Evaluating amenity access of new and repurposed housing within the 15-Minute City framework in Amsterdam

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Case Study

Evaluating amenity access of new and repurposed housing within the 15-Minute City framework in Amsterdam

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Abstract
Amsterdam has a housing shortage issue. To address this, the Municipality aims to provide 73,660 housing units by 2028, either by constructing new housing buildings or by repurposing existing buildings with other functions such as offices, schools or industrial spaces. The comparison between these two strategies in past research primarily focuses on lower construction costs, reduced raw material usage, and decreased energy consumption associated with demolition and new construction processes; on the other hand, comparisons of locational characteristics between new and repurposed housing projects have seldom been studied. In this paper, we compare access to amenities, specifically the number and diversity, between new and repurposed housing buildings based on their location in the city. Using the 15-Minute City concept as both a theoretical framework and a practical tool, we evaluate the amenities within a 15-min walking isochrone for 38,061 housing units (554 residential buildings) constructed between 2015 and 2019. By aggregating these results at district level, we deepen the analysis and provide insights that could support the development of locally tailored policies.

Keywords Housing shortage · Amsterdam · Repurposing building · 15-Minute city

1 Introduction

The housing crisis, driven by rapid urbanization and population growth, has led to a shortage of affordable housing in cities worldwide [1]. In Europe, this issue is exacerbated by limited construction sector capacity, increasing demand, and constraints on urban expansion [2–9]. Amsterdam, already one of the densest European capitals, is facing similar challenges. Its population is projected to grow from ~ 1.18 million in 2024 to ~ 1.24 million by 2035 [10]. Population density varies across the city's nine districts, with Centrum, West, and Zuid exhibiting the highest densities. Meanwhile, Noord, Weesp, and Nieuw-West have experienced the most significant absolute population growth, with each gaining approximately 3,000 residents between 2018 and 2023 [11].

To address housing shortages, Amsterdam has set a target of constructing 73,660 homes by 2028 through densification and transformation strategies [12]. These approaches build upon previous initiatives, including the "Koers 2025" plan, which sought to deliver 52,500 new homes between 2015 and 2025 [13]. Transformation strategies in

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Amsterdam emphasize repurposing single-function office and industrial areas into multifunctional urban neighborhoods [14]. Historically, building transformations in Amsterdam were aimed at reducing vacancy, particularly through the conversion of office spaces built between 1999 and 2011 [15]. Since 2011, policies encouraging office-to-residential conversions have been supported by regional incentives [16]. The introduction of the "2020 Erfpacht en Grondwaarde bij Transformatie" framework has further facilitated these transformations by providing clear guidelines on leasehold adjustments and financial terms [17]. By 2021, repurposed buildings accounted for 12% of new housing in the city [18].

Repurposing existing structures presents multiple advantages over new construction. Environmentally, adaptive reuse reduces carbon emissions by an estimated 34–48% [19–21] and mitigates urban sprawl [22, 23]. It is also more cost-effective than demolition and reconstruction [24–27]. Additionally, repurposing plays a crucial role in preserving urban heritage by preventing the demolition of historic buildings [28]. However, transformation strategies are not always the preferred approach due to concerns about the attractiveness of repurposed sites and their perceived suitability for housing purposes [29].

This study examines the accessibility of amenities surrounding repurposed and newly constructed residential buildings in Amsterdam. Access to essential services, such as healthcare, education, and public transport, directly influences residents' quality of life [30, 31]. Various urban planning models, including Ebenezer Howard's Garden City [32], Clarence Perry's Neighborhood Unit [33], and Carlos Moreno's 15-Minute City [34], emphasize proximity to amenities. The 15-Minute City model aims to create self-sufficient urban environments by integrating density, proximity, diversity, and digitalization [35]. Given that cities are responsible for 70% of global emissions—primarily from transport—the 15-Minute City approach offers a sustainable alternative to car-dependent urban planning [36, 37].

For instance, a study by Abbiasov et al. developed a 15-Minute City Index for 50 U.S. cities, categorizing amenities into nine groups, including restaurants, schools, parks, healthcare, drugstores, arts and cultural institutions, grocery stores, services, and religious organizations. This classification highlights the importance of accessibility to a wide range of urban functions to ensure comprehensive livability [42]. Similarly, another study examined the feasibility of the 15-min city globally, dividing amenities into nine categories, such as cultural activities, supplies, eating, healthcare, and transportation. The study by Bruno et al. emphasized the significance of both general and category-specific accessibility in urban planning [43]. In the context of Italian cities, the Next Proximity Index was introduced, which classified amenities into eight categories, including commerce, education, healthcare, public parks, and restaurants. This approach demonstrated the potential for scalability through open data while addressing localized needs [44]. For Hong Kong, another study assessed the 15-min city using five key urban functions: living, healthcare, education, entertainment, and public transit. Another work showcased the adaptability of the concept in high-density, transit-dependent cities [45].

When examining the literature, it is evident that amenity classification is context-dependent, with different studies applying varying categorization methods. However, healthcare consistently appears across all classifications, underscoring its universal importance in urban planning. Additionally, other common amenities include education, restaurants or eating establishments, public parks, and cultural activities or entertainment. Given that this study focuses on housing-related analysis, we adopt these five core categories while expanding the framework to include emergency services, shops, grocery stores, and other essential services.

To assess accessibility, this study analyzes the number and diversity of amenities in these 9 categories within a 15-min walking distance of repurposed and newly built housing across Amsterdam's nine districts. A particular focus is given to the impact of tourism-related amenities as Amsterdam's visitor numbers increased from four million in 2000 to over 21 million overnight stays by 2019. This intensified pressure on the urban infrastructure [38]. In response, policies such as the *Winkeldiversiteit Centrum* zoning plan were introduced in 2018 to limit tourist-oriented amenities in specific areas and improve urban livability [39].

By integrating housing transformation with proximity-based urban models, this study provides insights into sustainable strategies for addressing housing shortages while maintaining accessibility and livability.

2 Methods

2.1 Data preparation

2.1.1 Housing data

We use data of 38,061 planned housing units (located in 554 buildings) that were added to the municipal database between 2015 and 2019[40], 32,638 of these units (in 416 buildings) are newly constructed, and 5,423 units (in 138 buildings) are repurposed buildings. Projects involving residential-to-residential renovations were not included. The location and number of housing units in repurposed buildings (Fig. 1) and new buildings (Fig. 2) are visualized below using data sourced from the *Monitor Woningbouwplannen* on the Gemeente Amsterdam map portal. In the map, the size of the circles represents the number of housing units.

An examination of the distribution across Amsterdam's nine districts between 2015 and 2019 shows that buildings created through the repurposing strategy are most concentrated in the Centrum and Nieuw-West districts of the city, while newly constructed buildings are predominantly located in Noord and Oost. The map illustrates the number of newly constructed and repurposed buildings across the nine districts, with the ranges of building numbers shown gradually (Fig. 3). The graph, on the other hand, provides a comparative analysis of these numbers across the districts (Fig. 4). As the historical and administrative core of the city, the Centrum district has limited land available for new construction, which explains the prevalence of repurposing strategies in this area. Nieuw-West**,** characterized by its post-war housing estates, offers significant opportunities for modernization and densification, aligning with the city's smart densification policies [41]. In contrast, Noord and Oost possess larger, underutilized land areas that facilitate large-scale new

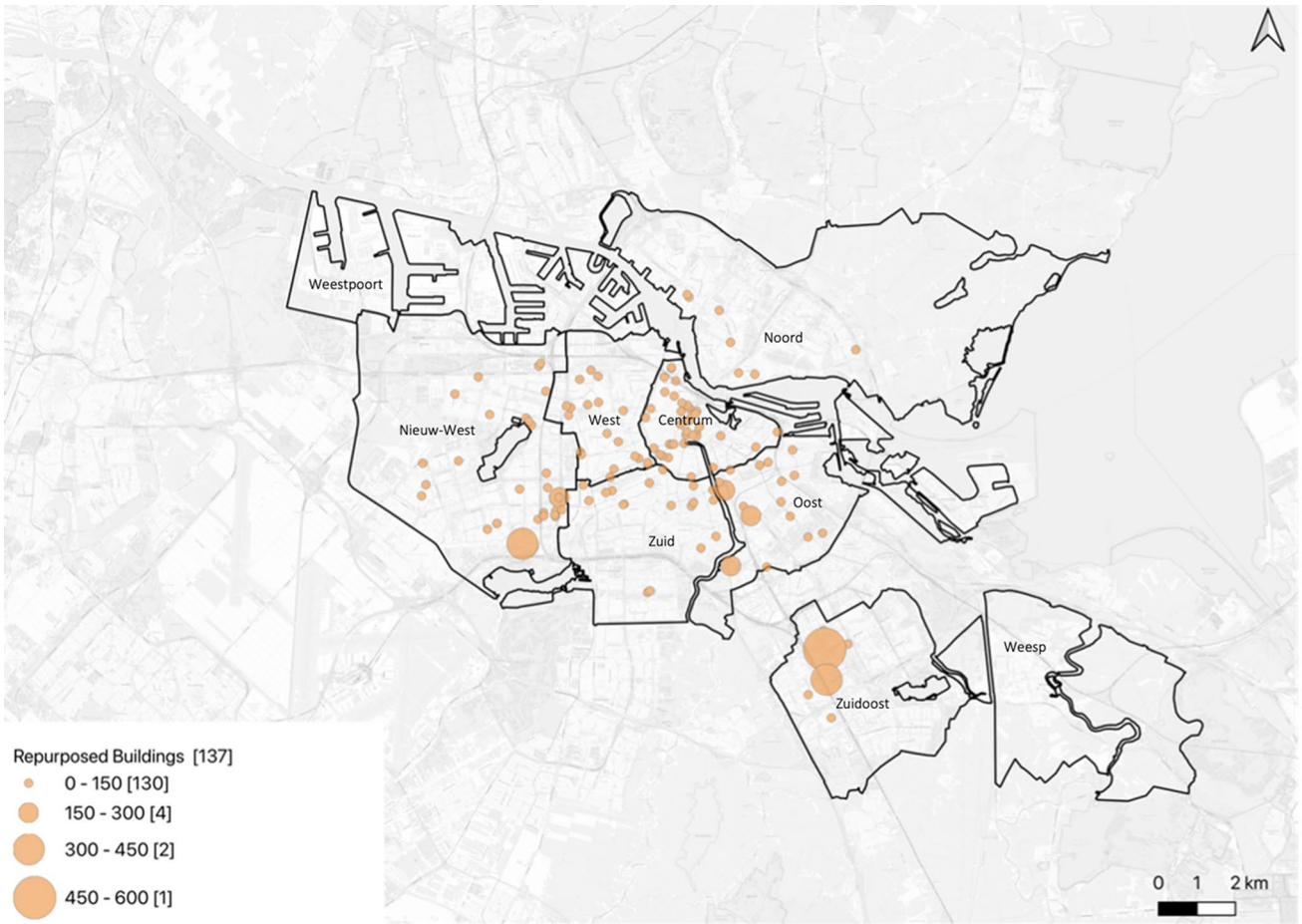

Fig.1 Repurposed buildings' location and housing units

Fig. 2 Newly constructed buildings' location and housing units

construction projects. Similarly, Oost, as seen in developments like IJburg, has become a focal point for meeting rising housing demands, making it a hub for new construction activity.

2.1.2 Point of interest (POI) data

We use the POI dataset of Geofabrik in OpenStreetMap (OSM). The classification of POIs can significantly impact the study's outcomes. In the context of the 15-min-city concept, Moreno argues that residents can experience an improved quality of life by fulfilling six essential urban social functions: living, working, commerce, healthcare, education, and entertainment [35]. However, the classification of these amenities can vary depending on the city's specific context and priorities. Based on the literature in the introduction, we identified 9 meaningful clusters for Amsterdam's context.

The map shows the distribution of amenities in the city in 2024 (Fig. 5), organized as follows.

Art and culture: Attraction, Museum, Monument, Art, Memorial, Castle, Ruins, Archaeological Site, Fort, Arts Centre, Theatre.

Emergency: Police, Fire Station.

Education: University, School, Kindergarten, College.

Grocery: Supermarket, Butcher, Bakery.

Health: Pharmacy, Hospital, Doctors, Dentist, Veterinary, Nursing Home.

Leisure: Park, Nightclub, Cinema, Playground, Dog Park, Sports Centre, Pitch, Swimming Pool, Tennis Court, Golf Course, Stadium, Ice Rink, Zoo, Theme Park.

Restaurant and cafe: Restaurant, Fast Food, Cafe, Pub, Bar, Food Court, Biergarten.

Service: Bicycle Shop, Car Repair, Car Wash, Travel Agency, Bank, ATM, Biergarten.

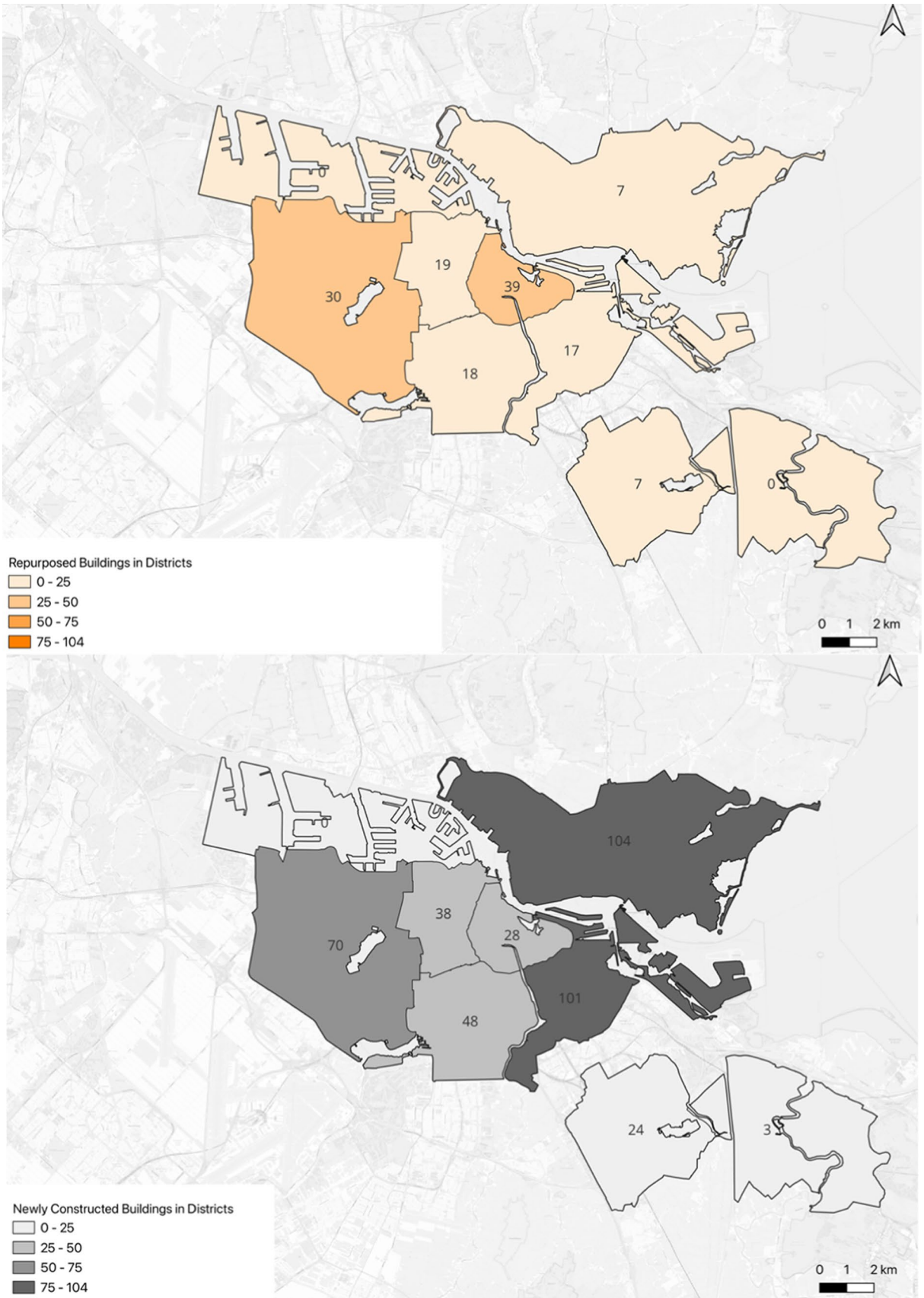

Fig. 3 Number of Newly constructed buildings' location and Repurposed buildings in 9 districts

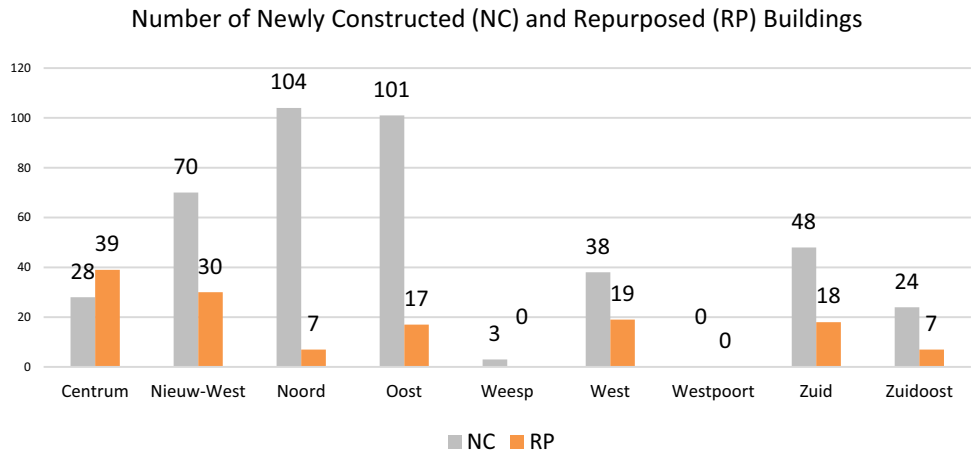

Fig. 4 Number of Newly Constructed (NC) and Repurposed (RP) Buildings

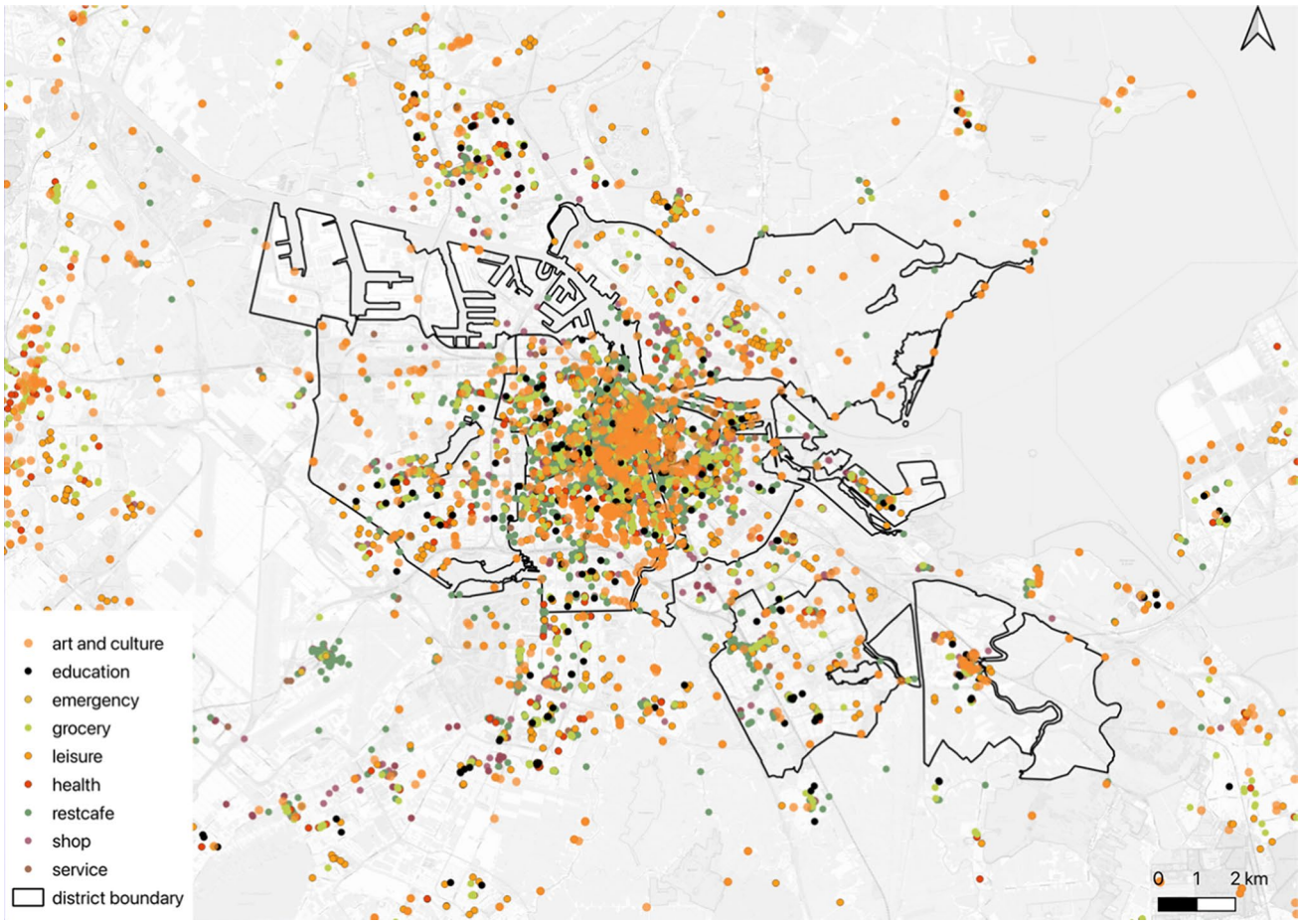

Fig. 5 Classified POI based on nine class

Shop: Kiosk, Mall, Department Store, Jeweller, Clothes, Florist, Chemist, Bookshop, Shoe Shop, Optician, Gift Shop, Sports Shop, Outdoor Shop, Stationery, Mobile Phone Shop, Toy Shop, Newsagent, Greengrocer, Beauty Shop, Video Shop, Computer Shop.

Amenity class codes based on dataset of Geofabrik are listed in Supplementary Table 1.

Additionally, touristic amenities are highly significant for everyday life in Amsterdam. Therefore, we have treated these as a separate dataset. Touristic Points of Interest (POIs) include restaurants, bars, cafes, souvenir shops, tourist shops, museums, and historical sites, based on the classification provided by OpenStreetMap (OSM). Although these amenities

fall within the nine main categories, they were identified as tourist related through additional tags. The tourist-related codes we used are listed in Supplementary Table 2. This approach allows us to create a separate category independent of any specific amenity class and compare this category with diversity and the total number of amenities.

2.2 Data analysis

We first count the number of amenities, based on our classification, which fall within a 15-min walking distance from the central point of each building by using the street network acquired via the OpenRouteService API. Then, we calculate the average number of amenities of each building computed from the year of construction and repeated each year for the first four years after construction.

We compare the diversity of amenities within each 15-min walkshed using the relative entropy, also known as the Shannon Entropy, which is widely used in urban studies to evaluate diversity. [46, 47]. In this context, entropy serves as a metric to quantify the uncertainty or disorder within the distribution of these nine amenities within the walkshed, averaged over five years. Higher entropy values indicate greater diversity, implying a more even distribution of different types of amenities. Conversely, a lower entropy value suggests less diversity, indicating a more uneven distribution of amenities. The formula for calculating Shannon entropy, adapted to our context with nine amenities, is as shown in Formula 1, where H(X) represents Shannon Entropy, and pi denotes the probability of each amenity category, indicating the proportion of each type of amenity within the walkshed. In summary, by employing the entropy method with nine different amenities, we can quantitatively assess the diversity of amenities within 15-min walksheds. To establish a diversity value, we computed the average diversity over five years as shown in Formula (2). In addition, we utilize the T-test as a comparison method for the two different datasets.

$$\mathrm{H(X)} = -\sum_{i=1}^{9} p_i \log_2(p_i) \tag{1}$$

$$\text{Diversity Value} = \frac{\sum_{i=1}^{5} H(X_i)}{5} \tag{2}$$

In Amsterdam, the expansion of tourist areas presents challenges for residential-oriented solutions, as these amenities do not cater to residents. Thus, we also obtain the number of tourist-related amenities within a 15-min walking distance for both newly constructed and repurposed housing projects. We tallied the count separately for each year and subsequently calculated a tourist-related value by averaging the counts over a period of five years in formula (3).

$$\text{Tourist Related Value} = \frac{\sum_{i=1}^{5} a_i}{5} \tag{3}$$

i = Year, and a_i = Number of amenities in year i.

3 Results

When examining the average amenity values within the 15-min walksheds of Repurposed and Newly constructed buildings based on location, the highest-value isochrones are generally concentrated in the city center. However, newly constructed buildings reach comparable average values in in a wider range of areas than repurposed buildings (Fig. 6). In analyzing these 15-min walkshed isochrones on a district level, we map the average amenity counts for repurposed and newly constructed buildings separately across each of the nine districts. When comparing the maps and tables, it is observed that within a 15-min walkshed, areas with relatively high average amenity values show that repurposed buildings generally have a greater number of surrounding amenities compared to newly constructed buildings. In the Centrum area, the average number of amenities within the 15-min walkshed around repurposed buildings over a 5-year period is 171.96, in Zuid it is 63.14, and in West it is 53.28. Conversely, in areas with lower average amenity counts, such as Nieuw-West (17.54), Noord (18.26), and Zuidoost (15.3), the average number of amenities within the walksheds around newly constructed buildings is higher than that around repurposed buildings (Figs. 7, 8).

Over a five-year period, repurposed buildings in Amsterdam consistently have greater access to amenities compared to newly constructed buildings. On average, the number of amenities within a 15-min walkshed of repurposed

Fig. 6 Average number of amenities in Repurposed (RP) and Newly Constructed (NC) buildings isochrones

buildings is 72.01, significantly higher than the 19.81 amenities found around newly constructed buildings (Supplementary Table 3). Yearly analyses further confirm this trend, showing that repurposed buildings maintain a higher density of nearby amenities across all years (Fig. 9, Supplementary Fig. 1). Additionally, the annual growth rate of amenities surrounding repurposed buildings is 11.27%, outpacing the 8.61% increase observed around newly constructed buildings.

Over five years, the growth in amenities within the 15-min walkshed of repurposed buildings is greater in Nieuw-West, West, Zuidoost, and Centrum, while Noord, Oost, and Zuid see higher increases around newly constructed buildings. Although Centrum has the highest overall amenity density, its growth rate is lower than in Nieuw-West, West, and Zuid. Notably, in Nieuw-West, repurposed buildings have fewer amenities on average than newly constructed ones, yet their amenity growth rate is significantly higher (Figs. 10, 11).

The previous results considered individual buildings; however, each building has a varying number of housing units. When focusing on housing units, the difference between the two strategies becomes more pronounced. For this analysis we normalized the number of amenities between 0 and 100 and showed the access of housing units to amenities it can access within a 15-min walkshed (Fig. 12).

Between 2015 and 2019, more housing units were built in newly constructed buildings; however, 86% of them have the lowest scores in terms of access to amenities (between 0–10), and less than 3% of them have accessibility score of 50 and above. Repurposed buildings, even though offering fewer units, have a higher access to amenities: 69% of these falls within the lowest 0–10 score range, and 7% scoring 50 or higher (Table 1). These findings indicate that, although newly constructed buildings provide a higher number of residential units, repurposed buildings contain a greater number of units with higher amenity scores.

When examining the number of residential units per amenity, newly constructed buildings place a greater load on amenities within their 15-min walksheds. In contrast, repurposed buildings generally have a lower number of residential units per amenity, indicating higher accessibility. This trend is particularly clear in categories like art and culture, education, grocery, shop, leisure, and rest-café, where the ratio of residential units per amenity is significantly lower. Although the difference is smaller for service, health, and emergency amenities, repurposed buildings still support a denser network of amenities across these categories (Fig. 13).

We calculated Shannon entropy to compare the diversity of amenities in repurposed and newly constructed buildings. The mean diversity value for newly constructed buildings is 2.34, slightly higher than the 2.25 for repurposed buildings, with median values of 2.40 and 2.32, respectively (Supplementary Fig. 2). Despite repurposed buildings having access to more amenities within a 15-min walkshed, newly constructed buildings exhibit higher diversity. This is due to the prevalence of specific amenities, such as restaurants and cafes, in the walksheds of repurposed buildings (Fig. 14).

For a more detailed analysis we compare the 5-year average number of amenities and entropies in the isochrones. We see that some amenities are more common in the 15-min walksheds of repurposed buildings, such as restaurant and cafe and shop. While they contribute to an increase in the number of amenities, they also reduce the entropy within the 15-min walkshed (Table 2).

To investigate why the diversity of amenities is lower for repurposed buildings we considered amenities commonly tailored for tourists which is particularly relevant in a touristic center such as Amsterdam. We see the relationship is

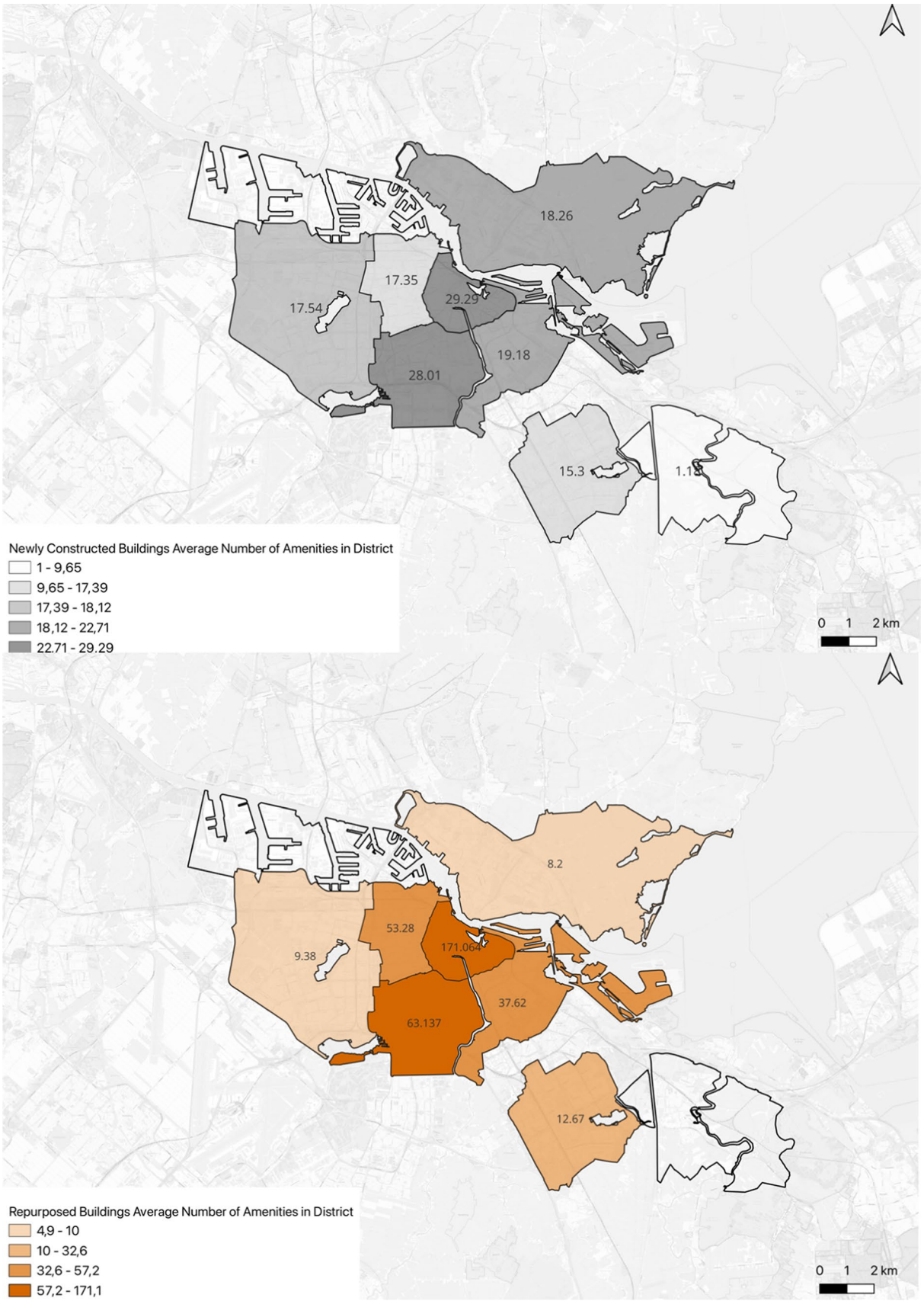

Fig. 7 Average number of amenities in Repurposed (RP) and Newly Constructed (NC) Buildings isochrones

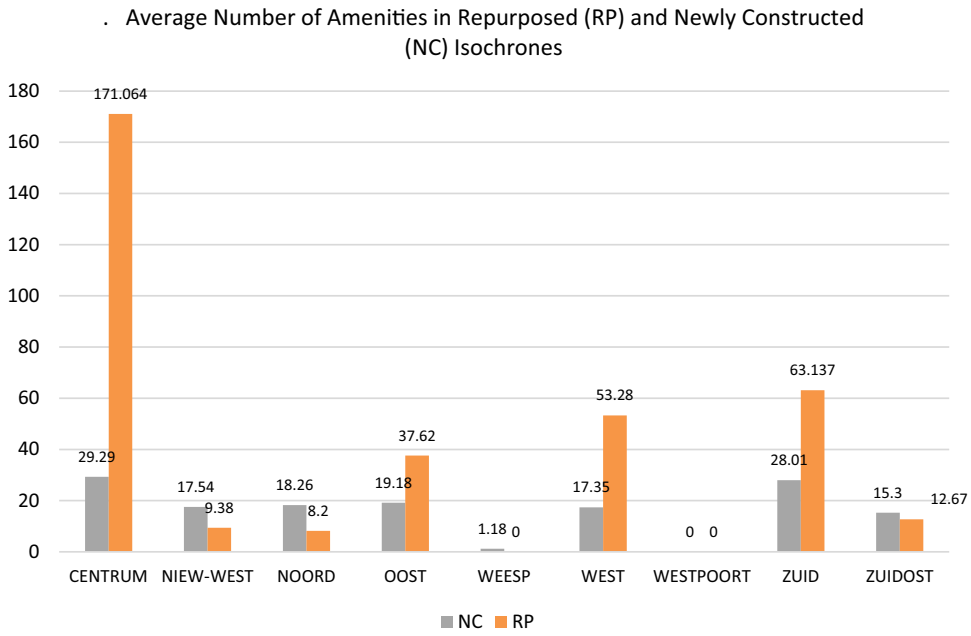

Fig. 8 Average number of amenities in Repurposed (RP) and Newly Constructed (NC) isochrones

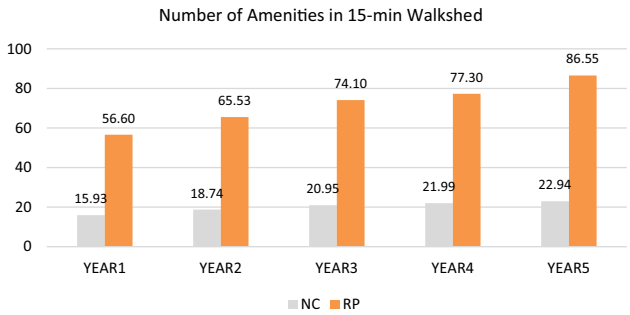

Fig. 9 Number of amenities in 15-min walkshed

between the number of amenities within the 15-min walkshed of the repurposed buildings and the number of tourist-related amenities—this relationship is not found for newly constructed buildings (Fig. 15).

The number of tourist-related amenities directly influences diversity of amenities: because repurposed buildings occupy more central locations in Amsterdam, they are located close to touristic areas, therefore positioned in areas with lower diversity of amenities, when compared to newly constructed buildings (Fig. 16). The percentage of tourist-related amenities in the isochrones of repurposed buildings is 42%, whereas it is 24% for newly constructed buildings (Supplementary Table 4). When analysing this diversity by location, it is observed that the lowest diversity across the nine districts is in the city centre. This can be explained by the high concentration of tourist-related amenities (Fig. 17).

4 Conclusion

This research compares access to the number and diversity of amenities between repurposed and newly constructed housing buildings in Amsterdam. This is particularly important in a city that is facing a housing crisis and is adding 73,660 houses by 2028. The findings underscore the importance of prioritizing repurposing strategies in urban development. By examining the district-level variation in amenities, the study reveals that repurposed buildings generally offer better access to amenities, with a higher annual growth rate in amenities compared to newly constructed buildings. However, the distribution of amenities is not uniform across all districts, with central areas like Centrum showing a concentration

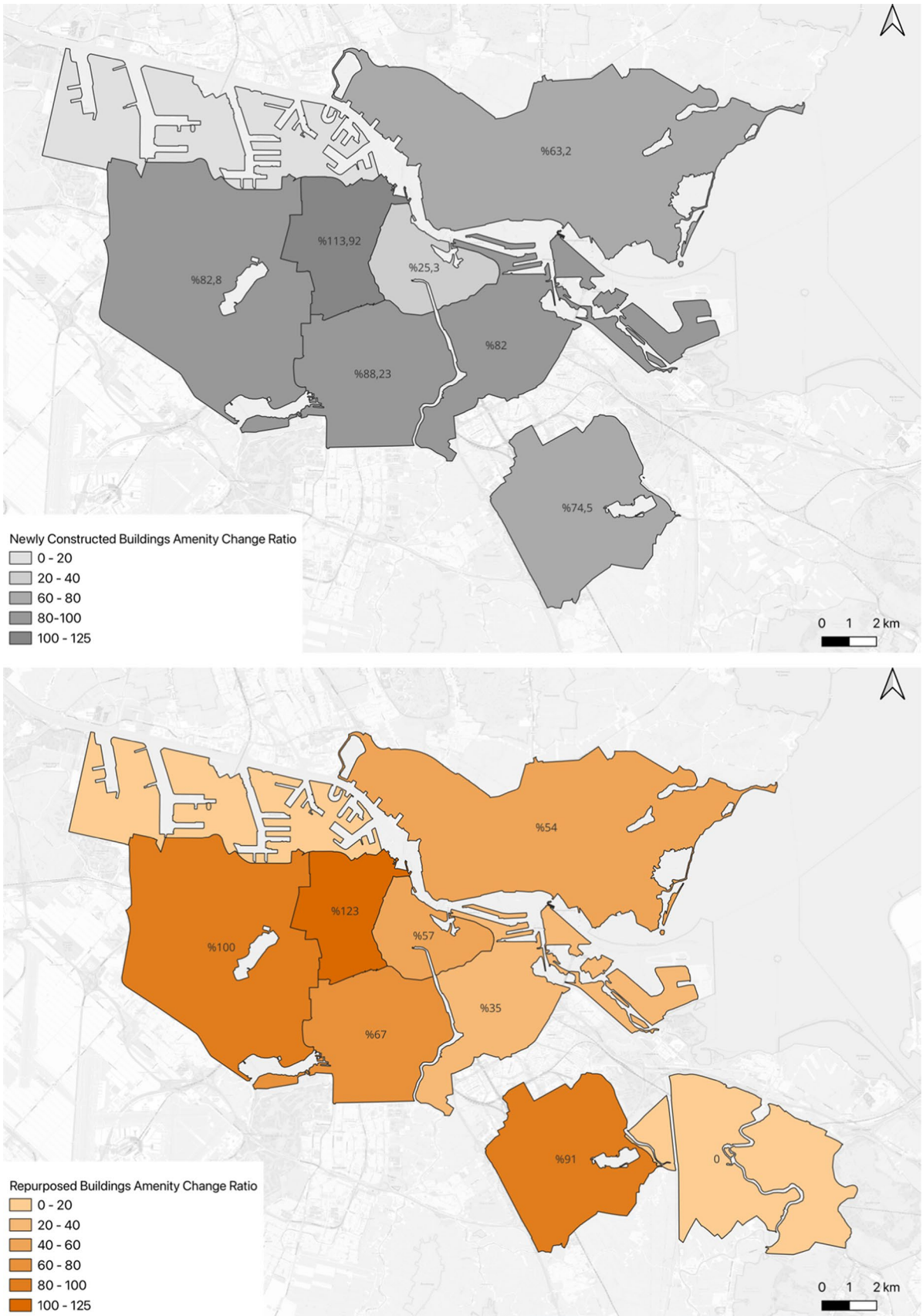

Fig. 10 Number of amenity change range in districts

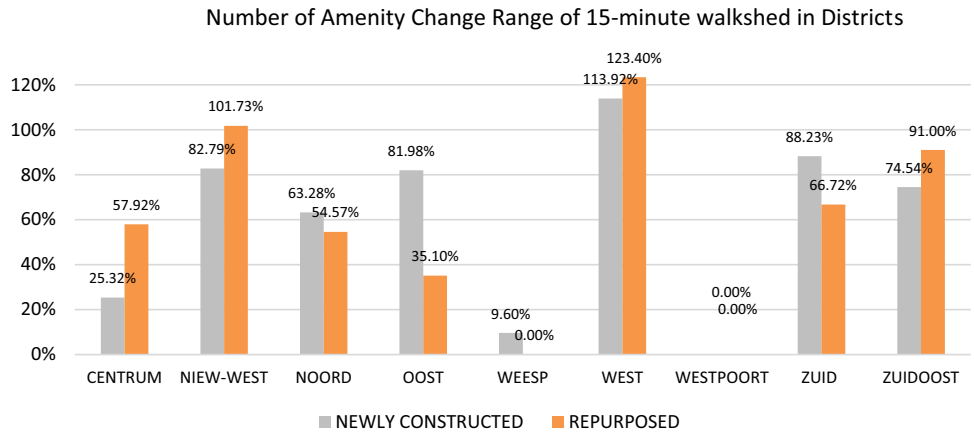

Fig. 11 Number of amenity change range of 15-min walkshed in districts

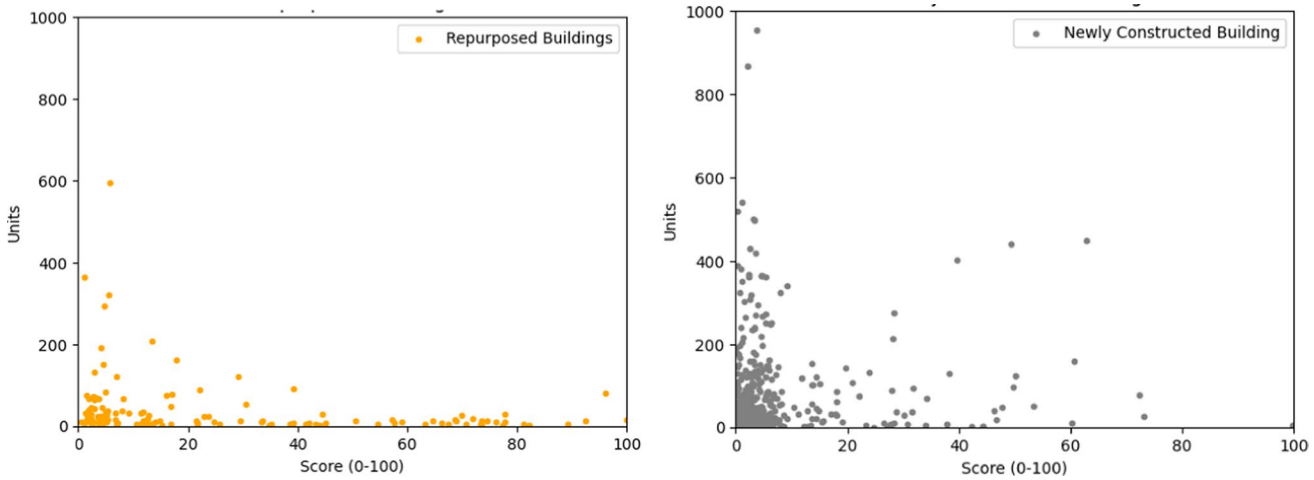

Fig. 12 Comparison of households accessing a greater number of amenities, where each dot represents a building

Table 1 Access Value and number of units for and Repurposed (RP) and Newly Constructed buildings (NC)

Score	RP	NC
0–10	3643	27,981
10–20	768	1437
20–30	309	962
30–40	190	783
40–50	58	652
50–60	49	177
60–70	85	619
70–80	108	105
80–90	14	0
90–100	109	12
Total Housing Units	5333	32,728

of tourism-related services, which reduces the diversity and accessibility of essential local amenities. This phenomenon points to the need for careful planning of amenities in line with housing development to ensure sustainability and equitable access across the city. This is a finding that resonates with other research, such as Akinsulire et al. [48] calling for the strategic planning of housing developments, or Chng et al. [49] who analyzed a similar issue in London.

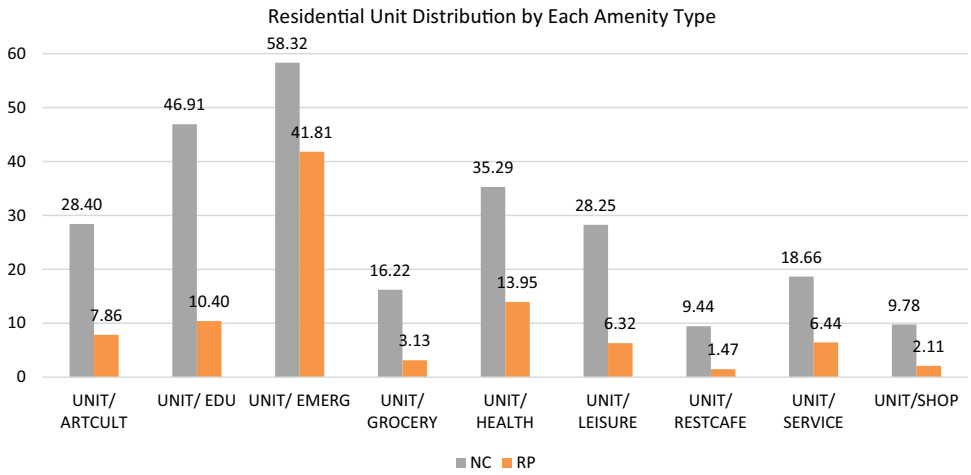

Fig. 13 Residential unit distribution by each amenity type

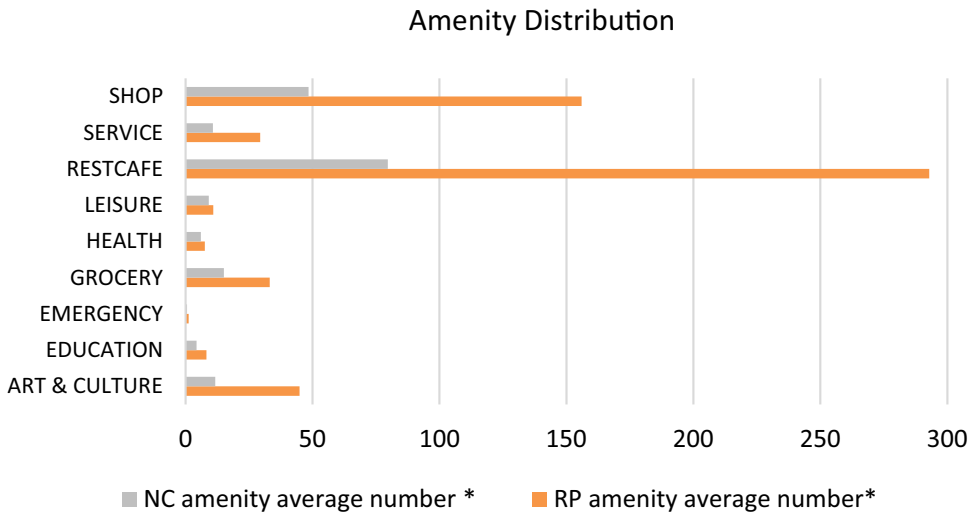

Fig. 14 Comparing distribution of average amenity numbers for 5 years

Table 2 Distribution of average amenity numbers and entropy of buildings built in different years

Construction year	Artcult		Education	Emergency	Grocery	Health	Leisure	Restcafe	Service	Shop	Entropy
2015RP	24	7		1	26	7	9	147	20	86	***2.43***
2016RP	41	9		1	37	8	12	328	32	186	***2.21***
2017RP	47	8		2	30	5	8	296	27	165	***2.16***
2018RP	44	8		0	32	7	12	270	28	160	***2.25***
2019RP	69	10		2	41	11	14	423	41	183	***2.28***
Average number of amenities of repurposed buildings	45	8		1	33	8	11	293	29	156	***2.25***
2015NC	11	3		1	13	4	8	51	9	33	***2.45***
2016NC	13	4		1	14	4	7	75	10	42	***2.29***
2017NC	9	6		0	15	6	9	60	11	46	***2.38***
2018NC	9	3		1	12	6	10	85	10	47	***2.27***
2019NC	15	5		1	22	10	13	128	14	74	***2.33***
Average number of amenities for newly constructed Buildings	12	4		1	15	6	9	80	11	48	***2.34***

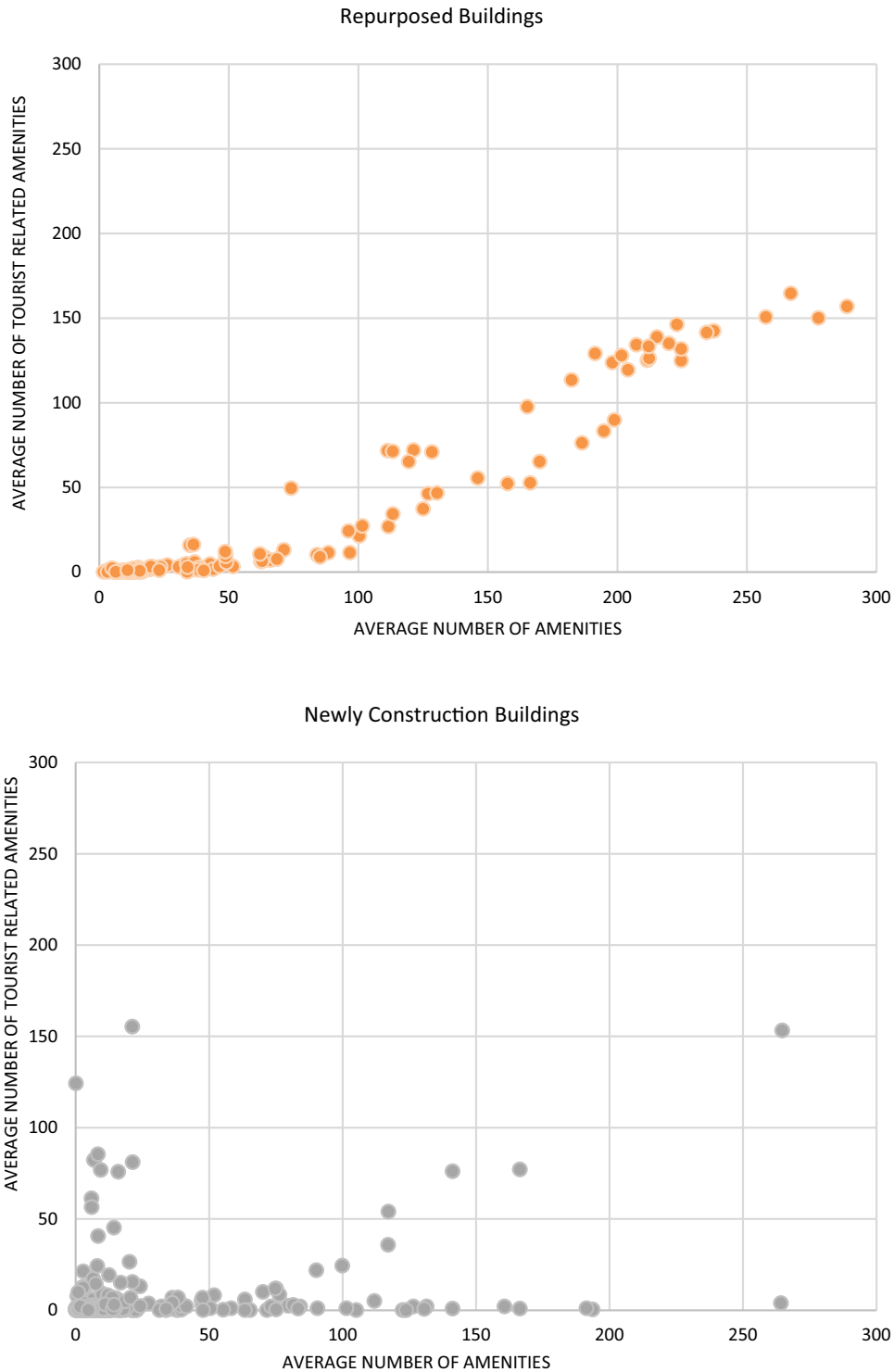

Fig.15 The average number of amenities and the average number of tourist-related amenities

Furthermore, a novel finding is that while newly constructed buildings add more residential units, they often rank lower in terms of amenity accessibility, highlighting the importance of considering the distribution of amenities when designing urban housing projects. The slightly higher diversity of amenities around newly constructed buildings reflects a broader mix of services, but this is offset by the dominance of tourist-oriented amenities close to repurposed buildings.

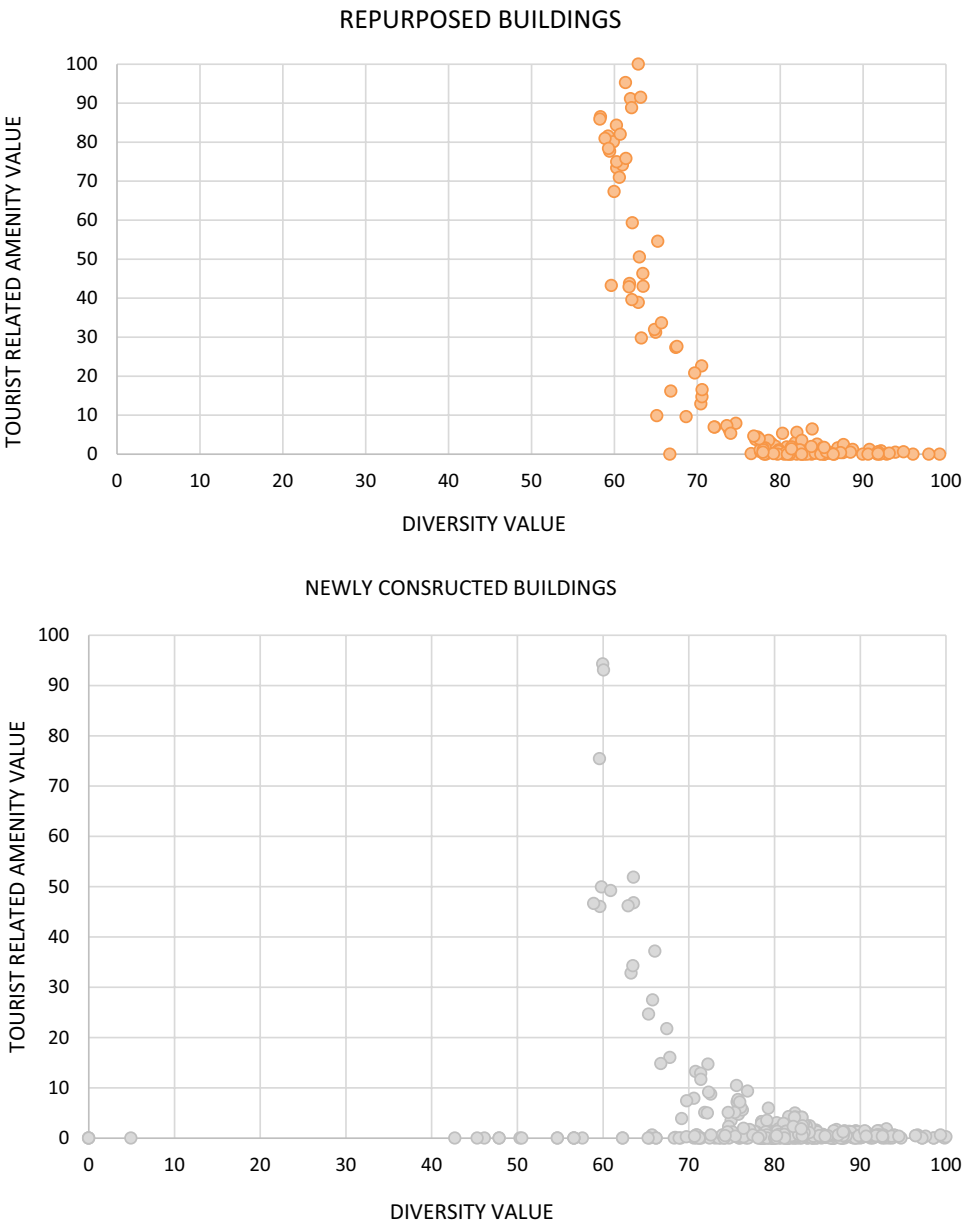

Fig. 16 Diversity value and tourist related amenities value

The analysis reveals that areas like Nieuw-West and Noord, with fewer tourist attractions, show less difference between repurposed and newly constructed buildings, reinforcing the need for a context-specific approach to urban planning.

The research emphasizes balancing local needs with the pressures of housing developments and tourism, particularly in city centers. It demonstrates that Amsterdam must plan its amenities alongside housing development to ensure the sustainability and accessibility of the city. This approach is not only crucial for Amsterdam but can be generalized to other European cities facing similar challenges, ensuring that housing strategies contribute to the broader goals of urban resilience and livability.

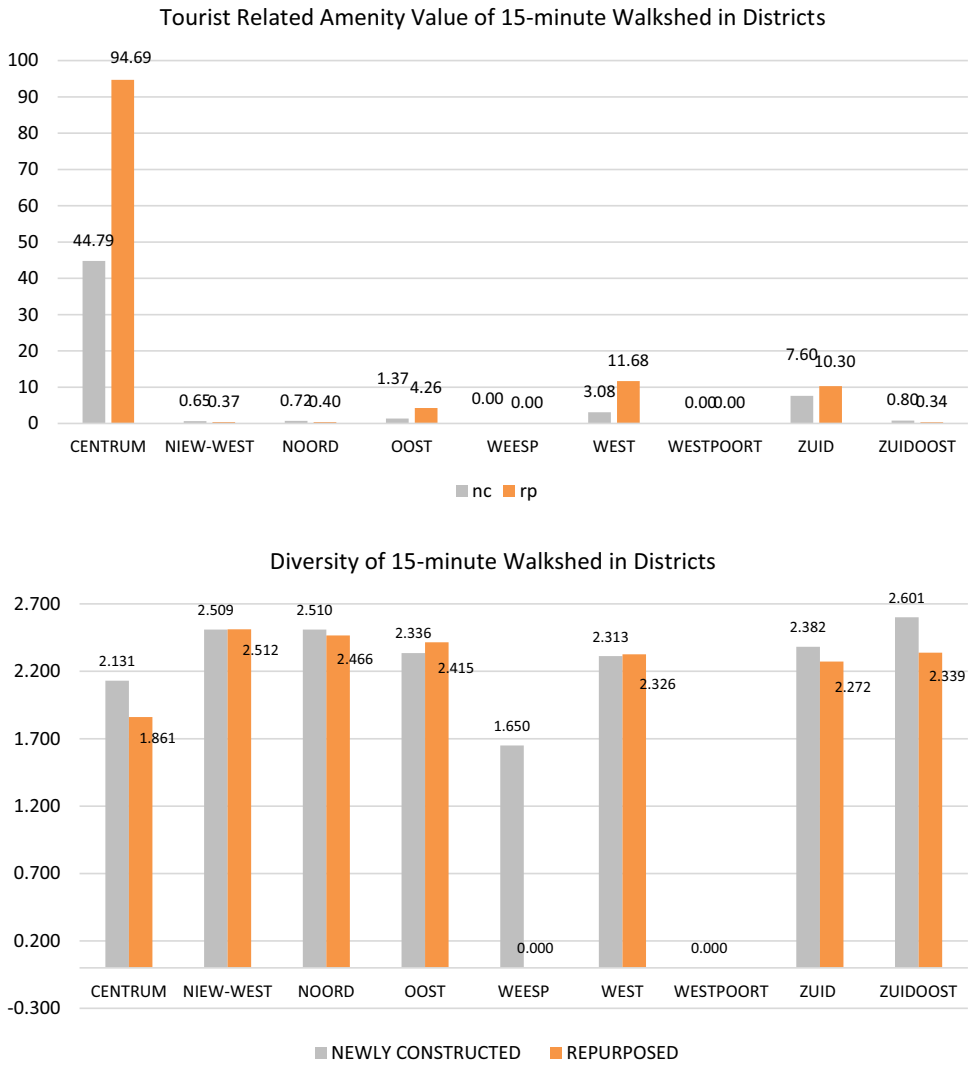

Fig. 17 Diversity and tourist related amenities value in districts

Author contributions All authors contributed to the design and execution of this project and reviewed and edited the manuscript. E.S.A. conceptualized the research design, acquired the data, conducted analysis, and wrote the first draft of the manuscript. F.D., T.V., and T.B. contributed to the conceptualization, methodological development, and editing of the manuscript.

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Data availability The dataset used in this research includes buildings that were classified and for which construction decisions were made between 2015 and 2019. Data on planned residential buildings from this period were prepared by creating two separate categories of housing strategies. Prior to this classification phase, planned building data were obtained from a site containing shapefiles from 2002 to 2019. The dataset was generated from WONINGWAARDE_2019_INFLATIE, which can be accessed at https://maps.amsterdam.nl/open_geodata/. The classified and analyzed building datasets generated during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate Not applicable'.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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