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URBAN DISTRIBUTION OF OLDER ADULTS: CONCENTRATION AND SOCIO-SPATIAL TYPOLOGIES IN SANTIAGO, CHILE [1]

DISTRIBUCIÓN URBANA DE ADULTOS MAYORES: CONCENTRACIÓN Y TIPOLOGÍAS SOCIOESPACIALES EN SANTIAGO DE CHILE

PATRICIO CORTÉS-RODRÍGUEZ [2]
MARCELO LUFIN-VARAS [3]

[2] Magíster en Economía Aplicada
Estudiante doctorado economía aplicada y doctorado economía y empresa(c). Facultad de economía y administración.
Universidad Católica del Norte, Antofagasta, Chile - Universidad de Oviedo, Oviedo, España
https://orcid.org/0000-0002-8587-8909
patricio.cortes@ce.ucn.cl

[3] Doctor en Ordenación del Territorio
Profesor jornada completa, departamento de economía, Facultad de economía y administración
Universidad Católica del Norte, Antofagasta, Chile
https://orcid.org/0000-0002-6856-6401
mlufin@ucn.cl

Aunque existen estudios previos sobre la distribución espacial de la población envejecida en diversas regiones del mundo existe una notable brecha en el conocimiento sobre Sudamérica. Esta investigación propone abordar el acelerado cambio demográfico hacia una población más envejecida en ciudades que no han sido planificadas para este cambio y no han desarrollado estrategias urbanísticas adaptativas. Se identificaron tipologías socioeconómicos y espaciales que influyen en las trayectorias de envejecimiento urbano en Santiago de Chile mediante tres métodos: un análisis geoespacial, un panel de datos y un análisis de k-media. Se encontró evidencia de un cambio en las zonas de concentración de adultos mayores, desde el centro hacia la periferia, y que variables como las familias monoparentales, la densidad poblacional y un alto nivel educacional son factores que aumentan la concentración de adultos mayores a nivel comunal. En contraste, ser propietario de una vivienda influye negativamente.

Palabras clave: envejecimiento poblacional, estrategias urbanísticas, distribución espacial, espacio urbano.

Although previous studies have examined the spatial distribution of the aging population in various regions of the world, a significant knowledge gap remains regarding South America. This research aims to address the accelerated demographic change towards an older urban population in cities that have not been planned for this shift and have not developed adaptive urban planning strategies. Socioeconomic and spatial typologies that influence urban aging trajectories in Santiago, Chile, were identified using three methods: geospatial analysis, a data panel, and k-means clustering analysis. It was found that there is a shift in the areas of concentration of older adults, from central to peripheral communes, and that variables such as single-parent families, population density, and high educational levels are factors that increase the concentration of older adults at a communal level. In contrast, homeownership has a negative influence.

Keywords: population aging, urban strategy, spatial distribution, urban space.

I. INTRODUCTION

The urban dynamics of Latin American cities are facing significant challenges due to the rapid aging of the population in urban areas that were not planned for this population. In this context, it is essential to identify how economic, social, and spatial processes shape the distribution of older adults in the urban territory. The lack of adaptive urban planning strategies has limitations for adequate infrastructure but also intensifies problems such as residential segregation, territorial marginality, and urban informality, which affect the sustainability of cities (Vecchio, 2022; Godoy Ossandón, 2024; Herrmann-Lunecke et al., 2024).

Traditional urban planning has proven to be insufficient to address the complexity of population aging. Faced with this challenge, an adaptive and comprehensive approach is required that considers the multifactorial dynamics of the territory. For this, it is important to overcome disciplinary fragmentation and adopt a transdisciplinary perspective that includes economic, political, cultural, and institutional dimensions. This approach must be based on a local contextualization, which promotes specific solutions that balance formal regulation with flexible mechanisms for emerging urban dynamics (Baigorri, 1995). This view coincides with what was proposed by Olay Varillas and Fernández Bustamante (2024), who highlight the need to overcome the multidisciplinary atony in urban management through planning capable of addressing structural problems from multiple, economic, social, and cultural facets, recognizing their interdependence.

In this context, different studies have explored how demographic dynamics affect urban planning. According to Sabatini and Wormald (2013), residential segregation limits social integration and accentuates inequalities. Barros (2004) points out that uncontrolled urban expansion generates vulnerable settlements and reinforces socio-spatial inequalities. Meanwhile, Seguin et al. (2015) identified *gentrification* in central urban areas, but also *juvenilization* and demographic renewal that displaces and/or replaces the aging population. On the other hand, some authors emphasize that social institutions have not evolved at the pace of demographic changes, which generates a *structural lag* (O'Rand & Bostic, 2016). In the Latin American context, Vecchio (2022) mentions that there is a limited institutional capacity to face the population's needs, which he conceptualizes as *territorial marginality*.

Although these studies have made progress in understanding the dynamics of urban and demographic planning, a gap persists in the literature about how social and territorial characteristics influence the spatial distribution of older adults in Latin American cities. This restricts the development of adaptive urban strategies that promote

social and territorial inclusion in a context of accelerated population aging and a territorial concentration of vulnerable populations. The relevance of this study contributes to the development of urban policies with an adaptive approach, which identifies the communal factors that drive the displacement and concentration of older adults, by facilitating the implementation of inclusive strategies in vulnerable areas.

Therefore, two hypotheses are formulated: (1) There is a displacement of the older adults towards the periphery, which generates an unequal demographic concentration pattern that is molded or contained in a planned urban environment, but not thinking about the aging population; and (2) The changing distribution of the older population concentrated in some communes is influenced by social variables associated with the life cycle.

To address these hypotheses, the following section outlines a theoretical framework on communal gentrification and juvenilization, followed by a methodology that integrates geospatial analysis (LQ segregation index) and a data panel to study the concentration of the aging population, which is complemented by *k-cluster* for their grouping. The subsequent sections present results, a discussion, and conclusions.

II. THEORETICAL FRAMEWORK

The older population has a territorial distribution that we try to identify through urban concentration during the life cycle. This distribution process implies different concentration levels, which are manifested in territorial, temporal, and socio-economic dimensions.

To understand the population distribution in an urban territory, the research structures the population according to *population heterogeneity*, characterized by the coexistence of people of different ages in the same space, and *population homogeneity* with a predominance of groups with similar characteristics, such as age, in nearby geographical areas.

When we consider the temporal factor, possible changes in concentration levels emerge, which is known as *urban cyclicity*. These changes are influenced by socio-economic characteristics of the population, which, according to Seguin et al. (2015), are based on mobility and competition hypotheses that explain the underlying factors.

This is how population homogeneity, closely linked to high levels of separation in different social groups within an urban environment (residential segregation), according to Janoschka (2018), tends to develop in contexts where urban planning and its state and private actors implement

market strategies aimed at specific groups. These strategies, often designed to meet the demands of aging middle-class sectors, prioritize elitist interests and exclude other population segments. These urban dynamics, supported by urban planning and reflecting and reinforcing patterns of exclusion by age and social class, contribute to the commodification of urban space (Hochstenbach & Boterman, 2018).

In this context, age is used as a key criterion to justify housing policies that benefit specific groups, such as affluent older adults, while neglecting others, such as young families with lower incomes or older adults with limited resources. Campos Alanis et al. (2024) also argue that the patterns of population homogeneity and heterogeneity by age are explained by a structural change in families, due to increased longevity. This change has expanded family structures to include older generations, such as great-grandparents. According to their analysis, low-income families tend to share the same dwelling, which encourages population heterogeneity.

Meanwhile, in *urban cyclicity*, it is proposed that the aging urban population tends to be concentrated in central territories initially. However, over time, it migrates towards the periphery, generating two possible results: residential segregation (Feitosa et al., 2007) and juvenilization, which is a phenomenon that describes the arrival of young people to areas traditionally occupied by older adults. This dynamic does not always imply forced displacement, but it does produce significant social and spatial transformations (Seguin et al., 2015).

Within this urban framework, the residential mobility hypothesis proposes that the population concentration changes due to residential mobility decisions, and according to Graff and Wiseman (1978), it focuses on some decisions such as: the emigration or immigration of young people, the departure or permanent arrival of older adults, and aging in place until death.

The lack of labor demand can generate emigration of young people to areas with higher employment, which influences the increase of older adults in the territory (labor emigration of young people). At the same time, an inverse phenomenon begins in areas with an increase in labor demand and educational supply, which generates juvenilization and gentrification in areas close to work or education (immigration of young people), which influences social exclusion (Burns et al., 2012).

While retirement and a loss of interest in living in residential areas close to work suggest that older adults may consider moving to areas with a greater provision of services and/ or close to relatives or places where they lived during their childhood, this mobility can lead to the depopulation of central urban areas and contribute to a population renewal as proposed by Hagestad and Dykstra's research (2016).

Finally, the decision to live in a place until the end of life can generate urban concentration of older adults, which contributes to residential segregation and juvenilization (due to the death of part of the aging population).

However, changes in population concentration may be due to a competition for territory as proposed by Park (1936), in the hypothesis of competitiveness that argues that territorial competition is driven by land value and population density, and could displace older adults to peripheral areas due to their limited economic capacity (Liu, 2024). This process, as described by Burns et al. (2012), structures residential segregation according to the life cycle and purchasing power of older adults who are less competitive compared to young professionals and families with greater resources.

In this context, older adults tend to be located in more economical areas, away from urban centers where demand and housing value are higher, which leads to gentrification. The search for accessibility to services and smaller spaces also reinforces this displacement. Recent studies agree on an intergenerational competition, where older adults are disadvantaged, which affects the development of residential segregation and a greater homogeneity of the aging population in peripheral areas (Seguin et. al., 2015). At the communal level, this is reflected in the concentration of older adults in areas of lower economic and social competitiveness.

For example, these competitiveness dynamics are accentuated by the specific conditions of the rental market in Santiago, which has dynamics that affect older adults, who face high levels of vulnerability due to the lack of formal contracts, dependence on internal relationships, and disproportionate spending on rent (Link et al., 2019), differing from other countries such as Mexico, where the conversion of housing is a strategy to address the economic insufficiency of older adults (Campos Alanis et al., 2024).

III. METHODOLOGY

To analyze the spatial and temporal distribution of the population, three approaches were used: the localization coefficient index (LQ) (Xu et al., 2018), to identify levels of communal concentration; a multiple regression model to capture temporal evolution and territorial distribution; and the k-means method that groups communes according to their sociodemographic similarity.

First of all, the LQ index analyzes the spatial concentration of the older adult population (Yao et al., 2019). This method compares the proportion of older adults in a specific commune with the total proportion of older adults in all communes, classifying them into three levels to identify the population's homogeneity or heterogeneity: low (LQ < 0.49), medium (LQ between 0.5 and 0.99), and high (LQ ≥ 1).

To calculate the LQ, the ages of older adults aged 60 and above and young adults aged 25 to 39 were used. The group of young adults was chosen to compare concentration trends because they are in the initial stages of independent life, characterized by the beginning of working life, the formation of a family, and the acquisition of the first home (Hagestad & Dykstra, 2016; Sabater & Finney, 2023).

Secondly, a multiple regression model with a data panel is used according to the typological structure proposed later. This approach evaluates how different explanatory variables affect the concentration of older adults (LQ_{anc}) in each commune, when considering the fixed and temporary effects (Equation 1). For its implementation, the R package of Croissant and Millo (2008) was used, following the methodology of Baltagi (2021).

$$LQ_{anc} = b_1 Perm_5 + b_2 F\_mon + b_3 Ppv + b_4 Den + b_5 LQjov + b_6 Ho\_uni + b_7 Due + b_8 Alta\_e + b_9 Tn + b_{10} Migra + \epsilon$$

(Equation 1)

The model is based on the theoretical framework and is structured in three main categories: (1) *residential mobility typologies*, represented by single-parent families (F_mon), the average number of people per dwelling (PPV), single-person households (Ho_uni), and the young people concentration index (LQjov). These typologies reflect occupation and displacement dynamics in the urban environment; (2*) territorial competitiveness typologies*, which includes a permanence greater than 5 years (Perm_5), the population density (Den), the home ownership (Due) and the university educational level (Alta_e), which indicate stability and economic capacity in the occupation of the space; and (3) *social and demographic factors typologies* such as the birth rate (Tn) and the proportion of foreign immigrants (Migrates), which are elements to measure the generational composition and renewal.

Thirdly, the k-means method is used to group communes according to the typologies of older adults who have similar characteristics and offer greater descriptive specificity, as proposed by Apparicio et al. (2015). The implementation of the method is based on the R package

of Kassambara and Mundt (2020). The model identified five groups with a better fit of older adults.

For the analysis presented in this article, census data from 1992, 2002, and 2017 were used as a primary source (National Institute of Statistics of Chile [INE], 1992; INE, 2002; INE, 2017), supplemented with information on the birth rate from the Department of Statistics and Health Information [DEIS] (n.d.). These data were standardized for each of the years of study, which ensures the comparability of trends over time in the 31 selected municipalities of the Metropolitan Region of Chile. The communes of Santiago were chosen because they have a broad socio-economic diversity and are geographically close. Another spatial selection criterion at the communal level was based on the fact that urban planning tends to be done at this administrative level. The comparison between the three years under study is also facilitated at the communal level, because the information from the 1992 Census (INE, 1992) does not permit a lower level of disaggregation, which prevents comparing each year at the neighborhood or district level.

IV. RESULTS

Population distribution

The LQ index at the spatial level for the 31 study communes is shown in Figure 1. In 1992, the urban center had a high concentration of older adults (LQanc > 1), while the peripheral communes showed lower levels of concentration. In 2002, the concentration in the urban central communes decreased, and a centrifugal displacement towards communes neighboring the center was observed, while in 2017, the LQ_{anc} index shows that the concentration of older adults is moving away from the center towards peripheral communes.

These results show a spatial trend away from central communes towards peripheral communes and evidence a decreasing trend of the concentration level over time, because in 1992 the concentration ranges give an LQ_{anc} index between 0.42 to 2.24; and for the 2002 census, the results indicate an LQ_{anc} index between 0.36 to 1.81; while in 2017 the LQ_{anc} index decreases to a range between 0.55 to 1.4, evidencing an increase in the heterogeneity or dispersion of older adults in the 31 municipalities observed.

Communal descriptors, data panel, and k-media.

Table 1 describes the results of the data panel, according to the proposed typology. The model in general explains 86% (R2) of the variability in the communal concentration of older adults.
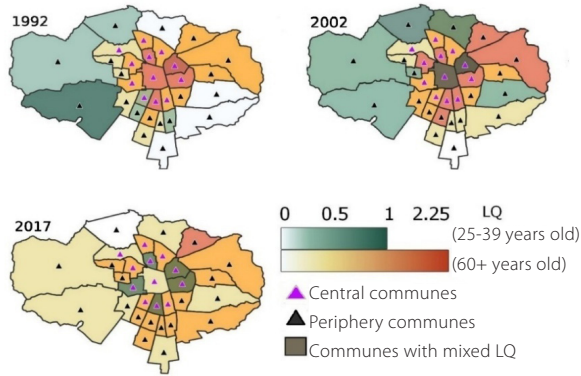
Figure 1: Communal concentration - LQ. Source: Prepared by the Authors.

Figure 2: Similar groups of older adults. Source: Prepared by the Authors.

Effect	Value	Std. Dev.	Weight
Idiosyncratic	0.00986	0.09930	0.644
Communes	0.00545	0.07387	0.356
Time	0	0	0
Theta	0.31 (Communes)	0 (Time)	0 (Total)

Estimator	Value	Error	Z-value	P(>/z|)	
(Intercept)	1.387	0.017	62.17	< 2.2e-16	***
(F_mon) Single-parent families	0.197	0.019	10.22	< 2.2e-16	***
(Due) Homeowner	-0.112	0.031	-3.63	0.000284	***
/Perm_5) Permanence over 5 years	-0.070	0.024	-2.92	0.003446	**
(Den) Population density per km2	0.040	0.021	1.89	0.058891	,
(Alta_e) University education	0.055	0.032	1.74	0.081187	,
(Tn) Communal birth rate.	-0.034	0.018	-1.87	0.062164	,
(Migra) Immigrants in the commune	-0.036	0.021	-1.71	0.087194	,
(LQ_joven) Concentration index 25-39 years	-0.033	0.021	-1.6	0.109147	
(PPV) Average number of people per household	-0.048	0.032	-1.49	0.135847	
(Ho_un) Single-person Households	-0.003	0.012	-0.23	0.817893	

Note: Significance, 0 *** 0.001 ** 0.01 '*' 0.05 ',' 0.1. R2 (0.86), R2 aj. (0.84), χ2 (504.7) with 10gl, p-value (< 2.22e-16). P. balanced: n=31, T=3, N=93.

Table 1: Descriptor data panel4. Source: Preparation by the Authors

The most significant result is explained as an increasing result, when the number of single-parent families is increased by 1%, the concentration of older adults increases by 0.19%; it is followed in significance by the level of university education with 0.055%; which implies that, the higher the education, the higher the level of territorial concentration. Following the theory of competitiveness, the territorial population density per km^2 is 0.04%, which explains that the more people per km^2, the higher the aging population density, being a factor of population homogeneity related to the hypothesis of competitiveness.

Among the negative and significant coefficients, the following stand out: homeownership, with an impact of -0.11% and high significance, influenced by competitiveness by land use, perhaps enhanced by younger age groups, but with higher income, which drives a gentrification process. Another negative typology is remaining in a property for five years or longer, which has -0.070% and high significance. This occurs when groups under 60 decide to stay in an area, which decreases the concentration of people over 60.

As expected, an increase in the birth rate decreases the weight of the LQ_{anc} index. The immigration process of foreigners is similar, with -0.036%. Therefore, when the number of people in the communes increases, a greater distribution of the population of different ages is generated (population heterogeneity).

Figure 2 shows the previous model, but groups of communal clusters of older adults are added. The best-fit model is the 5-commune model. Two main trends are observed: communes 3
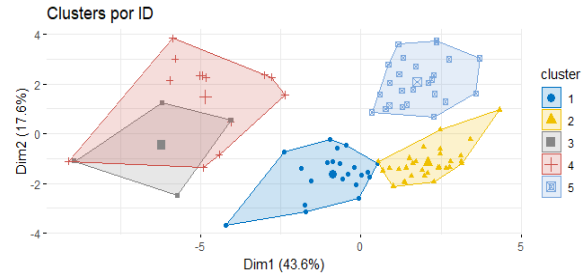
4 Descriptors with heteroscedasticity and autocorrelation were eliminated. In addition, the VIF excludes 5 descriptors due to multicollinearity. The Lagrange test ruled out temporal effects (χ2 = 0.524, p = 0.4691) but confirmed individual effects (communes). The Breusch-Pagan test validated the heteroskedasticity (χ2 = 22.608, p = 0.01229) that justifies the use of the model and the Breusch-Godfrey test did not detect autocorrelation (χ2 = 2.8, p = 0.41).

Estimator	Value	Error	T-value	Pr(>/t|)	
(F_mon) Single-parent families	0.157	0.022	7.11	4.84e-09	***
(PPV) Average number of people per household	-0.100	0.042	-2.35	0.022	*
(Den) Population density per km² (communal)	-0.145	0.083	-1.73	0.008	.
(LQ_joven) Concentration index 25-39 years	-0.043	0.025	-1.71	0.093	.
(Due) Homeowner	-0.02	0.110	1.82	0.073	.
(Ho_uni) Single-parent households	-0.014	0.011	-1.25	0.216	
(Perm_5) Permanence over 5 years	-0.019	0.028	-0.67	0.504	
(Alta_e) University education	-0.142	0.090	-1.48	0.144	
(Tn) Communal birth rate.	-0.029	0.020	-1.43	0.159	
(Migra) Immigrants in the commune	-0.009	0.022	-0.41	0.682	
(Cluster)2	-0.273	0.210	-1.28	0.204	
(Cluster)3	-0.058	0.080	-0.67	0.050	
(Cluster)4	-0.078	0.110	-0.68	0.497	
(Cluster)5	0.173	0.140	1.18	0.241	

Note: Significance, 0 '***' 0.001 '**' 0.01 '*' 0.05 ',' 0.1. R2 (0.85), R2 adjust. (0.73), F-statistical (23.1) with 13 gl, p-value (< 2e-16). Balanced panel: n=31, T=3, N=93.

Table 2: Data panel with k-means. Source: Preparation by the Authors.

and 4 have similar characteristics, while communal clusters 1, 2, and 5 show differences in communal typology.

In Table 2, the results are presented on incorporating the clusters that were not significant and did not improve the analysis, indicating that the demographic and spatial characteristics of older adults are adequately explained by the previous model and do not need to be differentiated by communal groups.

V. DISCUSSION

The LQ index confirms a change in the older population from urban centers to the periphery of Santiago de Chile, driven by processes related to the life cycle (gentrification and juvenilization), in line with previous studies in cities such as Montreal (Seguin et al., 2015).

The data panel model globally explains 85% and complements the theoretical framework of the study. Within the typologies, single-parent families are the most significant typology. They are positively correlated with the concentration of older adults (0.19%), which suggests specific family dynamics in the context of Santiago. This is similar to what was found in Montreal by Seguin et al. (2015), and it can be transformed into more vulnerable families, who need full-time jobs to support themselves, which aggravates their vulnerability to possible residential segregation processes.

Although the literature from Canada indicates that single parents tend to resort more frequently to the use of

private vehicles and full-time employment, especially in single-parent families (Roorda et al., 2010), a situation of vulnerability is likely to arise when these parents reach old age. As evidenced in Santiago de Chile, this dynamic can exacerbate residential segregation due to the lack of access to adequate or planned public transport, which results in territorial marginality.

Another positive relationship is generated between the level of university education (0.055%) and the concentration of older adults, consistent with the hypothesis of competitiveness. The communes with a higher proportion of older adults with higher education could be more consolidated areas, with better access to services and amenities, where this group has been able to stay over time due to their socio-economic position. This contrasts with the displacement processes associated with gentrification, which tend to affect populations with lower purchasing power and possibly greater dispersion in space.

Similarly, the positive correlation between population density (0.040%) and the concentration of older adults can be interpreted as a reflection of population homogeneity in areas that have experienced aging in place. These dense communes could have attracted and retained population cohorts that have co-aged. However, it could also indicate pressure on resources and infrastructure in these areas, which impacts the quality of life of older adults, as mentioned by the theoretical framework when referring to territorial marginality.

The negative and significant coefficients for homeownership (-0.11%) and residence over five years (-0.070%) are consistent with the theories of territorial competitiveness and gentrification/juvenilization. The lower concentration of older adults in communes with a high proportion of owners suggests that the increase in land value and the arrival of younger populations with greater purchasing power generate an indirect displacement of older adults, who could be forced to look for cheaper housing alternatives in the periphery, as proposed by the hypothesis of residential mobility and the theory of competitiveness. This dynamic makes a difference in the context of developed cities, where property can offer greater stability in old age.

The decrease in the LQ index due to an increase in the birth rate and the immigration of foreign people reinforces the idea of a growing population heterogeneity in the communes. These demographic processes contribute to juvenilization, which alters the proportion of older adults and, potentially, modifies the changing needs, according to the demand for specific services for the population according to the age group.

Despite the relevance of communal factors in the concentration of older adults, the study presents spatial limitations, focusing on the communal and non-district level due to the lack of disaggregated information in 1992. Likewise, the cross-sectional information does not allow determining, in the long term, whether people have died or migrated to other communes, which restricts the interpretation.

VI. CONCLUSIONS

The findings confirm the hypotheses about the distribution of older adults, who moved from the center to the periphery between 1992, 2002, and 2017. At the same time, dynamics such as educational level and family structure determine specific patterns of population redistribution, which generates a pattern of unequal demographic concentration that is molded or contained in a planned urban environment, but not thought of for an aging population, which leads to gentrification or juvenilization, in addition to the move away from central areas, which contribute to greater residential segregation.

On the hypothesis of the changing distribution of the older population, which is concentrated in some communes, the hypothesis on the influence of intrinsic variables on the competitive hypothesis, residential mobility, and social variables is accepted. However, it should be noted that the population characteristics in central and peripheral communes persist over time. This means that where there is a concentration of older adults, there are patterns of high educational level and single-parent family structure. An uneven demographic concentration pattern is generated that is molded or concentrated in a changing spatial location towards the peripheral communes of the city of Santiago.

These results highlight the need for adaptive strategies that reduce the structural gap between demographic dynamics and urban planning, avoiding reactive solutions to structural problems. Public policies are proposed, such as: (1) inclusive housing policies in central communes to curb exclusion due to gentrification; (2) mapping of critical areas (LQ) for social integration projects and services in peripheries; and (3) inclusive transport and land regulation. The evidence suggests taking inspiration from cases such as Asturias (Spain), where territorial rebalancing strategies mitigated marginality in contexts of population aging (Olay Varillas & Fernández Bustamante, 2024), which adapts its three priority lines: peripheral infrastructure, land regulation, and connectivity.

Future research could analyze the impact of the increase in land prices and services at the neighborhood level as a determining factor in the voluntary relocation of older adults to economic areas, and also explore the conversion of homes into businesses (to cover medical and orthopedic expenses) and its relationship with residential displacements in this age group, in addition to evaluating how the death of older adults influences urban renewal, particularly through inheritance processes and the establishment of younger relatives in such properties.

VII. CONTRIBUTION OF AUTHORS CRediT:

Conceptualization, P.C.R.; Data Curation, P.C.R.; Formal analysis, P.C.R.; Research, P.C.R.; Methodology, P.C.R.; Resources, P.C.R. and M.L.V.; Supervision, M.L.V.; Validation, P.C.R. and M.L.V.; Visualization, P.C.R.; Writing - original draft, P.C.R.; Writing - revision and editing, P.C.R.

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