020; Grodach, 2022; Nagao and Edgington, 2023). In combination, decades of rezoning established industrial areas to attract residential and commercial uses have produced a deficit of industrial land in many cities (De Boeck and Ryckewaert, 2020; Ferm and Jones, 2017; Leigh and Hoelzel, 2012). These trends have created hyper-competitive industrial property markets where many industrial firms must deal with intra-industrial gentrification, or with competition between established industrial activity and newer, specialised manufacturers that may bid up property prices (Ferm, 2023; Grodach, 2022). Within the context of low industrial land supply, industrial reshoring policy will require detail about the range of extant uses and clustering patterns on contemporary industrial land.

Rezonings and ongoing development pressures inside and adjacent to existing industrial land likely play a role in reshaping contemporary land uses in industrial zones. Policymakers do not have a good grasp on the range of activity that currently exists and how decisions to revise zoning or to rezone areas impact industry. Prior work highlights the industrial and occupational diversity of industrial zones (Grodach and Guerra-Tao, 2023), but research has yet to explore the variations that exist within and between them. Zoning is a blunt instrument, yet land use needs are diverse and often require more nuanced approaches. Given the range of issues described above, industrial zone activity may vary dramatically based on location, infrastructure, building stock, proximity to other industries and other factors. This means that different industrial areas may require different policy interventions. Knowledge of this variation is crucial to realise productive city ambitions.

Focusing on Melbourne, Australia, this study develops and analyses a comprehensive and data-driven typology of industrial zones. We argue that traditional industrial zoning geared towards use separation overlooks and obscures the complexity of contemporary activity that occupies industrial zones. To demonstrate this, we employ cluster analysis to capture the potential variation in place-based industry diversity in industrial zones in a more systematic and detailed manner than previous research. This approach is useful to understand the intricacies of industry location and clustering and their relationship to zoning. It further offers a foundation for more informed and responsive industrial policy at a time when policymakers need to better understand and plan for reshoring and reindustrialisation.

We begin with an overview of the varied conditions and potential uses on contemporary industrial land. We then explain the methodological approach before presenting the six distinct types of industrial clusters in Melbourne. We identify a mix of common, transitioning and specialised industrial zone clusters, which vary by industry mix, land area and job density. While some clusters represent traditional industrial areas, others are highly diverse in terms of firm and employment mix encompassing professional, retail and social services alongside specialised manufacturing activity. We conclude with a discussion of implications for future urban economic development policy and research in the context of ongoing productive city debates.

A diversity of industrial zones

Despite long-term economic restructuring around knowledge and consumer services industries, cities continue to support stable and even growing segments of manufacturing and industrial activity (Grodach and Martin, 2021). Industrial zoning is likely an important enabler because it defines land use regulations intended to provide appropriate space and to protect productive uses. Zoning at large has historically served to shield residential and commercial areas from potentially harmful industrial uses while simultaneously protecting and enhancing property values (Hirt, 2014; Sclar et al., 2020). Over time, this relationship has flipped. Increasingly, cities look to industrial zones to protect productive activity from the competition and conflict that residential and commercial mixed-use areas bring.

Research has long documented the importance of preserving industrially zoned land to protect vulnerable and often essential industries and the consequences of failing to do so (Bonello et al., 2022; Curran, 2007; De Boeck and Ryckewaert, 2020; Ferm and Jones, 2017; Gallagher et al., 2023; Sprague and Rantisi, 2019; Wolf-Powers, 2005; Yoon and Currid-Halkett, 2015). At the same time, traditional industrial preservation zones do

not always accommodate the needs of contemporary industry, particularly quasi-industrial activity such as manufacturing firms that incorporate on-site service functions (Grodach and Martin, 2023). In fact, industrial land has come to support a variety of industrial and non-industrial uses that seek out lower-cost, flexible space legally and otherwise.

As a result, industrial zones may exhibit distinct features and contain a diversity of activity that larger-scale statistics-based studies, which seek to identify generalised trends and explanations of industrial zone performance or industry location, may not capture (Chapple, 2014; Davis and Renski, 2020; Park, 2023). While useful, these studies may miss important contextual factors and industry variations that are difficult to measure. The industry mix in a zone, the location of the zone in a metropolitan region, its proximity to competing and complementary industries and local variation in zoning regulations may all play a role in explaining the character of industrial zones.

For a variety of reasons, industrial zones no longer contain predominately heavy industry and related uses that require high buffer distances. Industry mix in a zone is highly variable and depends on the location of the zone, the existing built environment, legacy industries, transport access and so forth. For example, older, central-city industrial zones possess a denser built environment and street network. Many small, highly networked manufacturing firms seek out these locations to be near associated labour, suppliers and clients (Hatuka and Ben-Joseph, 2022; Roost and Jeckel, 2021). Despite ongoing manufacturing dispersion (Doussard et al., 2017), zoning plays an important role in preserving space for small manufacturing firms that depend on centralised agglomeration economies (Chapple, 2014; De Boeck and Ryckewaert, 2020; Grodach and Martin, 2021). However, rezoning of central industrial zones has dramatically reduced land supply and created cost-competitive conditions (Ferm, 2023). This likely pushes out specialised, rent-sensitive industrial activity that may nonetheless depend on proximity.

Conversely, outer-suburban industrial zones provide larger lots on cheaper land with more immediate highway and airport access. These areas underpin freight logistics infrastructure and impact changing urban development patterns (Haarstad et al., 2024). Conventional planning approaches dictate that industrial zones are required to support large-scale warehousing and logistics operations to accommodate population growth. As regional populations grow, more space is needed to support warehouse and distribution functions, leading to 'logistics sprawl' (Dablanc and Browne, 2020). This may be accentuated by the rise of e-commerce during and subsequent to pandemic lockdowns and the proliferation of last-mile deliveries near consumers (Fried and Goodchild, 2023).

Additionally, industrial zoning ordinances vary, and this can affect industry dynamics. Most cities have different types of industrial zones and code language differs by the types of industrial activity that the zone is intended to support or contain. For example, ordinances may vary in terms of the permissible uses, size restrictions, buffer distances and other features that bear on possible location options for different industries depending on the potential impact on surrounding communities. Just as cities may restrict the location of noxious uses, they also may revise zoning codes to protect industrial activity from the incursion of non-industrial uses. This can potentially shelter industrial firms from land rent competition and create a space for manufacturing incubation and growth.

Conversely, cities can adopt more flexible or permissible code language, which can open the door to higher-rent non-industrial

uses. This can create conditions for the growth and even dominance of office spaces as well as various community and consumption activities including rock-climbing gyms, arts studios and religious institutions. Studies have long documented the incursion of live-work units in zones with heritage manufacturing buildings (e.g. Zukin, 1982). Code changes can also catalyse new office development that retains some industrial character, particularly near established business districts where land is comparatively cheaper but accessible. This shift may increase employment in professional services, healthcare and education sectors on industrial land. In some middle and outer-suburban areas, auto-accessible industrial zones may accommodate big-box stores and other large-format retail activities. Additionally, industrial zones may support local-serving industrial activities such as food production, auto repair and appliance maintenance that locate in industrial zones near residential areas.

In sum, industrial zoning is an integral urban planning tool, historically employed to shield residential and commercial areas from undesirable uses while protecting property values. However, as the examples above illustrate, industrial land today is considerably more diverse. Various types of manufacturing and industrial activity may develop in industrial zones. Zones may gentrify with the introduction of professional or consumer services, leading to industrial displacement. Zones may also support a mix of activity that relies on unique place-based agglomeration economies or concentrations of local-serving activities.

This reality complicates conventional zoning approaches, but it is not comprehensively documented. The potential spatial diversity and clustering on industrial land transcends the static categories of established zoning frameworks. This underscores the need to develop more contextualised zoning approaches that can respond to the nuanced and changing dynamics of industrial zone activity. However, studies have yet to document the types or clusters of activity that exist in industrial zones. This study aims to address this by asking: Do industrial zones support identifiable clusters of industry activity? If so, what is the industry employment and occupational mix that defines these clusters? Do the clusters exhibit distinct spatial patterns?

Creating an industrial zone typology

To address these questions, this article develops a typology of industrial zones in Greater Melbourne, Australia. We focus on Melbourne because it is the largest hub of manufacturing and industrial employment in the country supported by renewed State investment (Victoria State Government, 2023). Industrial production was core to the city's early growth through a mix of agricultural product processing, textiles and clothing and, later, automobile and heavy machinery manufacturing (Dingle, 1984). Like many European and North American cities, Melbourne's industrial base has diminished and evolved since the 1970s due to global competition and state-led industrial gentrification and redevelopment. At the same time, the region faces low industrial land supply, forcing attention to optimising land utility as in other high-cost cities (Braddock, 2023; Victoria State Government, 2020).

Current strategic planning initiatives consider this environment and seek to position Melbourne as a 'productive city that attracts investment, supports innovation and creates jobs' (Victoria State Government, 2017: iii). This direction aligns with the emergence of productive city policy in Europe, which aims to 're-integrate production into cities and urban areas, enabling and promoting new forms of mixed-use neighbourhoods' while supporting

innovation economies and sustainable urban development (European Commission, 2020: 5; Novy, 2022). The Victoria State Government's (2017: 35) strategic industrial policy for Melbourne focuses on preserving and redeveloping industrial land 'to support employment and investment opportunities'. It also aims to 'provide clear direction on locations where growth should occur' and support industries to 'innovate and operate efficiently … in areas identified for these purposes' (Victoria State Government, 2020: 32). To do so, strategic planning classifies industrial land into a three-part hierarchy (Victoria State Government, 2020). State-Significant Industrial Precincts (SSIPs) are priority areas to protect and grow industrial activity in strategic outer-suburban locations near freight and transport networks (Figure 1). Regionally significant industrial precincts 'support a range of industrial uses … and new uses'. Some will be maintained as 'key industrial areas' and others 'can transition to a broader range of employment opportunities' (Victoria State Government, 2020: vi). Local industrial precincts are intended to 'support local communities and other businesses operating in the local area' (Victoria State Government, 2020: 35). The latter two precincts allow for local discretion and the introduction of non-industrial uses to encourage more mixed-use industrial environments.

Data

We relied on 2021 industry employment data from the Australian Bureau of Statistics (ABS, 2021) for the Melbourne Greater Capital City Statistical Area to create the industrial zone typology. We compiled and analysed industry employment based on the Australia and New Zealand Standard Industry Classification (ANZSIC) system at the four-digit level. Because there are over 500 unique industry employment categories, we disaggregated the data into 17 composite categories based on prior research that reflects potential industrial zone activity (Appendix Table A1). This detailed data is particularly beneficial for disaggregating the larger industry groupings in the ANZSIC system, while allowing for delineation between different types of industrial activities. We disaggregate manufacturing activities more extensively than service-based sectors due to expected location patterns and to facilitate the identification of potentially specialised manufacturing clusters in industrial zones.

Additionally, we use the Australian New Zealand Standard Classification of Occupations (ANZSCO) system to group occupations. ANZSCO is a four-tier hierarchy of increasing occupational specificity. We group occupations at the two-digit level (sub-groups). This includes 43 different occupations (e.g. construction tradespersons, sales representatives). We classify these occupations based on the relative amount of formal education and training (e.g. long, moderate, short).[1]

We extracted industry employment and occupation data for all industrial zones in Greater Melbourne by Place of Work (POW) at the Destination Zone (DZN) level. Destination Zones are the smallest available census geography for POW data, enabling a granular examination of employment patterns closely tied to specific locations. This resulted in 358 industrial DZNs.

The Victoria State Government (2024b) is responsible for zoning regulations and sets out three types of industrial zones (IN1, IN2 and IN3 zones) in the Victorian Planning Provisions. The Planning Provisions approach to industrial zoning focuses predominately on residential amenity impact. IN1 zones account for 68% of industrial land area. The purpose of IN1 zones is 'to provide for manufacturing industry, the storage and distribution of goods and associated uses in a manner which does not affect the safety and amenity of local communities'

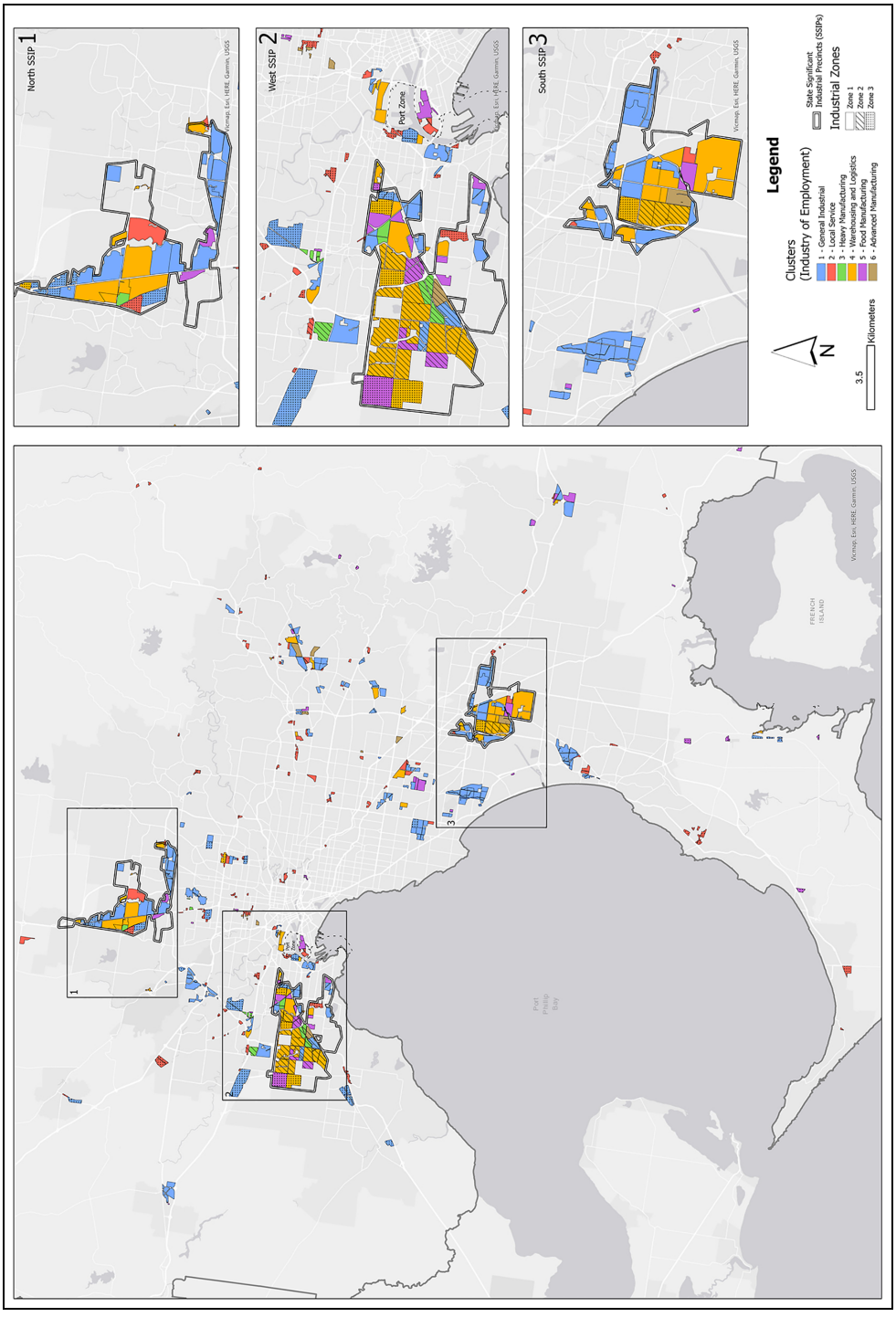

Figure 1. Greater Melbourne industrial zone cluster typology.

(Victoria State Government, 2023, S33.01). There are a limited number of IN2 zones (14% of industrial zoned land area). These larger zones are restricted to SSIPs and dedicated to heavy industry with high amenity impacts 'that require a substantial threshold distance' from other uses (S33.02). IN3 zones (18% of industrial zoned land area) serve as buffers between industrial and other zones and are intended to house 'industries and associated uses compatible with the nearby community' (S33.03). Beyond this basic variation in intent between the industrial zones, all are highly flexible because they specifically prohibit very few land uses (e.g. most types of accommodation, hospitals and 'shops' other than convenience and adult sex shops).[2] For a detailed review of Victoria's Planning System, see Victoria State Government (2024a).

While the majority of IN zones align closely with DZN boundaries, a potential limitation is that some DZNs overlap different zoning categories (e.g. industrial and commercial zones). To address this, we manually reviewed all DZNs and excluded those that contained minimal industrial zoned land (<0.02 km^2). However, due to data availability, we are not able to parse out DZNs that contain multiple IN zone types.

Method

Drawing on this data, we employed *k*-means cluster analysis to develop the industrial zone typology. *k*-Means clustering is an established method in urban studies for identifying and studying neighbourhood and demographic typologies (Delmelle, 2016; Mardaneh, 2016; Vicino, 2008).[3] We apply this method to industrial zones based on their industry of employment composition. *k*-Means aggregates observations in groups that are similar based on the considered parameters. It utilises an expectation-maximisation mathematical approach to form clusters, aiming to minimise intra-cluster differences while maximising inter-cluster disparities (Wu, 2012).

This approach does not evaluate the significance of variables in the dataset, requiring the researcher to assess the most suitable variables (Wu, 2012). In this study, we selected ABS industry of employment data because it is the most fine-grained and appropriate source available to capture the diversity of industrial activities within Melbourne.[4] Additionally, the determination of the number of clusters is contingent upon data interpretation rather than pre-established criteria (Cheshire, 2013). There is no standard principle to determine an optimal number of clusters (Vicino, 2008). After running trials, we considered six clusters as a response that maximised data interpretation and efficiency.

Following the cluster analysis, we utilised the ABS occupation data to gain deeper insights into the character of each cluster. This complemented the industry employment data, enabling a more nuanced understanding of employment diversity across clusters.

A typology of industrial zones

The cluster analysis produced a typology consisting of six distinct industrial zone types. The typology captures a mix of common and specialised industrial zone clusters. Some clusters appear stable, and others represent areas of transition defined by significant levels of non-industrial uses. They display varied levels of job density ranging from low-density job sprawl to more concentrated employment areas. They also vary by average zone size, total land area and location patterns (Figure 1, Table 1). As expected, each cluster contains above average shares of manufacturing, warehousing, construction and repair employment compared to Greater Melbourne. Virtually every cluster contains lower levels of professional

Table 1. Industrial zone cluster typology characteristics.

Cluster	No. of zones	%	Total area (km^2)	%	Avg. area (km^2)	Total jobs	%	Job density (jobs/km^2)
1 General industrial	143	39.9	76.8	44.8	0.54	172,810	39.6	2250
2 Local service	105	29.3	19	11.1	0.18	97,484	22.4	5131
3 Heavy manufacturing	7	2.1	3.5	2.1	0.51	3931	0.9	1123
4 Warehousing	56	15.6	52	30.3	0.93	99,954	22.9	1922
5 Food manufacturing	38	10.6	15.8	9.2	0.42	46,583	10.7	2948
6 Advanced manufacturing	9	2.5	4.3	2.5	0.47	15,081	3.5	3507
Total	358	100	171.4	100	0.48	435,843	100	2543

services employment compared to the region (e.g. finance, insurance and real estate; knowledge and creative industries).

However, the clusters also contain varying sets of industry activity, which contribute to their distinction. Some clusters possess strong concentrations of highly specialised manufacturing activity. Others contain notable shares of social services, government and retail and consumer services employment at rates that are above the Melbourne average. Nonetheless, even highly specialised clusters support a diverse range of industries.

Finally, there is not a clear association between individual clusters and IN zone types. For example, only two of the heavy industry clusters are in IN2 zones, which are intended to house this activity. Rather, a mosaic of different clusters occupy IN2 zones, particularly in the western SSIP (Figure 1). This implies that the inherent flexibility of Melbourne's industrial zone requirements outweighs larger strategic goals and that formal regulatory contexts may have a limited impact on the location of most activity. In this context, understanding clustering patterns may be a useful approach to plan for future industry.

Below, we discuss the character of each cluster based on land area, locations, industry employment and occupational mix.

General industrial zones

Cluster 1 (blue) represents general industrial zones, the most common type of industrial zone. These account for 40% of the zones and encompass the largest land area zoned industrial (77 km^2 or 45% of total land area). They are also the second largest zone on average (0.54 km^2). As a result, they are also distributed across the metropolitan area in IN1, IN2 and IN3 zones (Table 1, Figure 1).

General industrial zones support 40% of all industrial zone employment across a diverse range of industries (Table 1, Figure 2). These zones are a good representation of the industry and occupational diversity that defines contemporary industrial areas. They also belie the statutory intent of industrial zones geared towards isolating traditional industrial activity with high amenity impact. Instead, the dispersed and diversified nature of the zones means that they support large shares of varied and local-serving industries that need industrial land close to end users. These zones are important for the construction industries, with construction trade services and construction manufacturing accounting for 28% of employment in these industrial zones. Highly specialised industries that similarly require proximity to local markets locate here as well. For example, these zones contain two-thirds of all cultural

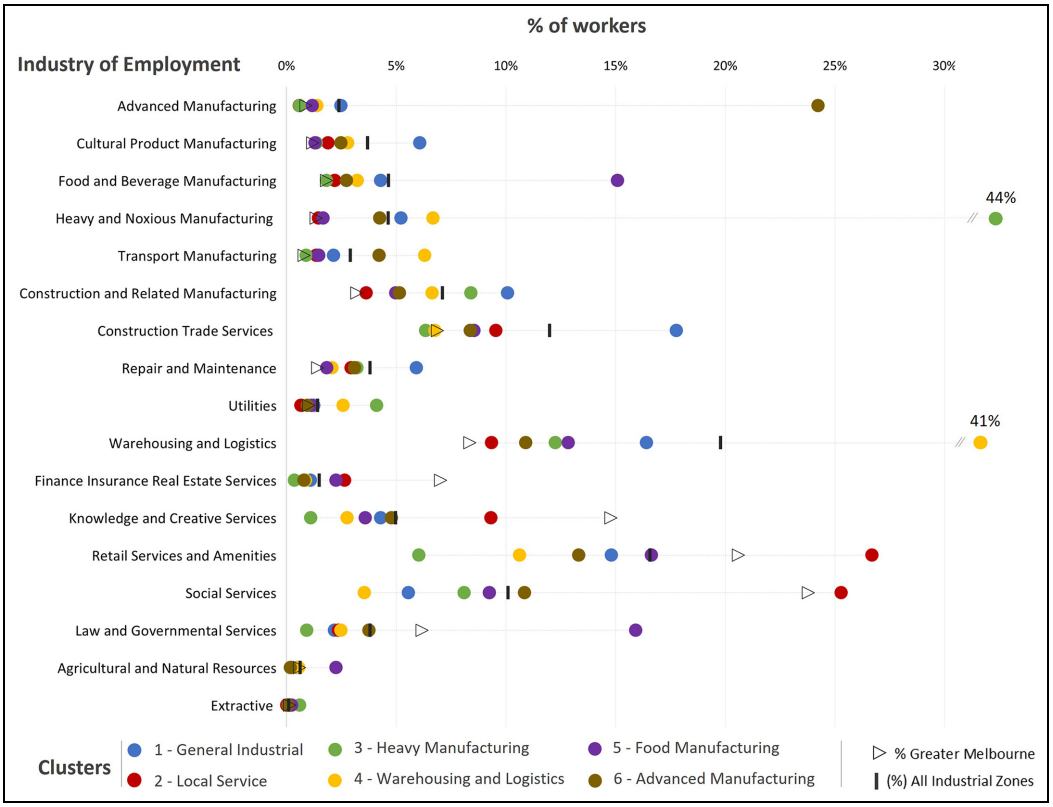

Figure 2. Industry employment share by industrial zone cluster, all industrial zones and Greater Melbourne.

product manufacturing employment and over one-third of food and beverage manufacturing. Retail and consumer services account for a moderate proportion of employment (15%). At the same time, this cluster supports significant warehousing and logistics and heavy industry employment but at lower shares than other clusters, as discussed below.

Industry employment patterns are reinforced by occupation data. General industrial zones support particularly high shares of skilled technician and trade occupations (e.g. automotive engineering and construction) and significant shares of specialist managers (e.g. construction, distribution and production managers). They also contain varied labourers and factory workers (Figure 3).

Local service zones

Cluster 2 (red), local service zones, represents the second largest share of zones (29.3%) but comprises only 11% of the total industrial land area. Reflecting their local service role, these zones are also regionally dispersed, but they are just as likely to inhabit general IN1 zones as they are the IN3 industrial buffer zones intended to house community-compatible activity. While similarly dispersed, these zones differ from general industrial zones in important ways. First, the total (19 km^2) and average (0.18 km^2) land area is considerably smaller. Second, while highly dispersed, they account for most of the remaining inner and middle suburban industrial zones (Figure 1). Due to

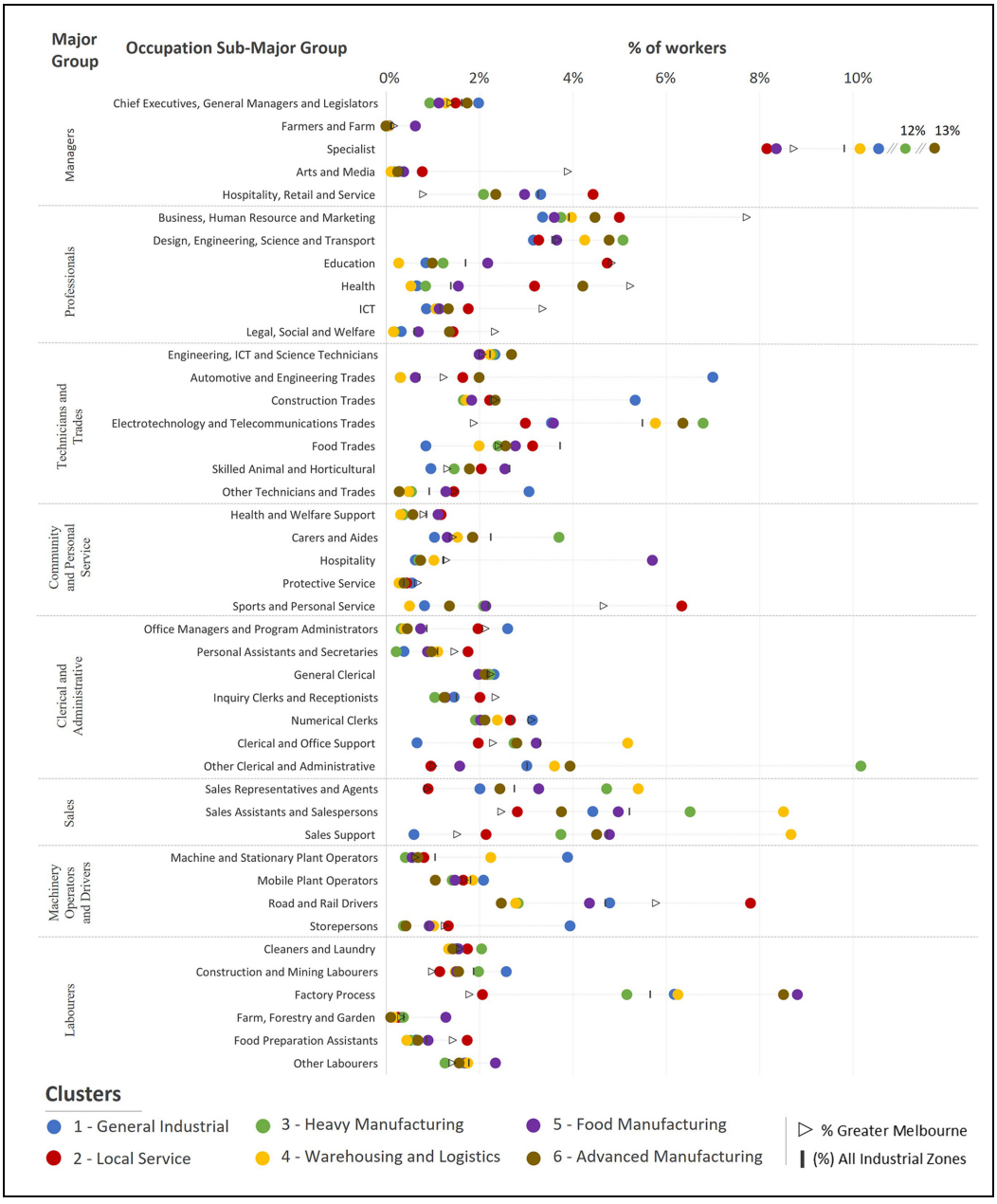

Figure 3. Occupation share by industrial zone cluster, all industrial zones and Greater Melbourne.

their location, these zones are likely less stable than other industrial areas and reflect places in transition or are smaller fragments of once-larger industrially zoned areas.

The employment profile is notably different from Cluster 1 as well. Significantly, local service zones are by far the most job dense in the typology (Table 1). They

support about 22% of industrial zone employment on typically small industrial zones. These zones represent important local service nodes. Combined, over half of industry employment is in retail and consumer services (27%) (including equipment rental, gardening services, laundries and personal services) and social services (25%) (including health, education and employment services) (Figure 2). They have comparatively little warehousing and logistics (9%) and virtually no heavy and noxious manufacturing (1%), which requires larger areas and buffer distances. They also support the largest proportions of knowledge and creative industries employment among the clusters (9%).

This cluster contains the highest shares of many professional occupations and, conversely, road and rail drivers (e.g. bus, truck and delivery drivers) (Figure 3). It possesses the greatest share of personal service workers and comparatively low shares of factory process workers. This indicates either gentrification and transitioning of many of these areas from industrial to other uses or that the zones fill a unique industrial niche in the region.

Heavy manufacturing zones

Cluster 3 (green) represents heavy manufacturing zones. There are only seven of these clusters on about 2% or 3.5 km^2 of industrially zoned land. All but two are located in the Western SSIP in middle-outer Melbourne (Figure 1). As noted above, although the planning code contains dedicated zones for heavy industry (IN2 zones), most heavy manufacturing clusters are not in IN2 zones. Rather, a diversity of other industries not necessarily related to heavy manufacturing locate in IN2 zones, particularly warehousing and logistics activity. This condition reflects the contradictory aims between statutory policy that prioritises heavy industry and the State's strategic emphasis on concentrating industrial land in SSIPs near freight and transport networks.

The cluster contains less than 1% of total industrial zone employment and the lowest job density among the clusters (Table 1). This is primarily concentrated in heavy and noxious manufacturing industries that require substantial separation from other uses (Figure 2). Plant and factory occupations that require less formal education and training comprise just over half of the workforce, while just over 30% work in managerial and professional occupations. Heavy manufacturing zones support comparatively large shares of specialist managers and design and engineering professionals, as well as labourers and clerical and administrative workers (Figure 3).

Warehousing and logistics zones

Cluster 4 (yellow) represents large, low-density warehousing and logistics zones. These sprawling industrial zones are on average the largest in size (0.93 km^2) and support the lowest job density outside heavy manufacturing zones. They represent just 15.6% of all zones but encompass the second-largest total land area (52 km^2). Due to their need for larger industrial spaces, they are primarily located in and around the three outer-suburban SSIPs (Figure 1) across IN 1, IN2 and IN3 zones. This reflects their importance in State industrial policy. In fact, despite their size, they are much less dispersed than Clusters 1 and 2.

Warehousing and logistics zones account for about the same share of total industrial zone employment as local service zones, yet do so on nearly three times the land area (19 km^2 and 52 km^2 respectively). This lower-density employment cluster supports predominately warehouse and logistics jobs (e.g. transport, warehousing and wholesale trade), at a considerably higher rate (41%)

than other industrial zones (Figure 2). It also houses the largest share and amount of transport manufacturing employment, which has traditionally located in the northern SSIP (centred on the former Ford plant in Broadmeadows) and the southern SSIP (the former GM-Holden plant in Dandenong).

The cluster contains the highest proportions of clerical and administrative workers and salespersons (Figure 3). It also supports above-average shares of specialist manager occupations (likely in wholesale, supply and distribution), and of machinery operators and drivers and factory process workers (Figure 3). Sixty per cent of occupations require short to moderate levels of formal education and are closely aligned to the transport and wholesale industries.

Food manufacturing

Cluster 5 (purple), food manufacturing, initially appears as an outlier among industrial clusters due to its eclectic pairing of industries. This cluster is strongest in law and government services (15.9%), predominately prisons, and food and beverage manufacturing (15.1%) (Figure 2). It encompasses about the same industrial land area as local service zones (9.2 km^2 and 11.1 km^2 respectively), but the average cluster area is over twice as large. It also supports a little less than half the employment share of the local service zones (10.7% compared to 22.2%). This zone contains mid-level job density in large-format spaces mostly for lighter industry.

Employment in the food and beverage manufacturing and law and government services industries is uniquely concentrated here, with no other zone type containing more than 4% of either industry. However, the latter's presence in the cluster is due to a string of four correctional facilities in West Melbourne near the warehouse and logistics zones in the Western SSIP. In contrast, food and beverage manufacturing is dispersed across each of the clusters, including the area around the prisons. This cluster represents the locations of many of Australia's largest food and beverage manufacturers (e.g. Bega Foods/Vegemite, Heinz) and newer large-scale alcohol manufacturers (e.g. Starward Whisky, Colonial Brewing) in the Port Melbourne industrial area. It also includes varied concentrations of smaller food production and processing in the South SSIP (predominately Asian foods) and West SSIP (including a Cargill oil seed crush plant).

This composition is underscored by the fact that the zone supports the largest shares of factory process workers (including food processing), farm workers and managers, and skilled horticultural trades among the clusters (Figure 3).

Advanced manufacturing zones

Cluster 6 (brown) captures highly specialised advanced manufacturing zones. This cluster supports only 3.5% of industrial zone employment in nine zones, with high shares in pharmaceutical, medical equipment, computer and other specialised forms of manufacturing (Figure 2). Clusters are located across a highly varied geography, including SSIPs, central innovation zones anchored by universities and medical facilities that incorporate industrial land, as well as the Bayswater pharmaceuticals and medical equipment manufacturing cluster in outer east Melbourne.

The concentration of advanced manufacturing employment (24%) is significant compared to the other clusters in the typology, which contain 2% or less of this sector on average. This cluster contains the highest shares of specialist manager occupations; engineering, ICT and science professionals and technicians; and engineering tradespersons and factory process workers that require less formal education and training (Figure 3).

Implications for industrial zoning in the productive city

The rise of productive city and reshoring mandates necessitates recognition and understanding of the diverse uses in industrial zones and a re-evaluation of conventional zoning practice. Our typological analysis of Melbourne's industrial zone clusters helps to conceptualise the varied nature of industrial land uses and provides insights into the diverse and specialised activities that occupy industrial zones. The findings indicate that traditional zoning frameworks geared towards use separation and amenity impacts may be outmoded, and therefore ineffective in supporting future productive city visions. Industrial zones support considerably more than heavy industry and warehousing activity which require separation from other land uses in low-density, outer-suburban locations. Further, there is no clear alignment between the intent of a specific industrial zone (IN1, IN2 and IN3) and industrial land use activity. This does not mean that zoning is an ineffective planning tool, but that it needs adaptation to new contexts and conditions.

We identified six distinct cluster types characterised by a unique mix of industries and aligned occupations. Clusters 1 and 2 illustrate how industrial zones are highly diverse and mixed-use places. General industrial zones (Cluster 1) comprise the largest share of industrial land area and support a mix of industries, including different types of specialised manufacturing, construction, warehouse and repair employment. Local service zones (Cluster 2) host outsized shares of retail and social services, which are likely accessed by local communities and businesses.

The other four clusters demonstrate how different industrial zones support particular industrial land uses. Heavy manufacturing zones (Cluster 3) and warehousing and logistics zones (Cluster 4) largely contain the traditional industrial land uses enshrined in planning policy. Cluster 5, food manufacturing, highlights the concentration of different forms of food and beverage manufacturing. Advanced manufacturing zones (Cluster 6) are highly specialised areas as well, supporting medical equipment and pharmaceuticals manufacturing in particular. However, these specialised areas also contain a mix of other activities. In fact, although there are predominant industries in each cluster, there is a significant range of industries that are smaller in proportion in all clusters.

The industry mix that defines each cluster is further tied to varying spatial and location-specific features. Clusters reflect the relationship between the predominate size and location of industrial land uses above the specifications of zoning code language. For example, local service zones are comparatively smaller, closer to the city centre and exhibit higher job density than other clusters. By contrast, heavy industry clusters and warehouse and logistics zones encompass large, low-density areas primarily in outer-suburban SSIPs. The advanced manufacturing clusters are dispersed yet concentrated in industrial areas near university and medical precincts.

At the same time, although IN2 zones are geared towards heavy and noxious industry, these zones support a richer mix of industrial land uses and heavy manufacturing occurs proportionately more outside IN2 zones than inside. In fact, none of the clusters in the typology neatly overlay a specific IN zone category.

This industry diversity creates opportunities and limitations that require policy attention to the distinct industrial zone conditions. On the one hand, flexible zoning codes encourage varied industrial and non-industrial land uses. This can support a larger network of interrelated activity ranging from service and supply to research and development (R&D) functions. This works

well for some areas and some types of industrial activity, particularly smaller-scale and highly networked advanced manufacturing and some craft-based production that can afford denser, mixed-use locations and that are less likely to create land use conflicts. Such areas have already experienced industrial gentrification, and it is highly unlikely that they will return to traditional industrial uses.

On the other hand, flexible codes also allow for the incursion of unrelated non-industrial uses into industrial zones, including big-box retail and professional services office space. Whereas the former accompanies the outward residential sprawl of Greater Melbourne, the latter threatens to displace essential manufacturing, construction and repair activity that relies on proximity to the related and centralised industries it services. In both instances, stricter industrial zone regulations can play an important role by channelling industrial activity into specific areas and/or by protecting it from encroaching uses, while potentially limiting industrial sprawl. While the Victoria State Government's (2017, 2020) productive city mandate sets up SSIPs to preserve space for traditional industry functions in strategic outer locations, it allows the property market to decide the fate of its regionally and locally significant industrial zones.

The legacy of rezoning inner and middle industrial areas to residential and commercial zones that command higher property values compounds the effects of weak industrial zoning regulations that prohibit few land uses. Melbourne's remaining patchwork of small, central industrial areas is therefore vital because it supports industries that require close proximity to their labour, suppliers and clients and that need zoning that is both restrictive and flexible enough to create financially feasible conditions for those activities. However, this very flexibility creates the classic conditions for industrial displacement by higher-rent commercial activity and more recent intra-industrial gentrification. Development of a blend of loose and restrictive industrial zones described above may help address this.

Given that the spatial diversity and clustering on industrial land transcend the static categories of extant zoning frameworks, more contextualised zoning approaches that respond to the nuanced dynamics of industrial zone activity are required. Our typology of industrial zone clusters is a first step towards this endeavour. It offers a new methodological pathway that captures the complexity of activities overlaying industrial zones. It offers prospects for testing new zoning tools that are more adapted, updated and context specific than current zoning. Regulations can be adjusted to support specific clusters in the typology or in response to location and property market dynamics by limiting or excluding particular land use types (e.g. office or retail), allowing or restricting the subdivision of space or setting conditional uses. For example, traditional industrial zone settings are generally appropriate for heavy industry and logistics zones (Clusters 3 and 4). Conversely, local service zones (Cluster 2), which possess high shares of retail and consumer services and virtually no heavy industry, can contain more relaxed requirements for showrooms and consumption spaces in areas without significant property market demand. General industrial zones (Cluster 1) that support a varied and diverse range of local-serving industrial activity as well as specialised local production require more strict protections because they typically rely on industrial spaces close to local markets. Advanced manufacturing clusters (Cluster 6) likely already have networks with universities and hospitals, and zoning can reinforce these links. With this kind of information in hand, planners can create decision-making processes that respond directly to the empirical reality of industrial land uses.

Finally, future studies could verify if the patterns in Melbourne are unique or if different cities in Australia and internationally exhibit similar clustering patterns. Researchers can also build from our cluster analysis to explain why specific clusters locate where they do and how they have changed over time, particularly following regulatory change. Stemming from this, studies could incorporate non-industrial zoning categories into the analysis (e.g. commercial zones or special use zones) to compare industry cluster patterns inside and outside industrial zones. They can also look at the interaction of zoning with business, workforce or other industrial policies to better understand how a combination of policy settings supports future productive cities.

Authors' Note

An interactive version of this article is available at https://arcg.is/1zWWyO1.

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Notes

1. The ABS (2023) groups occupations into a hierarchy of five skill levels depending on 'the range and complexity of the set of tasks performed. The greater the range and complexity of the set of tasks, the greater the skill level of an occupation'. Skill level is based on formal education and training, previous work experience required and amount of on-the-job training.
2. While industrial activity is predominately located in industrial zones, it is also allowed in a limited number of commercial zones and special use zones (including the Port of Melbourne Port Zone). However, we are specifically interested in industrial zones and do not account for the mix in other types of zones. This could reveal other relevant patterns but is outside the scope of this study.
3. This approach differs from previous studies of industrial districts and their industrial district typologies because they were concerned with organisational features in complementary industries and not specifically concerned with zoning (Becattini et al., 2009; Markusen, 1999).
4. According to the ABS (2021), 'an individual business entity is assigned to an industry based on its predominant activity'. However, it is possible that some industry codes do not accurately reflect the primary use or all uses. For example, a big-box retailer may operate a distribution warehouse that is misclassified as retail in an industrial zone.

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Appendix

Table A1. Composite industry employment groups.

Group	ANZSIC code	Title
Advanced Manufacturing Based on ABS definition of advanced manufacturing: 'any manufacturing process that takes advantage of high-technology or knowledge-intensive inputs as an integral part of its manufacturing process' except those that require substantial threshold buffer distances (certain Construction and Transport manufacturing and gas and chemicals manufacturing). (https://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/8166.0.80.001Main%20Features22013-14?opendocument&tabname=Summary&prodno=8166.0.80.001&issue=2013-14&num=&view=)	1841	Human pharmaceutical and medicinal product manufacturing
	1842	Veterinary pharmaceutical and medicinal product manufacturing
	2411	Photographic, optical and ophthalmic equipment manufacturing
	2412	Medical and surgical equipment manufacturing
	2419	Other professional and scientific equipment manufacturing
	2421	Computer and electronic office equipment manufacturing
	2422	Communication equipment manufacturing
	2429	Other electronic equipment manufacturing
	2431	Electric cable and wire manufacturing
	2432	Electric lighting equipment manufacturing
	2439	Other electrical equipment manufacturing
	2441	Whiteware appliance manufacturing
	2449	Other domestic appliance manufacturing
	2451	Pump and compressor manufacturing
	2452	Fixed space heating, cooling and ventilation equipment manufacturing
	2463	Machine tool parts and parts manufacturing
	2469	Other specialised machinery and equipment manufacturing
	2499	Other machinery and equipment manufacturing
Cultural Product Manufacturing Based on Grodach and Martin (2021)	1311	Wool scouring
	1312	Natural textile manufacturing
	1313	Synthetic textile manufacturing
	1320	Leather tanning, fur dressing and leather product manufacturing
	1331	Textile floor covering manufacturing
	1333	Cut and sewn textile product manufacturing
	1334	Textile finishing and other textile product manufacturing
	1340	Knitted product manufacturing
	1351	Clothing manufacturing
	1352	Footwear manufacturing
	1523	Paper stationery manufacturing
	1611	Printing
	1612	Printing support services
	1620	Reproduction of recorded media
	2010	Glass and glass product manufacturing
	2029	Other ceramic product manufacturing
	2511	Wooden furniture and upholstered seat

(continued)

Table A1. Continued

Group	ANZSIC code	Title
		manufacturing
	2512	Metal furniture manufacturing
	2519	Other furniture manufacturing
	2591	Jewellery and silverware manufacturing
	2592	Toy, sporting and recreational product manufacturing
	2599	Other manufacturing n.e.c.
	9532	Photographic film processing
Food and Beverage Manufacturing	11	Food product manufacturing
	12	Beverage and tobacco product manufacturing
Heavy and Noxious Manufacturing	1332	Rope, cordage and twine manufacturing
Manufacturing processes that require	1510	Pulp, paper and paperboard manufacturing
substantial threshold distances and/or high	1521	Corrugated paperboard and paperboard
space and utility requirements. Generally low		container manufacturing
R&D activity. See Appendix A: https://	1522	Paper bag manufacturing
www.planning.vic.gov.au/__data/assets/	1524	Sanitary paper product manufacturing
pdf_file/0018/467010/PPN92-Managing-	1529	Other converted paper product
buffers-for-land-use-compatibility.pdf		manufacturing
	1701	Petroleum refining and petroleum fuel manufacturing
	1709	Other petroleum and coal product manufacturing
	1811	Industrial gas manufacturing
	1812	Basic organic chemical manufacturing
	1813	Basic inorganic chemical manufacturing
	1821	Synthetic resin and synthetic rubber manufacturing
	1829	Other basic polymer manufacturing
	1831	Fertiliser manufacturing
	1832	Pesticide manufacturing
	1851	Cleaning compound manufacturing
	1852	Cosmetic and toiletry preparation manufacturing
	1891	Photographic chemical product manufacturing
	1892	Explosive manufacturing
	1899	Other basic chemical product manufacturing n.e.c.
	1911	Polymer film and sheet packaging material manufacturing
	1912	Rigid and semi-rigid polymer product manufacturing
	1913	Polymer foam product manufacturing
	1914	Tyre manufacturing
	1915	Adhesive manufacturing
	1916	Paint and coatings manufacturing
	1919	Other polymer product manufacturing
	1920	Natural rubber product manufacturing
	2110	Iron smelting and steel manufacturing

(continued)

Table A1. Continued

Group	ANZSIC code	Title
	2121	Iron and steel casting
	2122	Steel pipe and tube manufacturing
	2131	Alumina production
	2132	Aluminium smelting
	2133	Copper, silver, lead and zinc smelting and refining
	2139	Other basic non-ferrous metal manufacturing
	2141	Non-ferrous metal casting
	2142	Aluminium rolling, drawing and extruding
	2149	Other basic non-ferrous metal product manufacturing
	2231	Boiler, tank and other heavy gauge metal container manufacturing
	2239	Other metal container manufacturing
	2291	Spring and wire product manufacturing
	2461	Agricultural machinery and equipment manufacturing
	2462	Mining and construction machinery manufacturing
	2491	Lifting and handling equipment manufacturing
	2513	Mattress manufacturing
	7320	Packaging services
Transport Manufacturing	23	Transport equipment manufacturing
Construction and Related Manufacturing	1491	Prefabricated wooden building manufacturing
All codes under C Manufacturing and E Construction that pertain to production of	1492	Wooden structural fitting and component manufacturing
inputs for construction materials, excl.	1493	Veneer and plywood manufacturing
ceramics and glass, included under Cultural	1494	Reconstituted wood product manufacturing
Product Manufacturing	1499	Other wood product manufacturing n.e.c.
	2021	Clay brick manufacturing
	2031	Cement and lime manufacturing
	2032	Plaster product manufacturing
	2033	Ready-mixed concrete manufacturing
	2034	Concrete product manufacturing
	2090	Other non-metallic mineral product manufacturing
	2210	Iron and steel forging
	2221	Structural steel fabricating
	2222	Prefabricated metal building manufacturing
	2223	Architectural aluminium product manufacturing
	2224	Metal roof and guttering manufacturing (except aluminium)
	2229	Other structural metal product manufacturing
	2240	Sheet metal product manufacturing (except metal structural and container)
	2292	Nut, bolt, screw and rivet manufacturing

(continued)

Table A1. Continued

Group	ANZSIC code	Title
	2293	Metal coating and finishing
	2299	Other fabricated metal product manufacturing n.e.c.
	3019	Other residential building construction
	3020	Non-residential building construction
	3101	Road and bridge construction
	3109	Other heavy and civil engineering construction
	6631	Heavy machinery and scaffolding rental and hiring
Construction Trade Services	3011	House construction
All codes under E Construction and 73	3211	Land development and subdivision
Building Services that pertain to construction trade services	3212	Site preparation services
	3221	Concreting services
	3222	Bricklaying services
	3223	Roofing services
	3224	Structural steel erection services
	3231	Plumbing services
	3232	Electrical services
	3233	Air conditioning and heating services
	3234	Fire and security alarm installation services
	3239	Other building installation services
	3241	Plastering and ceiling services
	3242	Carpentry services
	3243	Tiling and carpeting services
	3244	Painting and decorating services
	3245	Glazing services
	3291	Landscape construction services
	3292	Hire of construction machinery with operator
	3299	Other construction services n.e.c.
	7311	Building and other industrial cleaning services
	7312	Building pest control services
Repair and Maintenance	94	Repair and maintenance
All repair and maintenance codes, including automotive, appliance and machinery		
Utilities	D	Electricity, gas, water and waste services
Warehousing and Logistics	F	Wholesale trade
	I	Transport, postal and warehousing
Finance, Business and Real Estate Services	K	Financial services
	67	Property operators and real estate services
	7220	Travel agency and tour arrangement services
	7291	Office administrative services
	7292	Document preparation services
	7293	Credit reporting and debt collection services
	7294	Call centre operation
Knowledge and Creative Industries Services	J	Information media and telecommunications
	M	Professional, scientific and technical services
	6640	Non-financial intangible assets (except copyrights) leasing

(continued)

Table A1. Continued

Group	ANZSIC code	Title
	8102	Higher education
	90	Creative and performing arts
Retail and Consumer Services	G	Retail trade
	H	Accommodation and food services
	6611	Passenger car rental and hiring
	6619	Other motor vehicle and transport equipment rental and hiring
	6632	Video and other electronic media rental and hiring
	6639	Other goods and equipment rental and hiring n.e.c.
	7299	Other administrative services n.e.c.
	7313	Gardening services
	89	Heritage activities
	91	Sports and recreation activities
	92	Gambling activities
	9511	Hairdressing and beauty services
	9512	Diet and weight reduction centre operation
	9520	Funeral, crematorium and cemetery services
	9531	Laundry and dry-cleaning services
	9533	Parking services
	9534	Brothel keeping and prostitution services
	9539	Other personal services n.e.c.
	96	Private households employing staff and undifferentiated goods- and service-producing activities
Social Services	721	Employment services
	954	Religious services
	955	Civic, professional and other interest group services
	Q	Health care and social assistance
	80	Preschool and school education
	8101	Technical and vocational education and training
	82	Adult, community and other education
Law and Governmental Services	O	Public administration and safety
Agricultural and Natural Resources	A	Agriculture, forestry and fishing
	1411	Log sawmilling
	1412	Wood chipping
	1413	Timber resawing and dressing
	6620	Farm animal and bloodstock leasing
Extractive	B	Mining

Note: All four-digit codes are included where a higher-level code is specified. For the complete ANZSIC list of codes, see ABS (2006). N.e.c.: Not elsewhere classified.