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Spatial configuration of warehouses of different sizes in the City of Cape Town municipality

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Background: Various metropolitan areas have become key centres for logistics activities, leading to a significant increase in the number of warehouses. However, there is a gap in the literature regarding the locational patterns of warehouses of different sizes in Africa.

Objectives: To analyse the locational patterns of warehouses of different sizes within the City of Cape Town municipality, South Africa. The analysis focuses on the main factors influencing the placement of warehouses: transport infrastructure, land availability, proximity to customers and land-use zoning.

Method: The study categorised warehouses based on their building footprint sizes, using the classifications of xx-small, x-small, small, medium, x-large and mega. A total of 396 warehouses were categorised accordingly. Proportional symbol mapping was then conducted in ArcGIS 10.1, assigning each warehouse type a specific weighting.

Results: The study found that the areas surrounding the Port of Cape Town predominantly accommodated x-small warehouses. A diverse concentration of warehouses was identified along the railway, near the junctions of regional and national roads and within the areas enclosed by these roads. In addition, warehouses of diverse sizes were primarily situated in the main industrial zones of the municipality.

Conclusion: The City of Cape Town municipality is encouraged to promote the consolidation of particularly large warehouses in strategic locations. These include industrial areas not geographically near the Port of Cape Town but with railway access to the port.

Contribution: The study will contribute towards enhancing the sustainability and efficiency of logistics processes within the City of Cape Town.

Keywords: City of Cape Town; warehouse configuration; warehouse sizes; logistics; supply chain; distribution.

Introduction

Freight volumes and flows have increased exponentially in cities and regions, driven primarily by globalisation and e-commerce (De Oliveira, Dablanc & Schorung 2022; He et al. 2018). Therefore, various metropolitan areas around the globe have become the centres for logistics activities, resulting in a surge in warehousing facilities (Andreoli, Goodchild & Vitasek 2010; Bowen 2008; De Souza, Ballare & Niemeier 2022; Yuan 2019). As warehousing is an integral component of logistics and supply chain processes, it enables the efficient movement of goods from production zones to consumption areas (Rocha & Perobelli 2020). Primarily responsible for the physical distribution of goods (Hesse & Rodrigue 2004), warehouses are the most space intensive and visually prominent components of logistics and supply chain (Mokhele & Fisher-Holloway 2022). The environmental ramifications of warehouses adversely affect communities, making warehouse placement a critical sustainability issue (De Souza et al. 2022). As a generator and attractor of freight activity (Andreoli et al. 2010), other adverse effects associated with warehousing include noise pollution, traffic congestion, traffic collisions and wear and tear of public roads (De Souza et al. 2022). In Cape Town, the City of Cape Town (2016) notes that around 20% of the vehicular traffic on one of the main roads, the N1 corridor, consists of heavy trucks, and the anticipated growth of containerised freight will increase the share of trucks to about 40%, leading to significant congestion at the Port of Cape Town and the central business district (CBD) surroundings.

The literature on the locational patterns of warehousing often oversimplifies the diversity of warehouses. At worst, it treats warehousing as a homogeneous entity, disregarding the different sizes of the facilities, and at best, it merely categorises warehouses as either small or large. Analysing the locational patterns of warehouses of different sizes would enable policymakers, spatial planners and other stakeholders to differentiate these facilities and understand their specific locational attributes regarding proximity to transport infrastructure, land-use regulation, land availability and proximity to customers. This insight would help ensure that spatial planning efforts related to warehouse placement contribute towards improving the efficiencies of logistics processes and reducing the adverse effects. For instance, it is noted that a greater physical separation of supply chain or logistics stages results in larger vehicle miles travelled (VMT), exacerbating environmental impacts (Rivera-Gonzalez, Holguin-Veras & Calderon 2023). Therefore, planners and other stakeholders should have the insight to influence the placement of warehouses in a way that improves efficiencies of distances between suppliers and market and the modes of transport used.

Despite the importance of warehousing in logistics and supply chain processes, there is, to our knowledge, a lack of literature analysing the locational patterns of warehouses of different sizes in the Global South, particularly Africa. This implies that planners and other stakeholders may not comprehend ways the negative externalities of logistics and warehousing can be circumvented or reduced and the efficiencies improved. To fill this gap in the literature, the article uses the study area of the City of Cape Town municipality in South Africa (refer to the study area section) to analyse the locational patterns of warehouses of different sizes relative to the main factors that influence the placement of warehousing. As highlighted in the literature review section, these factors are listed as follows:

- Transport infrastructure (Bowen 2008; Carpenter, Dudensing & Van Sandt 2022; Gingerich & Maoh 2019; Guerin et al. 2021; Pajić et al. 2024; Sivitanidou 1996)
- Land availability and affordability (Guerin et al. 2021; Pajić et al. 2024; Pavolová et al. 2021)
- Land-use planning (Demirel, Demirel & Kahraman 2010; Yuan 2019)
- Proximity to customers (Demirel et al. 2010; Jaller, Pineda & Phong 2017; Makushin & Goryachko 2022).

Against this backdrop, the rest of the article is structured as follows: Section 2 reviews literature on the factors that influence warehouse placement. Section 3 introduces the study area of the City of Cape Town municipality. Section 4 outlines the research methods. Section 5 presents findings on the locational patterns of warehouses of different sizes in the City of Cape Town. Section 6 discusses the findings. Section 7 concludes the article.

Literature review

Durmus and Turk (2014) posit that the geographical patterns of warehouses are not erratic: their placement follows specific economic principles. Identifying a warehouse location includes several factors (Pajić et al. 2024), encompassing land availability and cost, transport infrastructure, location of consumers, and government policies, as expounded in this section. Although numerous studies have been conducted on factors influencing the placement of logistics facilities broadly, this article focuses on the literature on warehousing specifically.

Land availability and cost

As it impacts the overall investment in establishing a warehouse, land availability is one of the significant factors influencing the location of warehouses (Pajić et al. 2024). Warehouses tend to be located in zones that have lower land costs or real estate values (Guerin et al. 2021), which could include greenfield areas. It is typically argued that greenfield developments are relatively cheaper than brownfield development (Pavolová et al. 2021). In Cape Town, Sinclair-Smith and Turok (2012) note that suburban nodes have attracted new economic activity, especially space-intensive, lower-value land uses. However, the assertion that warehousing prefers land with lower cost is not applicable in some contexts. For instance, Guerin et al. (2021) found that not all cheaper land necessarily attracted warehouses in Sao Paulo, Brazil; instead, well-located zones near Sao Paulo were attractive.

Transport accessibility

The literature has argued that transportation accessibility plays a vital role in influencing the location of warehouses (Bowen 2008; Carpenter et al. 2022; Guerin et al. 2021; Sivitanidou 1996). Transportation is essential for moving the goods from producers to warehouses and ultimately to the retailers or end customers (Pajić et al. 2024). In this way, the strategic placement of warehouses is paramount because good access and mobility are crucial in improving the efficiency of logistics and supply chain processes. Therefore, in various contexts, warehouses tend to be located near major infrastructure like highways and airports (Bowen 2008; Gingerich & Maoh 2019; Guerin et al. 2021). Warehouses are also attracted to inland hubs, particularly locations with multimodal connections (Carpenter et al. 2022).

Proximity to customers

The spatial distribution of potential consumers or clients also influences warehouse location choices (Demirel et al. 2010; Makushin & Goryachko 2022). To provide logistics services in a timely and efficient manner, logistics facilities are often positioned geographically close to their customers, which could include manufacturing firms (Yan et al. 2022). In their study on the concentration of warehousing in Southern California, United States, Jaller et al. (2017) found that the presence of manufacturing firms influenced the number of warehouses in a zip code, wherein zip areas with a high number of manufacturing activities were more likely to host warehousing. Similarly, in Cape Town, Mokhele and Fisher-Holloway (2023) found that warehouses agglomerated in the transport zones with the biggest floor area of industrial land use. Typically, finished products are delivered to a warehouse to be dispatched to various destinations, showing that the efficient delivery of products from the manufacturer to a warehouse and then to retailers is essential (Singh, Chaudhary & Saxena 2018).

Policies and land-use planning

Government policies, laws and development plans are also fundamental factors in the decision-making processes regarding the location of warehouses (Demirel et al. 2010). For instance, Sivitanidou (1996) analysed the factors driving the location of warehouses in Los Angeles, California, and established that restrictive land-use regulation tools influenced the locational choice of warehouses. This finding was supported by Yuan (2019), who, among others, found that industrial zoning played a crucial role in locating warehouses in Los Angeles. However, Mokhele and Fisher-Holloway (2022) found that the spatial development frameworks in the Cape functional region in South Africa (comprising the City of Cape Town, Stellenbosch and Drakenstein municipalities) did not explicitly guide the placement of warehousing.

Analysis of the literature

The existing literature often examines the factors influencing the locational choices of warehousing. As overviewed earlier, these factors include various elements of the transport infrastructure (Bowen 2008; Carpenter et al. 2022; Gingerich & Maoh 2019; Guerin et al. 2021; Pajić et al. 2024; Sivitanidou 1996), land availability (Guerin et al. 2021; Pavolová et al. 2021; Pajić et al. 2024), land-use planning (Demirel et al. 2010; Yuan 2019) and proximity to customers (Demirel et al. 2010; Jaller et al. 2017; Makushin & Goryachko 2022). However, a comprehensive understanding of how these factors interact to influence the placement of warehousing is lacking.

Therefore, this research aims to empirically investigate the intricate relationships and interconnections among these key factors that influence the location of warehouses. By so doing, the study seeks to provide insights into how these elements collectively impact the efficiency of warehousing and logistics processes. Subsequently, the study intends to offer recommendations on optimising warehousing placement to enhance the overall performance of freight and logistics processes, thereby contributing to more sustainable supply chain management amid the growing e-commerce activities.

Study area

The study was centred on the City of Cape Town municipality in the Western Cape province, South Africa (Figure 1). The level of analysis was the entire municipal area, where warehouses located within the municipality served as the units of analysis.

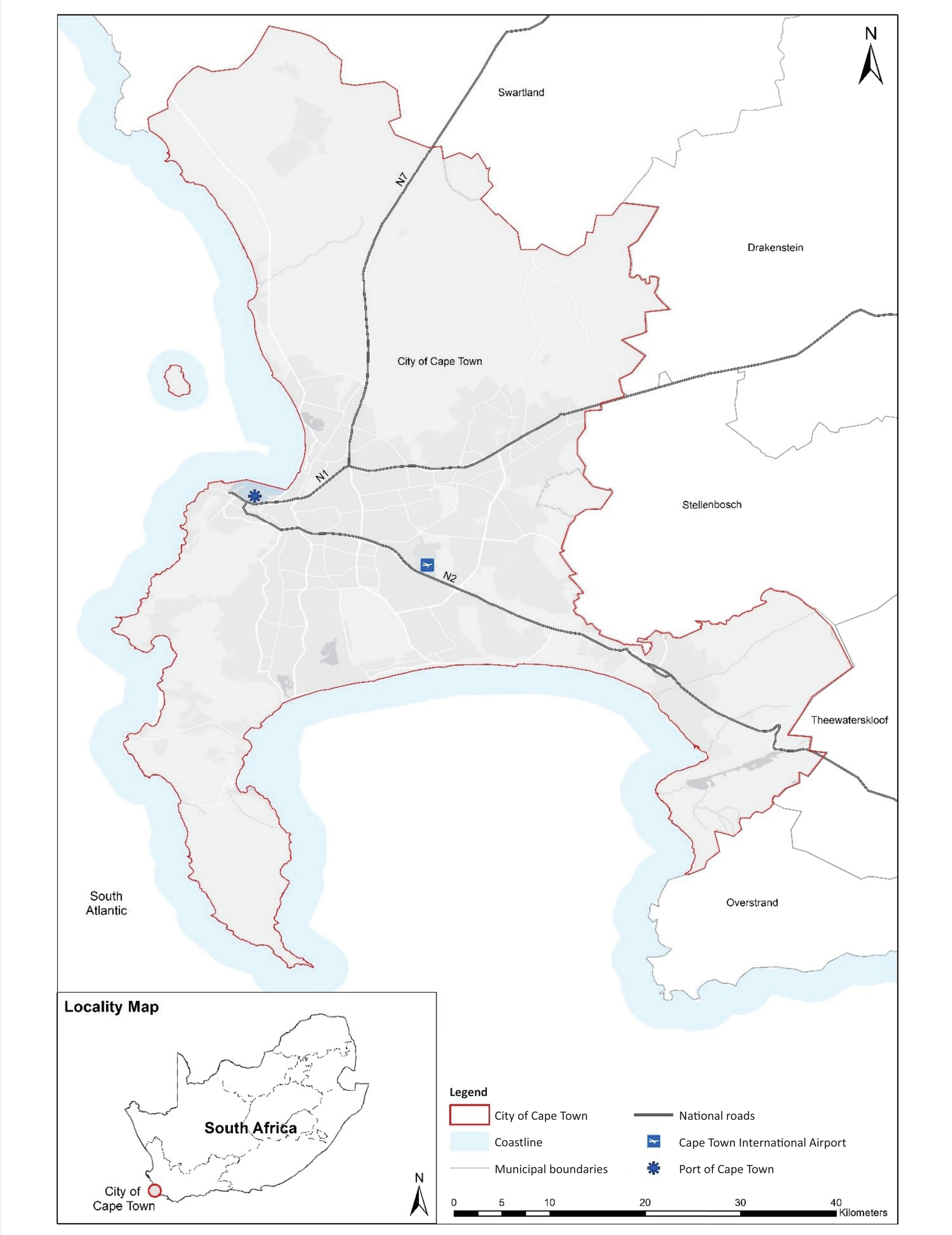
The City of Cape Town was selected as a study area because of the following reasons:

- Firstly, the City of Cape Town boasts the second-largest municipal economy in South Africa and stands as the largest metropolitan area in the Western Cape province. As a result, it accommodates a large concentration of logistics facilities, including warehouses.
- Secondly, the City of Cape Town is home to transport infrastructure of international significance. Notably, the Port of Cape Town is the second-largest container port in South Africa, and Cape Town International Airport is the second-busiest airport in the country. These key transport nodes play a pivotal role in freight distribution, both nationally and internationally. Therefore, as discussed in the findings section, the area near the port accommodates numerous warehouses.
- Thirdly, the municipality is well connected to transport corridors of national significance. These include the N1 national road, linking the City of Cape Town with Gauteng province, the economic hub of South Africa; the N2 national road, connecting the City of Cape Town with the Eastern Cape province and the N7 road, which connects the municipality with the neighbouring country of Namibia. These transport arteries, as depicted in Figure 1, facilitate the movement of freight, and contribute towards the attractiveness of the City of Cape Town as a location for logistics firms (Havenga et al. 2015). As discussed further in the article, areas near these roads, particularly the N1, accommodate a large number of warehouses.
- Fourthly, the City of Cape Town boasts a railway network that facilitates the transportation of passengers and freight. This network connects various areas within the municipality and facilitates transport on regional and national scales. However, it is important to acknowledge the declining utilisation of rail for freight over time. For instance, the rail's market share of the tonnes shipped in South Africa declined from 23% in 2011 to 16% in 2019 (Havenga et al. 2021). Despite this decline, the railway network still plays a significant role in the overall transport infrastructure for the City of Cape Town.

Methods

The study relied on the geographic information system (GIS) shapefile point data of 396 warehouse facilities in the City of Cape Town, obtained from AfriGIS. These data were instrumental in determining the location and the sizes of warehouses within the municipality.

While various approaches exist in the literature for measuring warehouse sizes, such as using the number of employees (Bowen 2008), this study opted for the approach of analysing building footprints. Given the absence of warehousing employment data, the study utilised building footprint analysis, a technique commonly used in similar research (Onstein et al. 2021). This involved overlaying warehouse points onto 1:50 000 topographical maps obtained from the



Source: Adapted from Mokhele, M. & Fisher-Holloway, B., 2023, 'Locational patterns of warehousing facilities in the City of Cape Town municipality', *Town and Regional Planning* 83, 33–44. https://doi.org/10.38140/trp.v83i.7353

FIGURE 1: City of Cape Town municipality.

National Geo-spatial Information (NGI). These maps provided detailed topographical information, including the footprints of large structures like warehouses. Using QGIS 3.30.1, the 'add polygon' command was used to delineate the building footprint of each warehouse within the municipality.

Following the logic outlined by Onstein et al. (2021), the sizes of the building footprint polygons were used to classify the warehouses into specific size categories, as presented in Table 1. This classification scheme facilitated the analysis of warehouses of varying sizes across the City of Cape Town.

Once the warehouses were categorised, the study employed proportional symbol mapping, a form of thematic mapping that visually represented point data varying the symbol sizes according to an attribute variable (Tanimura, Kuroiwa & Mizota 2006). Each warehouse category was assigned a weighting and colour code in ArcGIS 10.3.1. The size of the weighting ranged from small circles representing smaller warehouses and larger circles denoting larger warehouses (for instance, xx-small warehouses were represented by the smallest circle, while mega warehouses were represented by the largest circle). In addition, to enhance the distinction between categories, the percentage ratio of each warehouse size was depicted in a pie chart, illustrating the frequency of each category across the municipality.

The subsequent concentration and the size of warehouses were analysed in relation to the selected factors influencing the placement of warehousing facilities, identified from the literature. These factors encompassed various elements of the transport infrastructure, land-use zoning, land availability and proximity to customers in the form of industrial and retail activities. To determine the concentration of warehouses relative to the industrial and retail floor area across the City of Cape Town's transport zones, the intensity of warehousing was measured in ArcGIS 10.3.1 by calculating the *join_count* of all warehousing point data. The *join_count* represents the collective number of features (i.e. warehousing point features) that overlap on a target layer (i.e. transport zone polygons) to determine its spatial join. Out of the 848 transport zones in the City of Cape Town, only 86 contained warehouses and were, therefore, the subject of the retail and industrial floor area analyses.

TABLE 1: A classification of warehouses in the City of Cape Town municipality.

Warehouse category	Size (m²)	Count	%
Xx-small warehouses	1–200	8	2
X-small warehouses	201–2000	223	56
Small warehouses	2001–8000	123	31
Medium warehouses	8001–15 000	16	4
Large warehouses	15 001–20 000	10	3
X-large warehouses	20 001–40 000	8	2
Mega warehouses	40 001+	8	2
Total	-	**396**	**100**

Source: Adapted from Garatsa, F., 2024, 'Typology and spatial patterns of warehousing in Cape Town, South Africa', Master's thesis, Cape Peninsula University of Technology, Cape Town

By examining how the spatial distribution of warehouses within the City of Cape Town correlated with the transport infrastructure, land-use zoning, land availability and industrial and retail floor area, the study aimed to gain insight into the locational patterns of warehouses of various sizes.

Results

This section presents the findings of the study on the concentration of warehouses in relation to transport infrastructure, land-use zoning, proximity to customers and land availability.

Concentration of warehouse categories relative to transport infrastructure

The results of proportional symbol mapping, illustrating the distribution of warehouses relative to transport infrastructure, are displayed in Figure 2 and described hereunder according to the various warehouse size categories.

Xx-small warehouses

Only eight xx-small warehouses (with building footprints ranging from 1 m² to 200 m²) were identified within the City of Cape Town. Areas of Killarney Gardens, Milnerton Rural and Bellville accommodated one xx-small warehouse each, and two were identified in Salt River. There was no concentration of xx-small warehouses near the junctions of major roads, in Paarden Eiland near the Port of Cape Town, or around Cape Town International Airport (Figure 2).

X-small warehouses

Approximately 31 x-small warehouses (with building footprints ranging from 201 m² to 2000 m²) were identified near the Port of Cape Town, including Paarden Eiland north of the N1 national road and Woodstock, and Salt River, enclosed by the N1 and N2 roads. These areas benefit from good road accessibility, with additional access to the railway infrastructure connecting the CBD to different parts of the municipality. There was also a concentration of about 29 x-small warehouses to the north of the junction of the N1 and N7 national roads and near the junction of the R300 and N1. According to Mokhele and Fisher-Holloway (2023), the area north of the N1 and N7 junction is among the most accessible areas in the City of Cape Town because of its unique position as the intersection of national roads. A smaller concentration of 12 x-small warehouses was identified near Cape Town International Airport (Figure 2).

Small warehouses

The concentration of small warehouses (with building footprints ranging from 2001 m² to 8000 m²) was highest in Epping, with 20 facilities. This area benefits from significant road infrastructure including the surrounding national roads and expansive railway infrastructure that serve various sections of the City of Cape Town. Montague Gardens, near the junction of the N1 and N7 national roads,

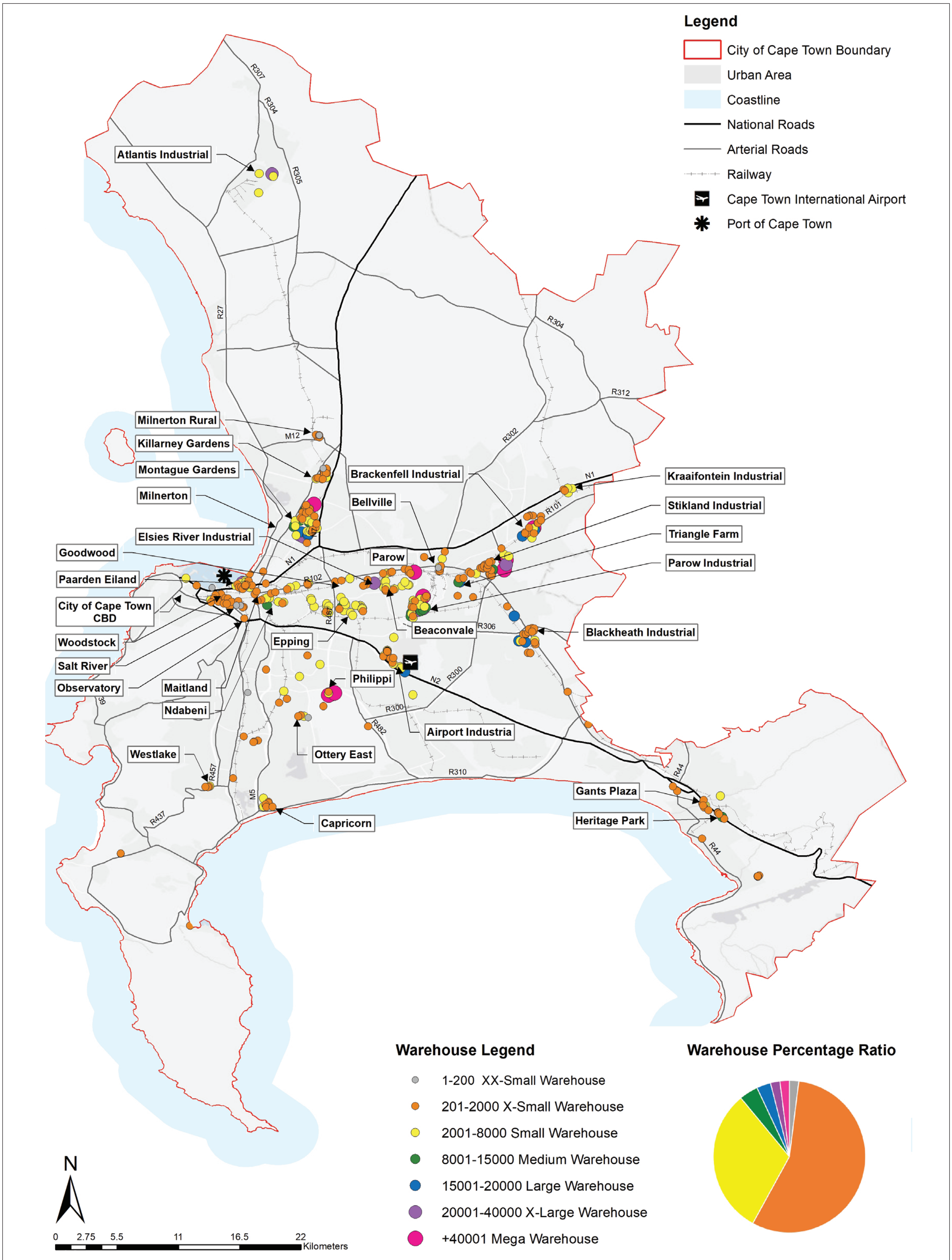


FIGURE 2: The positioning of warehouse types relative to transport infrastructure.

was home to 19 small warehouses. As noted earlier, this zone is one of the most accessible areas in the City of Cape Town from an interregional perspective. About eight small warehouses were identified near Cape Town International Airport, and 10 were located near the Port of Cape Town (Figure 2).

Medium warehouses

Illustrated in Figure 2, the concentration of medium-sized warehouses (with building footprints ranging from 8001 m² to 15000 m²) was less widespread across the City of Cape Town. The highest concentration of six facilities was identified in Parow Industria, followed by five in Montague Gardens, near the junction of the N1 and N7 national roads. Notably, Parow Industria includes the Belcon Terminal, a Port of Cape Town extension located inland. There was no concentration of medium-sized warehouses near the Port of Cape Town and Cape Town International Airport.

Large warehouses

Concerning large warehouses (with building footprints ranging from 15001 m² to 20000 m²), three facilities were identified in Montague Gardens, near the junction of the N1 and N7 national roads, and three in the Blackheath Industrial area along the R102 road, near the railway extending from the Cape Town CBD to Strand and Wellington. One large warehouse was identified near Cape Town International Airport, three in Blackheath and two in Brackenfell. Conversely, no large warehouses were located in Paarden Eiland, near the Port of Cape Town (Figure 2).

X-large warehouses

Two x-large warehouses (with building footprints ranging from 20001 m² to 40000 m²) were identified in Paarden Eiland, near the junction of the N1 and N7 roads and the Port of Cape Town, as well as two to the south of Voortrekker corridor (R102 road) in Parow. The latter area is endowed with railway infrastructure and a well-developed road system, providing connections to national roads. Conversely, no x-large warehouses were identified near Cape Town International Airport.

Mega warehouses

Two mega warehouses (with building footprints exceeding 40001 m²) were identified near the junction of the R300 arterial road and the N1 national road, as well as two in Philippi to the south of the N2 road. This pattern suggests that mega warehouses tend to locate in accessible areas towards the eastern edge of the municipality, particularly areas with ample land for greenfield development, such as Philippi, with efficient arterial road connections to national roads. There was one mega warehouse in Parow near the R102 and northern railway and one in Montague Gardens. No mega warehouses were located near the Port of Cape Town or Cape Town International Airport.

Concentration of warehouse categories relative to land-use zoning

The concentration of warehouses relative to land-use zoning in the City of Cape Town municipality is depicted in Figure 3. Approximately 73% of warehouses were located within industrial zones, including the categories of general industrial 1 (GI 1) and general industrial 2 (GI 2). Areas zoned GI 1 encompassed locations north of the junction of the N1 and N7 national roads, Killarney Gardens near the N7 and M12 junction, Airport Industria near Cape Town International Airport and the zone bounded by the N7 road to the west, the N1 road to the north, the R300 road to the east and the N2 road to the south. Areas predominantly zoned GI 2 included the Epping Industrial area between the N1 and N2 roads and Paarden Eiland near the Port of Cape Town north of the N1 road.

In addition to the industrial zones, 12% of warehouses were present in mixed-use (MU) zones, specifically MU 1 and MU 3, predominantly along diversified development corridors like the R102 road, contrasting the industrial zones of the municipality. Another 12% of warehouses were concentrated in general business (GB) zones, specifically GB 2, GB 3, GB 4 and GB 5. These zones included areas in Salt River and Woodstock near the Port of Cape Town and properties along the R102 road (Voortrekker Corridor).

Against the background of the overall patterns of the location of warehouses relative to zoning within the City of Cape Town, the following subsections present the findings relating to the categories of xx-small, x-small, small, medium, large, x-large and mega warehouses.

Xx-small warehouses

As depicted in Figure 4, of the eight xx-small warehouses (with building footprints ranging from 1 m² to 200 m²) in the City of Cape Town, 25% were situated on the premises zoned GI 1. The GB 1, GB 4, GI 2, MU 1, MU 2 and TR 1 zones each accommodated 12.5% of the xx-small warehouses.

X-small warehouses

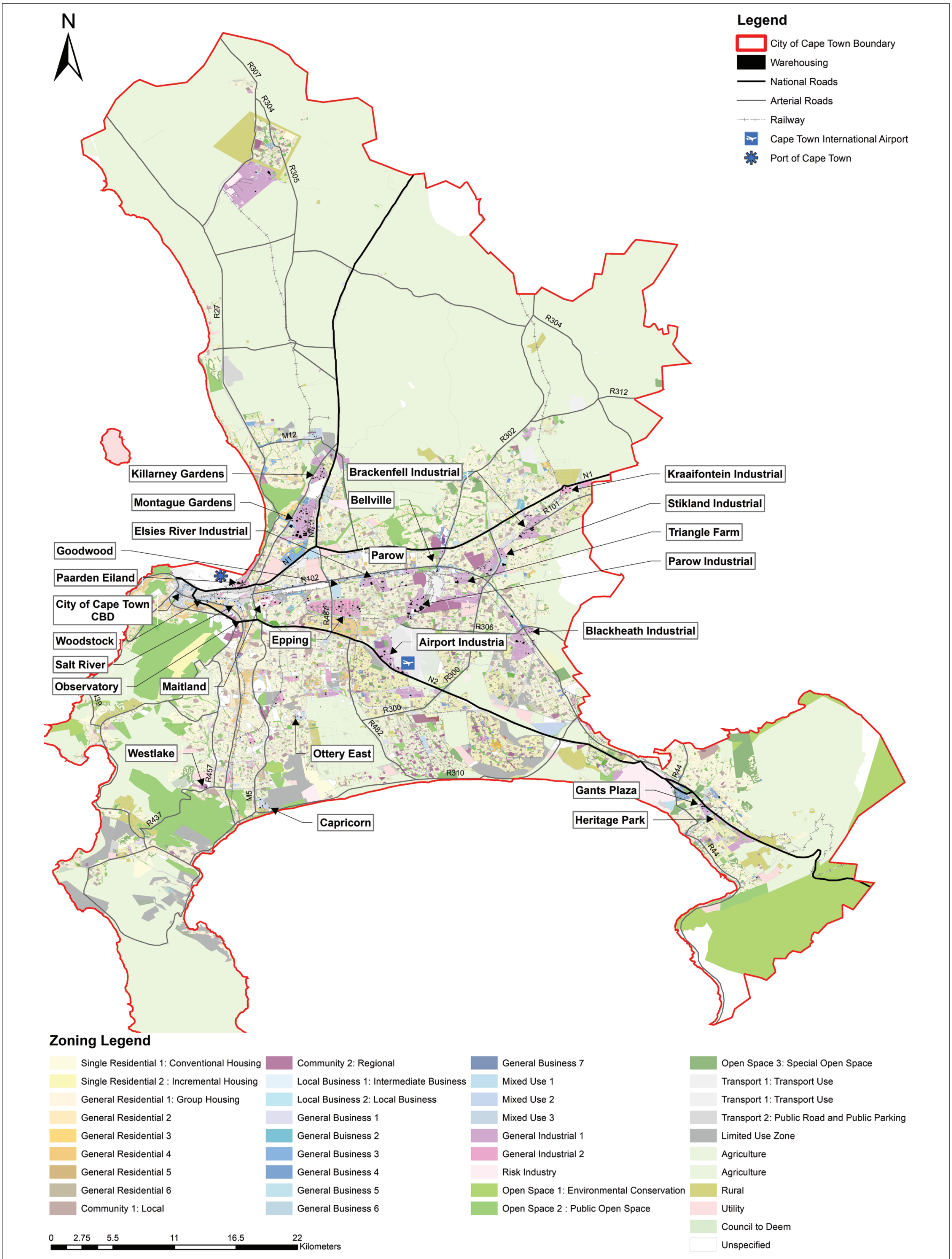
As shown in Figure 5, of the 223 x-small warehouses in the City of Cape Town (with building footprints ranging from 201 m² to 2000 m²), the majority (54.7%) were developed on the land zoned GI 1. The premises zoned GI 2 followed at 13.5% and MU 2 at 12.1%.

Small warehouses

As depicted in Figure 6, of the 123 small warehouses in the City of Cape Town (with building footprints ranging from 2001 m² to 8000 m²), 52.8% were positioned on the land zoned GI 1, followed by GI 2 at 30.1%.

Medium warehouses

Figure 7 depicts that of the 16 medium-sized warehouses within the City of Cape Town (with building footprints ranging from 8001 m² to 15000 m²), a significant majority (81.25%) were located within the premises zoned GI 1, followed by GB 3 at 12.5% and GI 2 at 6.25%.



Source: Adapted from Garatsa, F., 2024, 'Typology and spatial patterns of warehousing in Cape Town, South Africa', Master's thesis, Cape Peninsula University of Technology, Cape Town

FIGURE 3: The positioning of warehouse types relative to land-use zoning.

Large warehouses

All 10 large warehouses in the City of Cape Town municipality (with building footprints ranging from 15001 m² to 20000 m²) were zoned GI 1.

X-large warehouses

As depicted in Figure 8, of the eight x-large warehouses within the City of Cape Town (with building footprints ranging from 20001 m² to 40000 m²), three-quarters were on the land zoned GB 1, followed by GI 1 and GI 2 at 12.5% each.

Mega warehouses

Of the eight mega warehouses within the City of Cape Town (with building footprints exceeding 40001 m²), 55.6% were situated within the premises zoned GI 1, followed by MU 1 at 33.3% and GB 1 at 11.1% (Figure 9).

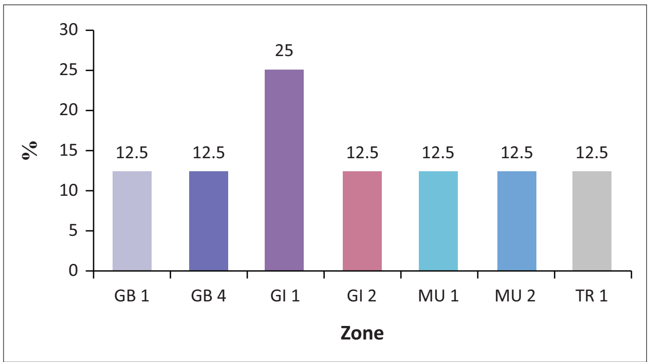
The findings on the location of warehouses of various sizes in relation to zoning within the City of Cape Town underscore the preference for situating warehouses within designated industrial zones.

Concentration of warehouses relative to customers

As noted in the literature review section, one of the factors influencing the placement of warehousing is proximity to customers, which includes industrial and retail firms. Therefore, Figure 10 illustrates the intensity of warehouses relative to industrial and retail floor area, revealing a strong connection between warehousing concentration and transport zones with high industrial floor area percentages and a comparatively weaker connection with retail.

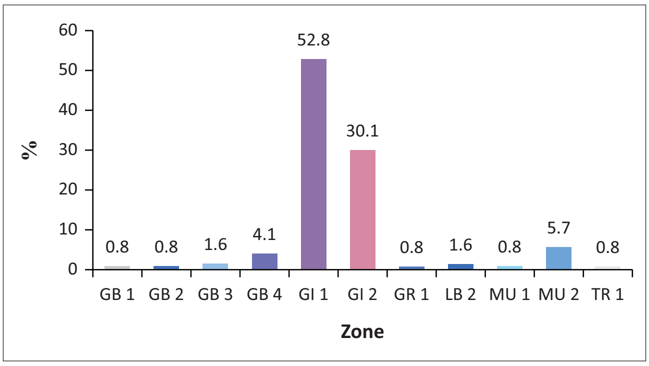
Transport zones with the highest percentages of industrial floor area (81% – 100%) exhibited the greatest concentration of warehousing. This correlation suggests that warehousing facilities are strategically located in areas with significant industrial activity, likely because of the complementary nature of warehousing and industrial operations. Warehouses in these zones benefit from proximity to transport infrastructure (Mokhele & Fisher-Holloway 2023) and manufacturing and production facilities, reducing transport costs and enhancing logistical efficiency (Jakubicek & Woudsma 2011).

The intensity of warehousing in transport zones with high retail floor area (81% – 100%) was minimal. Warehousing was predominantly situated on land with low retail floor area percentages (1% – 20%). This inverse relationship highlights a spatial separation between retail and warehousing facilities or functions. It has been argued that retail zones, which focus on consumer-facing activities, require prime locations with easy customer access, often in urban centres or commercial hubs (Léo & Philippe 2002). Logistics facilities are less dependent on local markets than retail locations are. Therefore, when



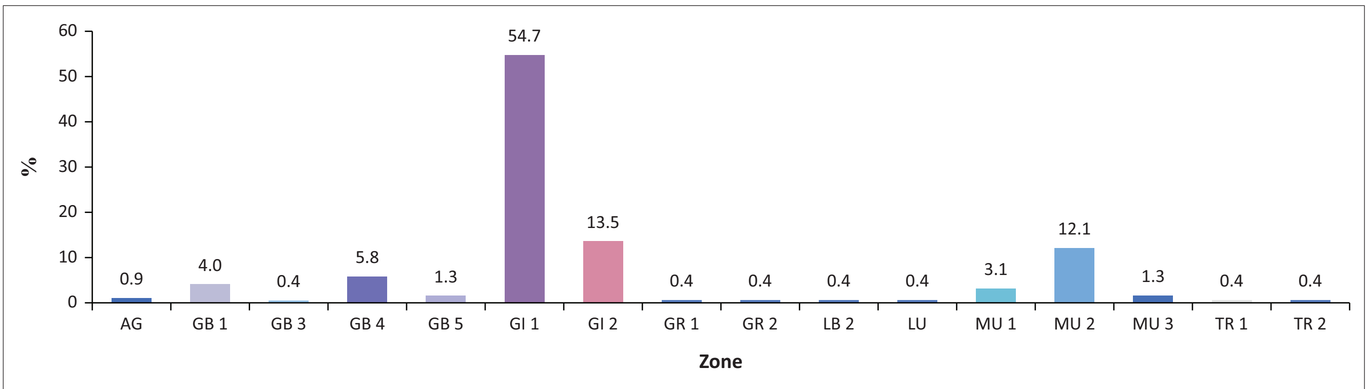
GB, general business; GI, general industrial; MU, mixed-use; TR, transport.

FIGURE 4: Zoning of xx-small warehouses.



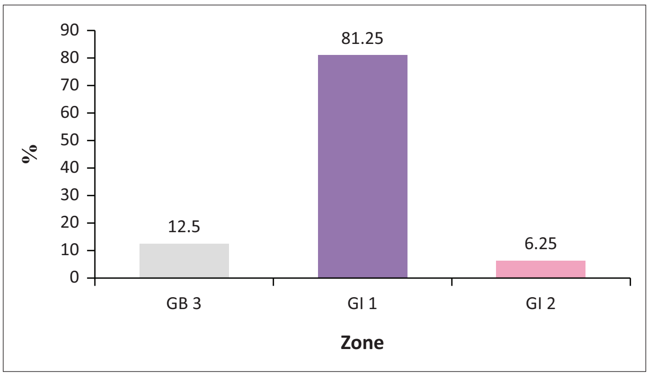
GB, general business; GI, general industrial; LB, local business; MU, mixed-use; TR, transport; GR, general residential.

FIGURE 6: Zoning of small warehouses.



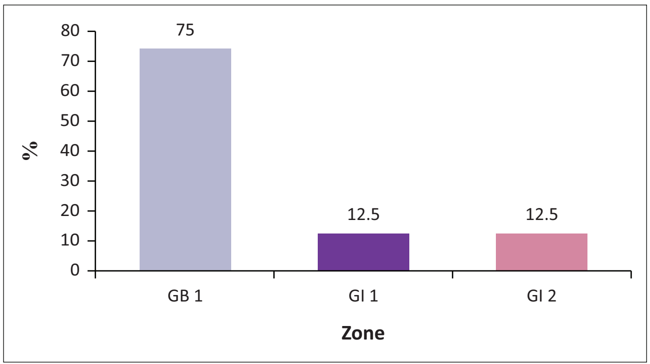
GB, general business; GI, general industrial; LB, local business; LU, limited use; MU, mixed-use; TR, transport; AG, agriculture.

FIGURE 5: Zoning of x-small warehouses.



GB, general business; GI, general industrial.

FIGURE 7: Zoning of medium-sized warehouses.



GB, general business; GI, general industrial.

FIGURE 8: Zoning of x-large warehouses.

choosing a location, logistics facilities consider the cost of land and construction in relation to the proximity of their primary clients (Jakubicek & Woudsma 2011).

The spatial distribution of warehousing in the City of Cape Town's transport zones accentuates the alignment between warehousing and industrial land use while demonstrating a lesser connection with retail-dominated areas. This pattern reflects the differing locational requirements and operational dynamics of industrial and retail activities. Notably, a strong connection was observed between warehousing and industrial floor area regardless of the varying warehouse sizes displayed in Figure 2.

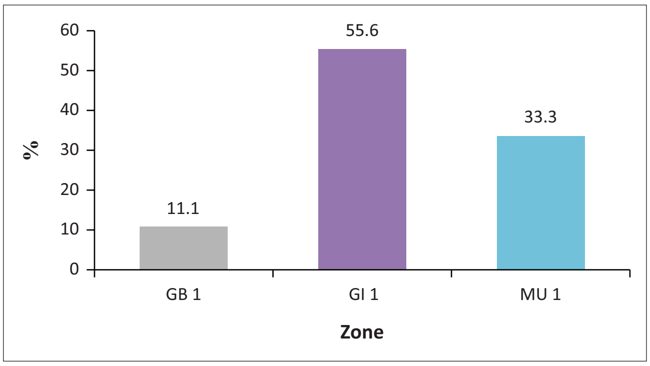
Concentration of warehouse categories relative to land availability

X-small and small warehouses

As noted earlier, areas around the Port of Cape Town, including Paarden Eiland, Woodstock and Salt River, predominantly accommodated x-small and small warehouses. These areas were established in the early 1900s. There was also a notable concentration of small warehouses in Montague Garden, near the junction of N1 and N7 roads. This area was primarily developed in the 1980s.

Large and mega warehouses

Mega warehouses were concentrated on the northern edge of the Philippi horticultural area, which is being repurposed



GB, general business; GI, general industrial; MU, mixed-use.

FIGURE 9: Zoning of mega warehouses.

for nonagricultural activities like warehouses. Another significant concentration of mega warehouses was near the junction of the R300 arterial road and the N1 national road, an area developed between 2018 and 2021.

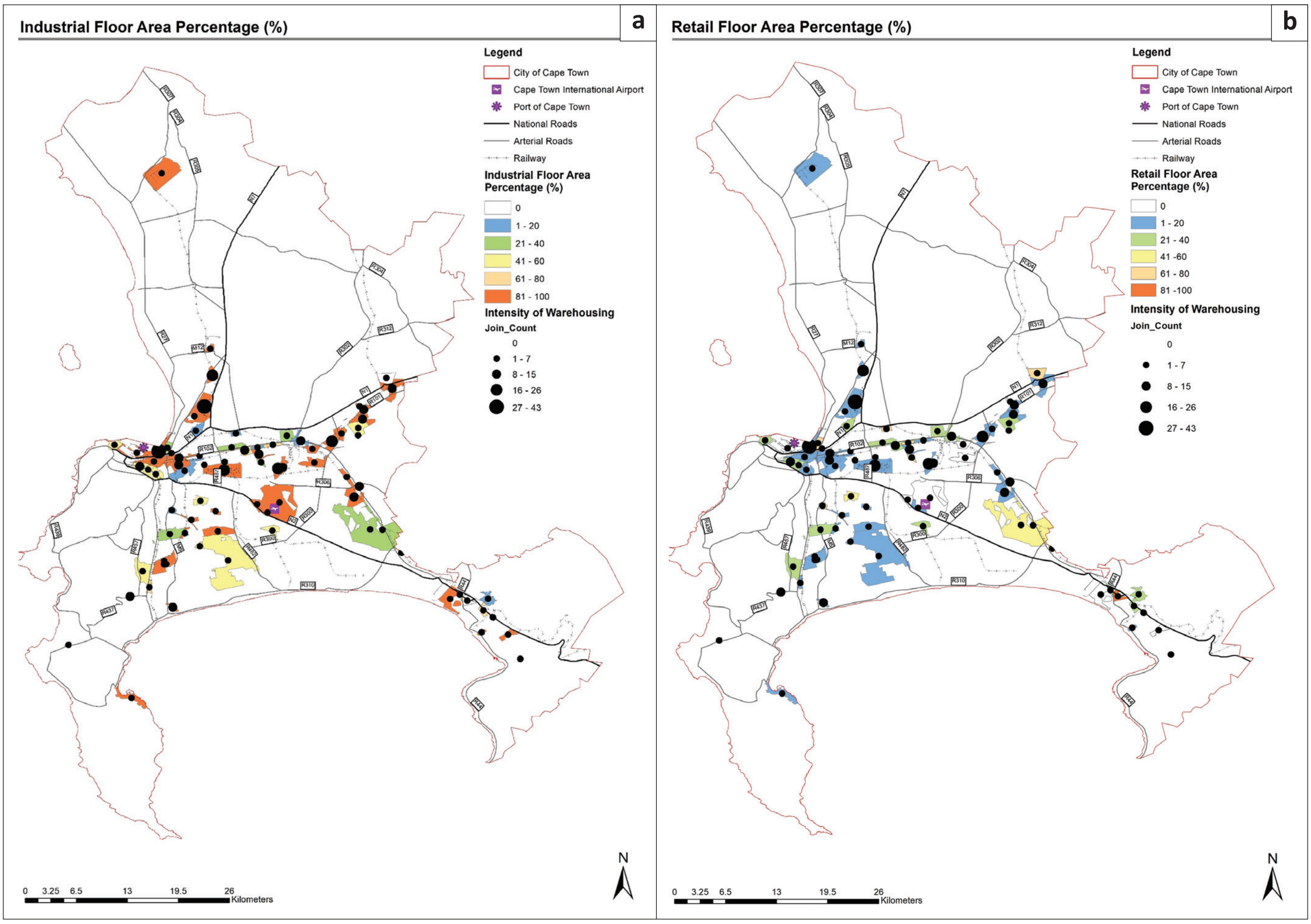
The findings indicate a connection between the positioning of large warehouses and recently developed areas within the City of Cape Town. Cementing the influence of land availability, the findings show that such warehouses are attracted to peri-urban zones with land for greenfield development.

Discussion

The study revealed insights into the spatial distribution of warehouses in the City of Cape Town municipality relative to various locational factors, including road-based access, railway proximity, airport proximity, seaport proximity, zoning regulations, proximity to customers, and land availability. Road-based access and mobility emerged as significant determinants of warehouse placement. The findings indicated that warehouses, ranging from x-small to mega sizes, tended to cluster in highly accessible areas, particularly near major road intersections such as the junction of national roads (e.g. the N1 and the N7) and the junction of national and regional and arterial roads (e.g. N1 and R300). This observation underscores the pivotal role of road infrastructure in warehouse placement, aligning with similar studies that highlight the importance of proximity to highways in augmenting freight transportation (De Oliveira et al. 2020).

In contrast, the study suggests that railway proximity plays a less influential role in warehouse placement within the City of Cape Town. While many warehouse facilities were situated near railway lines, the suboptimal utilisation of railway for freight transportation (Havenga et al. 2021) implies that road infrastructure predominantly drives warehouse positioning.

Regarding airport proximity, compared to other industrial nodes in the City of Cape Town, a low number of warehouses near Cape Town International Airport contradicts the conventional notion linking air transport services to



Source: Adapted from Mokhele, M. & Fisher-Holloway, B., 2023, 'Locational patterns of warehousing facilities in the City of Cape Town municipality', *Town and Regional Planning* 83, 33–44. https://doi.org/10.38140/trp.v83i.7353

FIGURE 10: The positioning of warehouses relative to the industrial and retail floor area: (a) industrial floor area percentage and (b) retail floor area percentage.

warehousing facility placement. Although some studies suggest a strong correlation between airports and warehouse locations (Bowen 2008), the findings here highlight the unique dynamics of Cape Town's logistics landscape.

The study highlights a significant concentration of warehouses, particularly x-small warehouses, near the Port of Cape Town. This observation underscores the attractiveness of industrial nodes around the port, facilitated by major traffic corridors like the N1 national road.

The decline in warehouse presence with increased facility size near the port aligns with studies indicating that large warehouses may not necessarily cluster near ports because of factors such as land cost (Bowen 2008).

Regarding zoning, the study underscores a strong connection between warehousing and industrial zones, with most warehouses situated in areas zoned for general industrial use. This finding aligns with similar studies highlighting the influence of land-use zoning regulations on warehouse location decisions (Yuan 2022). Relatedly, concerning the relationship between warehousing and industrial and retail land use, the study established a strong correlation between warehousing and industrial floor area regardless of the varying sizes of warehouses within the municipality.

Finally, the study suggests a connection between the presence of large warehouses and recently developed zones in Cape Town, indicative of the preference for greenfield development and the evolving nature of the city's logistics landscape. Large warehouses are positioned in semi-urban areas formerly designated for agricultural use, reflecting the ongoing urbanisation and conversion of land for industrial and warehousing purposes.

The study provides valuable insights into the complex interplay of locational factors potentially influencing warehouse placement within the City of Cape Town, contributing to a better understanding of urban logistics dynamics in the municipality.

Conclusion

The article analysed the spatial distribution of warehouses of various sizes within the City of Cape Town municipality relative to the main factors that influence the placement of warehousing facilities. The analysis encompassed factors such as transport infrastructure, land availability, proximity to customers and land-use zoning, shedding light on the dynamics that shape the urban logistics landscape.

The findings underlined the pivotal role of transport infrastructure in influencing warehouse placement. It was observed that a high concentration of warehouses existed near major transport nodes and road intersections, particularly around the Port of Cape Town and the junctions of national roads. This highlights the significance of road accessibility in facilitating efficient freight movement and underscores the importance of strategic transport planning in urban logistics management. Furthermore, this study revealed insights into the relationship between warehouse distribution and industrial zoning. The majority of warehouses were concentrated in areas designated for industrial use, emphasising the symbiotic relationship between warehousing activities and industrial production. This finding emphasises the importance of aligning land-use planning with logistics needs to ensure the optimal utilisation of urban space. In terms of land availability, the analysis indicated a notable concentration of mega-sized warehouses in recently developed areas, suggesting a dynamic interplay between urbanisation trends and warehouse expansion. This highlights the evolving nature of the city's logistics landscape and the importance of proactive land-use planning policies to accommodate growing logistics demands.

Based on the findings, we advocate that the strategic spatial planning initiatives be aimed at promoting the development of particularly big warehouses in key logistics hubs, such as industrial zones not geographically near the Port of Cape Town but with railway access to the port and access to major road intersections. This would avert the traffic congestion that can result from the development of large warehouses near the port and the Cape Town CBD surroundings. The trucks would deliver the goods from the warehouse to the market instead of transporting them from the port to the distant warehouse and then to the customers. The approach would also curb the sprawling of large warehouses to areas on the edge of the municipality with ample land available for development. By fostering the integration of transport infrastructure, land availability, proximity to customers and land-use planning considerations, policymakers can improve the utilisation of rail infrastructure within the City of Cape Town and optimise the efficiency and sustainability of urban logistics processes.

Our study offers valuable insights into the spatial dynamics of warehouse distribution within the City of Cape Town municipality, providing a foundation for informed decision-making in urban logistics planning. By addressing the interplay of factors influencing warehouse placement, the municipality and relevant stakeholders can work towards creating sustainable and efficient logistics processes that meet the evolving needs of modern cities amid globalisation and increasing e-commerce.

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Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

Authors' contributions

M.M conceptualised and drafted the manuscript. The manuscript can be traced from F.G.'s thesis, which M.M. supervised. B.F-H. assisted with the original spatial analysis and subsequently conducted additional analysis to respond to the reviewers' comments.

Ethical considerations

Ethical clearance to conduct this study was obtained from the Cape Peninsula University of Technology Faculty of Informatics and Design Research Ethics Committee (No. 222688289/2023/16).

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Data availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Disclaimer

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