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The relationship between gentrification and public transport investments: A study on French cities

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Abstract
Socio-spatial dynamics, such as gentrification, often result from urban planning and development processes that include public transport investments. The construction of a new tramline (or light-rail transit, LRT) is one of the most impactful transport infrastructure projects that can be implemented within a territory. This work focuses on the fourth tramline in Bordeaux (France), which crosses 3 suburban municipalities with different accessibility and socio-economic profiles. It aims to evaluate the impact of this project on multiple indicators: population density, the socio-professional composition of the population, average household income, and the number of poor households, to detect a possible gentrification process. Municipal data, as well as grid-based data from the French national statistics institute, were used to obtain a global view of cities' dynamics, and a more precise view at a 200 × 200 m cell scale. Using a GIS tool and R for visualisation, the evolution of those indicators over the course of the implementation was studied. The results show an acceleration in density growth, most evident in the peripheral cities farthest from the city centre, as well as a subtle, nuanced increase in the proportions of higher-income socio-professional groups. Gridded data on the population's income along the tram's route yield mixed conclusions: the study does not allow for the identification of a clear ongoing gentrification process. The research could be completed by evaluating other urban development indicators, such as housing market trends, and by collecting more data on the years following the launch to establish the project's long-term impact.
Keywords: *gentrification, public transport, tramline, tramway, attractive neighbourhood, socio-spatial dynamics*

1. Introduction

In France, urbanisation occurred largely through the growth of existing cities since the 1950s (Eaton and Eckstein, 1997). Over the past decade, approximately 80% of the population has lived in urban areas, reflecting a strong concentration of inhabitants in metropolitan areas (Veneri, 2018).

1.1. Transport infrastructure development as a factor of special gentrification

Spatial gentrification refers to a process of neighbourhood change characterised by the socio-economic upgrading of an area, typically through the arrival of higher-income households and the displacement or replacement of lower-income populations. This metamorphosis of the territory's social profile is often accompanied by changes in housing markets and the built environment (Nilsson and Delmelle, 2018). Previous studies often describe the process as the result of interactions between multiple urban dynamics rather than a single cause, including transport accessibility, land and housing market pressures, and public or private redevelopment (Padeiro et al., 2019). Therefore, gentrification is the spatial manifestation of urban restructuring processes influenced by infrastructure investment, neighbourhood rehabilitation, and development (Bardaka et al., 2018).

Transport infrastructure is frequently identified as an important factor in gentrification because it improves accessibility and reduces travel costs relative to personal vehicles (Dong, 2017). Rail-based systems, particularly those integrated into transit-oriented development (TOD) strategies, can enhance neighbourhood appeal and stimulate land development around stations (He et al., 2021). Improved accessibility may then be reflected in higher property values and changes in residents' socio-economic profiles (Bardaka et al., 2018). However, transit investments do not systematically generate gentrification, as local demographic conditions and planning policies also influence outcomes (Crescenzi and Rodríguez-Pose, 2012; Padeiro et al., 2019).

In this perspective, transit-induced gentrification should be understood as a contingent and context-dependent process, in which accessibility improvements act as a catalyst rather than a deterministic driver. The socio-spatial outcomes depend on the interaction between transport investment, housing supply conditions, planning

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regulations, and resident mobility strategies. This theoretical position guides the empirical interpretation developed in the present study.

1.2. A study on a French city: Bordeaux's 4th tram line

In 2020, tramline D was launched in Bordeaux, a city in southwestern France (Fig 1). The project was announced publicly in 2009; construction began in 2017 and was completed in 2019, followed by the trial period. In December 2019, the first section began operating, and in February 2020, the entire line was launched, serving 3 suburban municipalities outside of Bordeaux (Ligne D du tramway de Bordeaux, 2026).

Figure 1. Route of the tramline D in Bordeaux, France (Ligne D du tramway de Bordeaux, 2026)

Bordeaux is France's 9th largest city, with around 270 000 inhabitants in 2026 (Marin et al., 2024). and its current public transport network has been developing since 2004 (Dupas et al., 2023). Regarding its mobility profile, in 2021, 40% of intra-Muros inhabitants used the car as their main mode of transport (the average for the 20 largest French cities). Still, it was 64.4% in its agglomeration, ranking it the largest of the 20. It was in the lower half for the proportion of people using public transport within the Muros and in the agglomeration (Adetec, n. d.).

This project affects multiple cities (Bordeaux, Le Bouscat, Bruges, and Eysines – later referred to as 0, 1, 2, and 3 to indicate their distance from the city centre) and neighbourhoods, not on the same scale, depending on the infrastructure route or the existing demographics at the beginning of the project.

The most recent LRT infrastructure, which is the focus of this study, crosses Bordeaux and 3 cities in the metropolitan area. The project traverses substantial portions of both Le Bouscat and Eysines, while entering Bruges only along the municipal boundary.

The impact of this new infrastructure on the central city of the metropolitan area, Bordeaux, will not be as widely discussed as its effect on the suburban area, since many other transit modes were already operating before its implementation, potentially leading to interference with the measured indicators. Moreover, the city closest to the centre also benefits from this extensive transport network, which might explain the lower changes after the opening of the tramline.

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1.3. The study hypothesis

The hypothesis investigated in this study is that the introduction of a new tramline within a metropolitan area induces spatial gentrification, characterised by the settlement of higher-income social groups and an increase in local living standards, particularly in areas located close to the tram route.

In addition to its urban and transport dimensions, this study is situated within the broader framework of cognitive sustainability, which conceptualises sustainability as the efficient utilisation and distribution of knowledge, decision-making capacity, and informational resources within socio-technical systems. In this perspective, transport infrastructure, such as tramway systems, not only modifies physical accessibility but also reshapes how individuals perceive, evaluate, and utilise urban space. Accessibility improvements can therefore be interpreted as a transformation of cognitive opportunity structures, influencing residential choices, mobility behaviour, and long-term socio-spatial organisation.

1.4. Methodology overview

An LRT is considered to be a more structuring transit mode in urban planning than a bus, due to the permanence of its infrastructure (Dubé et al., 2018). This leads to more confidence in the sustainability of its attractivity, and its capacity to influence significatively property value on its route. Introducing an LRT service also has a broader impact, affecting value up to hundreds of meters around compared to less than a hundred for a Bus Rapid Transit (BRT) (Zhang and Yen, 2020). A BRT system could affect the study if it is located near the LRT, with a dedicated lane (Ingvardson and Nielsen, 2018), but that is not the case in the focus territory. Furthermore, the other tramline in Bruges is over 1 km away from the studied area and was launched in 2016 (Ligne C du tramway de Bordeaux, 2026).

The following visualisation tools were used to identify the socio-demographic dynamics created by the construction of a tramline in a neighbourhood and, consequently, the increase in accessibility, using indicators such as population evolution, age group evolution, socio-professional categories (later referred to as SPC), inhabitants' standard of living, and housing prices.

2. Data sets, visualisation and modelling tools

The data used for this study are from the French National Institute of Statistics and Economic Studies (INSEE), which provides access to population evolution data for each municipality each year. This data set contains many precise categories, such as population in each age category, where the inhabitants lived the year before, and, most importantly for our study, their SPC. To identify the possible impact on the territory, data collection starts with the public announcement year of the LRT construction and ends in 2022, the last census year available at the time of the study.

Moreover, the impacts of a project on a neighbourhood at a more local scale were identified using grid-based data and analysed with the GIS tool. This data set was only available for 2015, 2017, 2019, and 2021, which cover the phases before and during construction, as well as a year after launch.

2.1. Indicators calculation using a GIS tool

2.1.1. Accessibility indicator

Access to urban opportunities is commonly modelled in the literature as a function of generalised travel cost, which is a combination of access to infrastructure and in-vehicle (here, in-tram) distance (Kapatsila et al., 2023). This indicator, Accessibility (Eq. 1) was calculated using the shortest distance from the center of mass of each square area (200 × 200 m) to the tram stops (it was considered that the shortest distance was a straight line, between the cell's centroid and the stop, without accounting for parcel boundaries or street network constraints) and the distance from the closest stop to the city center, measured with GéoPortail (n. d.) (1). The most central stop was chosen. The weights for each variable are based on the time spent during each phase of the journey (Wardman, 2004), with access and waiting times weighted more heavily than in-vehicle time (Table 1). Waiting time and tram operating speed were derived from the published weekday timetable. Waiting time was estimated using the average scheduled headway during weekdays (TBM, n. d.). The access speed was set to walking speed because most daily

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public transport trips begin with a walking segment (Hillnhütter and Sick Nielsen, 2026). Accordingly, the catchment area represents users who access the LRT infrastructure on foot for their daily commute.

$$Acc_i = 2{,}5 \cdot \frac{D_{access,i}}{C_{access}} + 1{,}5 \cdot T_{wait} + \frac{D_{in-tram,i}}{C_{tram}} \qquad (1)$$

where,

Acc_i is the accessibility calculated for a 200 × 200 m square area;
C_{access} is the access speed to the transit mode (here on foot);
$D_{access,i}$ is the distance between the square area's centroid and the closest stop, disregarding street layouts;
T_{wait} is the average waiting time for the tram to arrive;
$D_{in-tram,i}$ is the summed distance from the closest tram stop from the square area to the city centre stop;
C_{tram} is the tram operating speed.

Table 1. Data for calculating the accessibility indicator

Project	Tramline D in Bordeaux
C_{tram} (km/h)	18.2
C_{access} (km/h) on foot	4
T_{wait} (min)	7.5

This indicator enabled the representation of the accessibility of each square areaon a map (Fig. 2) and the subsequent evaluation of its effects on the socio-demographic variables in each square area. From a transport engineering perspective, the spatial distribution of accessibility reflects the combined influence of access time, waiting time, and in-vehicle travel time within the generalised cost framework. The higher sensitivity of users to access and waiting components implies that relatively small reductions in these components may significantly increase perceived accessibility, particularly in peripheral areas that were previously poorly connected. This helps explain why the greatest relative impacts are observed in municipalities located further from the urban core. These spatial differences in accessibility can also be interpreted as differentiated cognitive landscapes across the metropolitan area. Areas experiencing larger accessibility gains benefit from a relative expansion of perceived opportunities, which may influence residential attractiveness and location choices. This mechanism provides an additional explanatory layer for the observed redistribution of population and socio-economic groups.

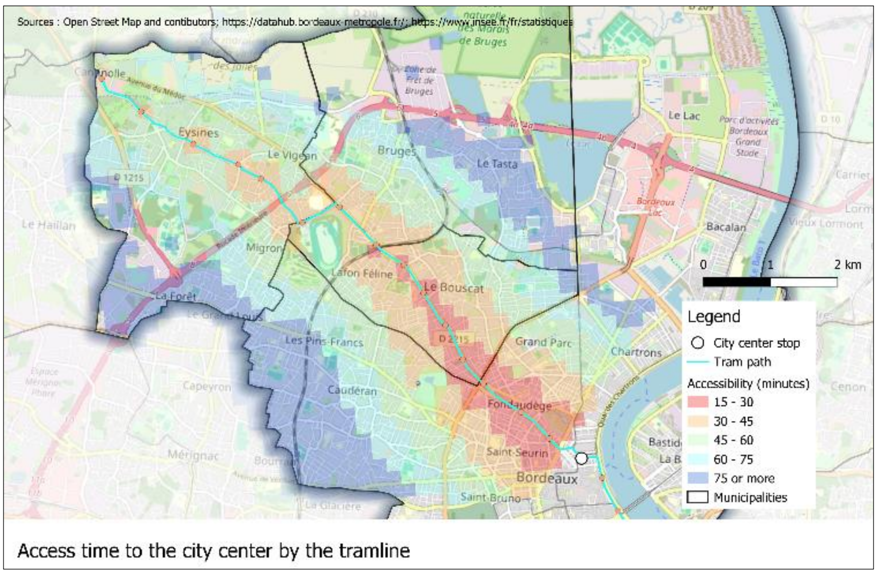

Figure 2: Accessibility time of the city centre from each square area by the tramway (tram stop accessed on foot)
Source: won data

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This heat map gives an idea of how the tramline's impact might be spreading across the territory. However, the furthest cities, which were less accessible before the project's arrival, such as Eysines (the westernmost municipality), are more likely to be affected by it, even though travel times are longer than for cities closer to the central stop. On the contrary, the central city already has extensive public transport infrastructure, so residents living near the new tramline might not use this mode of transit (Kasraian et al., 2019).

The accessibility formulation adopted in this study relies on geometric distances and uniform access speeds, which simplifies the representation of real-world travel conditions. This approach allows for a consistent and transparent comparison across spatial units, but it does not account for network topology, intersection density, pedestrian infrastructure quality, or multimodal interactions. Consequently, the resulting accessibility values should be interpreted as approximations of relative accessibility rather than precise travel times. Future extensions of this work could incorporate network-based shortest-path calculations and multimodal accessibility measures to more accurately capture the spatial structure of urban mobility systems and the interactions between tram services and other transport modes.

From a cognitive sustainability perspective, the accessibility indicator used in this study may be interpreted as a proxy for the cognitive effort required to access urban opportunities. Reductions in generalised travel costs effectively decrease the informational and decision-making burden associated with daily mobility, thereby expanding the set of feasible choices available to individuals. In this sense, accessibility improvements induced by the tramline can be understood not only as gains in physical connectivity but also as enhancements in cognitive efficiency within the urban system.

2.1.2. Average household income

Utilisation of grid-based data for each year and municipality affected by the project enabled measurement of the standard-of-living indicator. A GIS tool was chosen for this study because of the size of the data: it is detailed at 200 × 200-meter squares, using this scale for French data collection. The 35 variables on the age structure of individuals, household and housing characteristics, and income are used to compare the same municipalities over the course of the project realisation. The maps were created for each year and display two indicators: the number of poor households (a variable available in the dataset) and average household income.

$$AHI_i = \frac{Ind\_snv_i}{Nb\ H_i} \tag{2}$$

where,

AHI_i is the average yearly household income for a 200 × 200 m square area;
Ind_snv_i is the sum of the winsorised living standards of individuals in the square area;
$Nb\ H_i$ is the number of households in the square area.

The variable available for income calculation within the data set is the "sum of the winsorised living standards of individuals", Ind_snv_i, which is equal to the sum of the living standards after winsorisation for each 200 × 200m square area. Winsorisation involves replacing extreme values with threshold values to limit the influence of outliers (Winsorisation, 2025). To obtain a more relevant indicator for our study (because the sum of living standards is higher and almost homogenous in the urban area, which does not allow a precise interpretation), the Average Household Income was introduced (2), using the number of households in each square area. The maps obtained for this indicator allow for comparison between different phases of each project.

2.2. Data tidying and visualisation

This tool was first used to get an impression of the 3 population indicators (density, age groups and SPC distribution). To calculate density evolution over time, the precise area covered by each municipality was obtained in the 2022 annual "French municipal administrative divisions based on OpenStreetMap" shapefile from the national open data base (*Data.Gouv.Fr*, n. d.). To assess changes relative to the year in which the project was publicly announced, the data were normalised using that year as the baseline. (3).

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$$Density_{evol} = \frac{\frac{Pop}{Popann}}{A} \times 100 \quad (3)$$

where,

$Density_{evol}$ is the evolution of density for a certain city for the past year;
Pop is the population for the given year;
Pop_{ann} is thin e population the year of the project announcement;
A is the area of the municipality.

The charts for SPC composition of the population are obtained from pivot tables filtered by municipality, to identify differences between all those affected by the project.

It is important to note that the methodological framework adopted in this study is primarily descriptive and exploratory. While it allows identification of temporal and spatial correlations between tramline implementation and socio-economic changes, it does not establish causal relationships. In particular, the absence of a counterfactual reference group limits the ability to isolate the tramline's specific effect from broader metropolitan dynamics. More advanced econometric approaches, such as difference-in-differences or synthetic control methods, could provide a stronger basis for causal attribution and represent a promising direction for future research.

3. Results of the study

The four indicators chosen to identify a gentrification process linked to the arrival of a tramline were calculated using previously developed methods, and the results are presented below. They were then interpreted to analyse the true impact of the new tramline in the neighbourhoods.

3.1. Density evolution

The density trends are strongly differentiated across municipalities (Fig. 3): the two cities furthest from the city centre show a significant increase in density, while the closest city remains nearly stable.

Before the tramline launch (in 2020 for cities 2 and 3), those 2 municipalities follow similar upward trends, suggesting pre-existing metropolitan expansion or suburbanisation dynamics but without strong divergence. Around the project launch, we observe a shift in trends across all three cities, especially in Bruges (municipality 2), where growth accelerates significantly. This timing suggests a possible link to the introduction of the tram line, which may have increased the attractiveness of mid-distance and peripheral municipalities by improving access to the city centre. These areas likely benefit from better connectivity enabled by this new infrastructure, combined with lower land prices and greater residential availability. In contrast, the central municipality's growth may be restrained by housing market saturation and already extensive transit supply (Higgins et al., 2014).

While this does not, in itself, demonstrate gentrification, it suggests a restructuring of the territory's spatial attractiveness that can serve as a base mechanism for future spatial gentrification processes.

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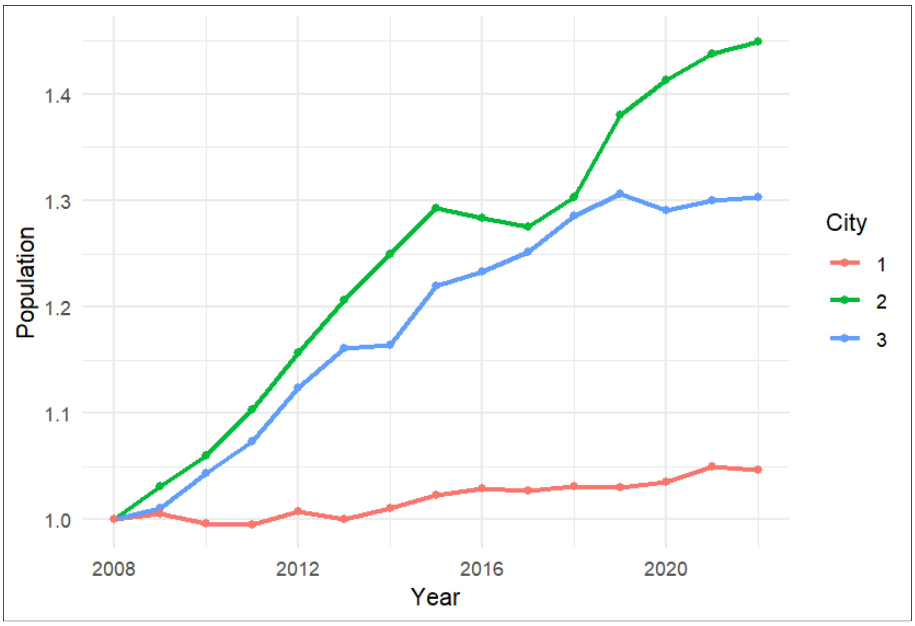

Figure 3. Density evolution of the 3 suburban cities crossed by the new LRT service

From a cognitive sustainability perspective, the observed increase in density in peripheral municipalities may reflect adjustments in how households process spatial information and evaluate trade-offs among location, accessibility, and housing costs. Improved transport connectivity reduces perceived distance to the urban core, effectively reconfiguring the metropolitan area's mental map and enabling previously less attractive locations to become competitive residential alternatives.

3.2. Socio-professional categories

For the first project, in Bordeaux (announced in 2009, operating since 2020), the chart visualisation of the evolution of socio-professional categories of the population (Fig. 4), the observation can be made that higher income categories indeed come to settle over the years, such as "executives", "intermediate professions" or "retired". However, the "blue-collar workers" category has decreased over the years. The impact of the project's launch can be identified around 2020, with a sudden shift in trends among some groups. The most obvious example is in the third city (further from the city centre), where the "executives" trend replaces the "blue-collar workers" trend.

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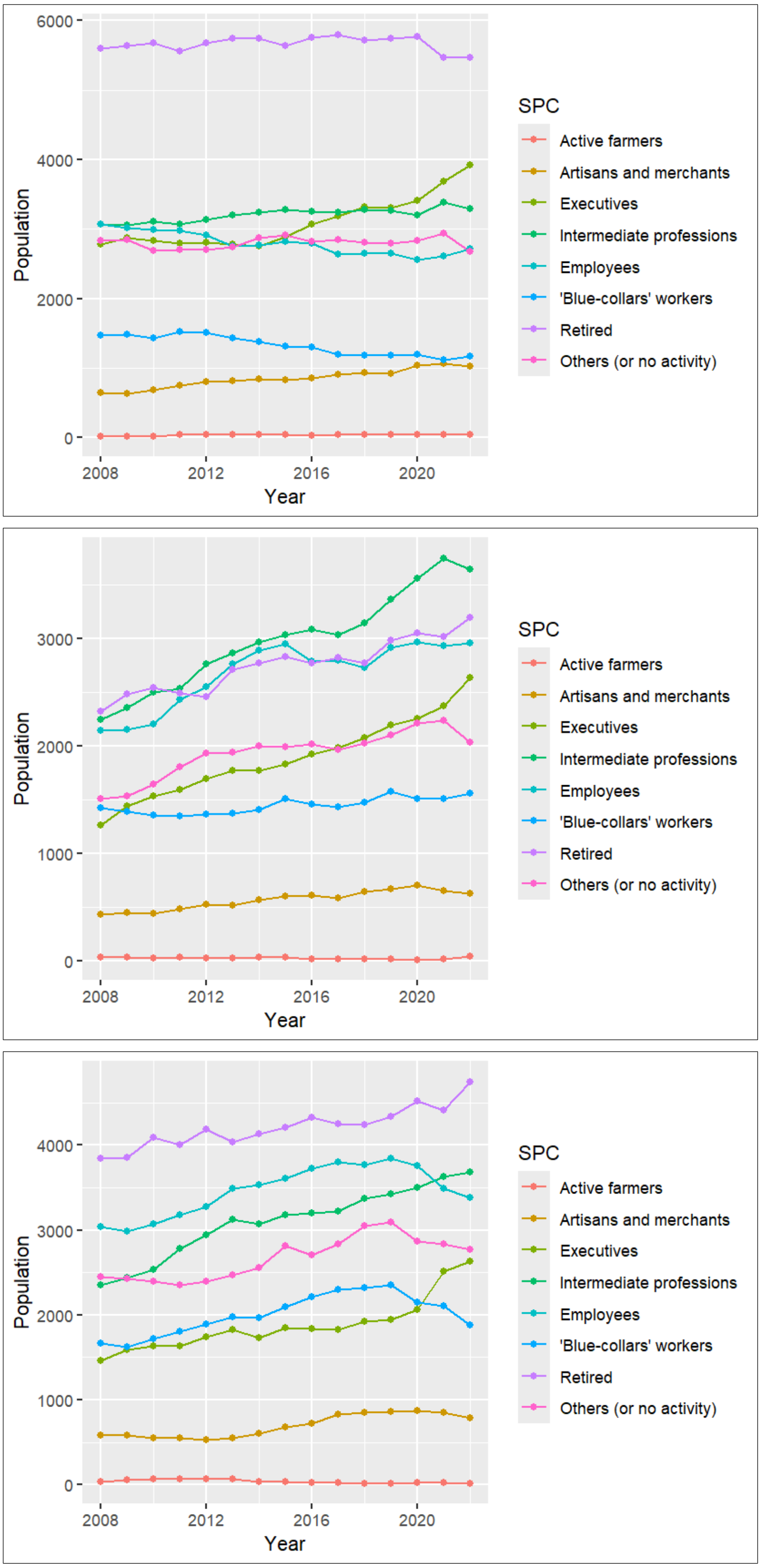

Figure 4. Evolution of socio-professional categories representation in the 3 metropolitan cities affected by the project (Bordeaux) – from left to right: closest to furthest from the city centre

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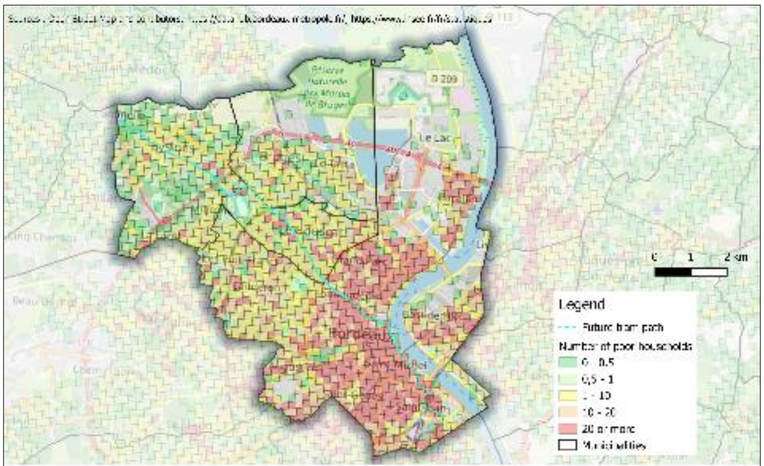
These changes in socio-professional composition can also be interpreted as a selective response to enhanced cognitive accessibility. Higher-income and more mobile groups may be better positioned to recognise and exploit new accessibility advantages, leading to differentiated spatial sorting processes. This suggests that cognitive factors, such as access to information and decision-making capacity, may interact with economic variables to shape the socio-spatial effects of transport investments.

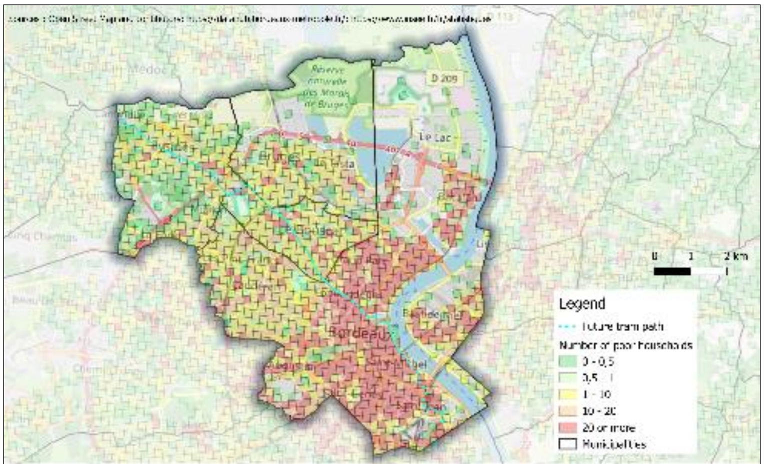
3.3. Standard of living

3.3.1. Number of poor households

As Fig. 5 shows, the number of low-income households in the area studied was already lower than in the city centre, allowing us to observe its evolution during the construction of the tramline and after its launch. However, the prediction that this number would decrease over the course of the project and along the tramline is not verified. The indicator's evolution does not follow a specific trend, and some cells with more low-income households appear along the tramline in 2021, where they were absent in previous years. This leads to the conclusion that this indicator is not really relevant for this study:



Number of poor households in the cities crossing the path of the tramway project - 2015 (before construction)



Number of poor households in the cities crossing the path of the tramway project - 2017 (construction)

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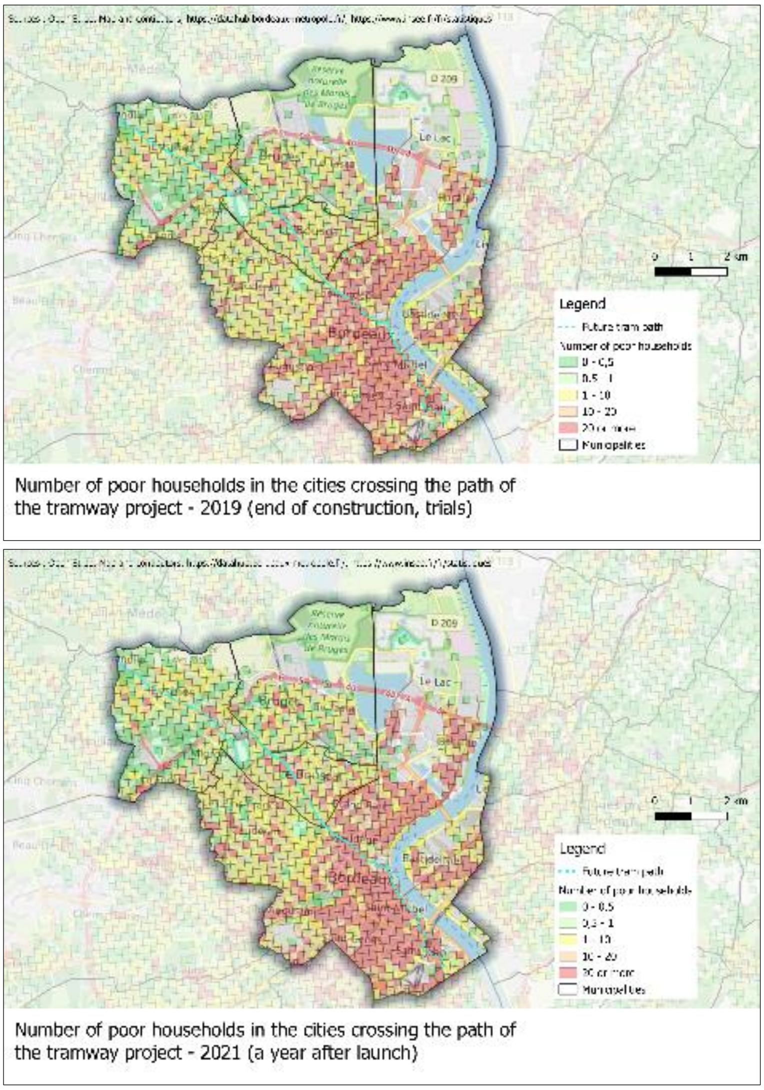

Figure 5. Evolution of the number of poor households over the course of the project: 2015–2021

3.3.2. Average household income (AHI)

The impact of the tram project on the population's standard of living is also evident in the average annual income of households along the tramline. Figure 6 shows the evolution of this indicator over time, in parallel with the project's implementation stages. We observe that along this path, even when the project is not completed, the average income increases. This change is more drastic in the farthest city, but is also observed in Bruges, where the tramline only crosses the municipal boundary. Yet, this area has a more significant evolution than the rest of the territory. Finally, we can see that in Bordeaux's central city, average income increases along the tramline, particularly after its launch, right next to Le Bouscat (the southernmost suburban municipality). However, the effect is minimal at the river's edge and beyond, which is related to the transit supply already being substantial in the city centre.

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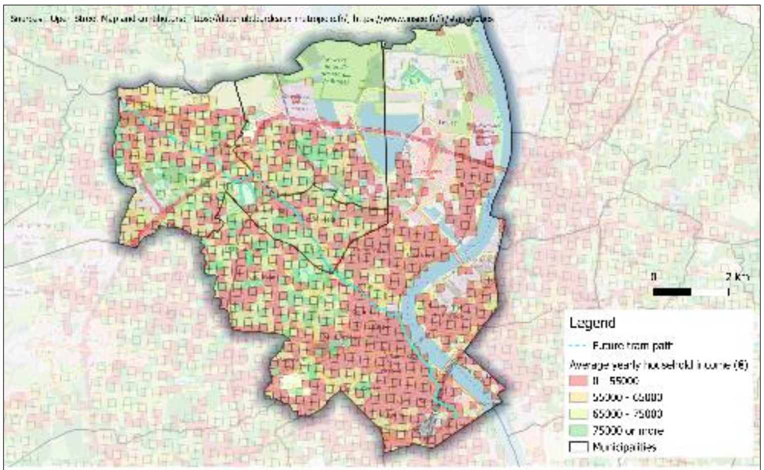
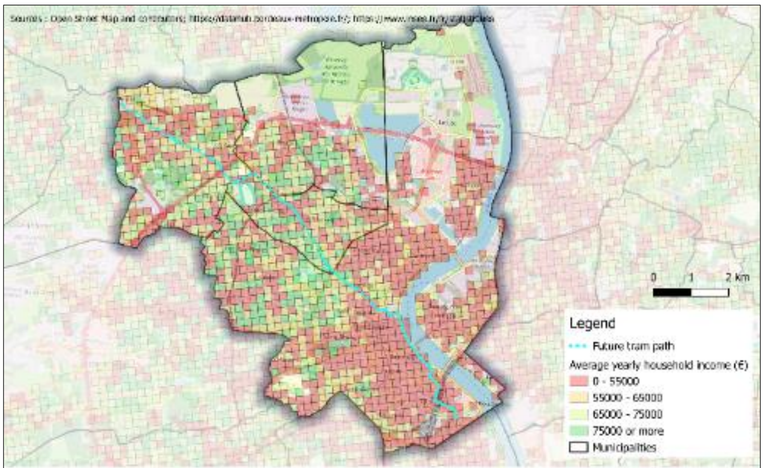


Average household income in the cities crossing the path of the tramway project - 2015 (before construction)



Average household income in the cities crossing the path of the tramway project - 2017 (beginning of construction phase)

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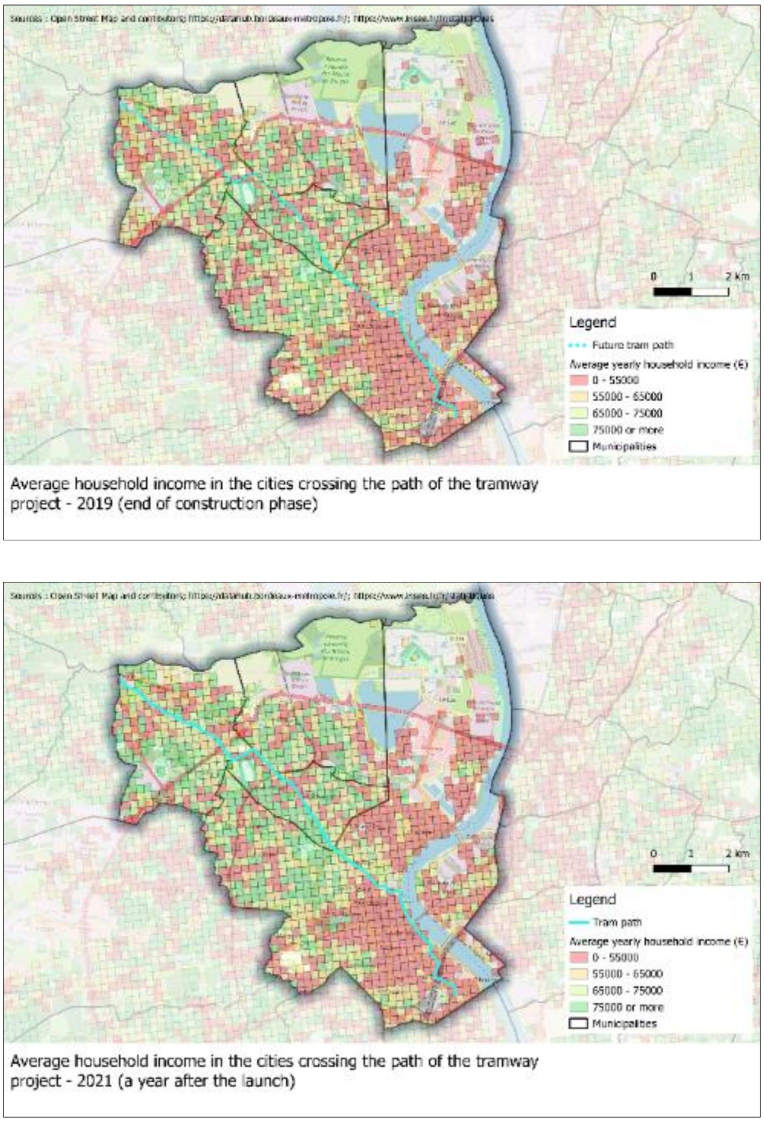

Figure 6: Evolution of AHI over the course of the project: 2015-2021

However, the dataset's temporal scope remains relatively short compared to the typical duration of gentrification processes. Socio-spatial transformations associated with transport investments often unfold over one or two decades, particularly when mediated by housing market adjustments and regulatory frameworks. As such, the absence of clear displacement patterns in the present analysis should not be interpreted as evidence that such processes will not occur, but rather as an indication that they may not yet be observable within the available time horizon.

The increase in average household income observed along the tramline corridor may therefore be understood in part as a manifestation of cognitively driven spatial selection processes. As accessibility improves, households with greater capacity to process and act upon new information about locational advantages may relocate to these areas, reinforcing income gradients without necessarily implying immediate displacement.

4. Analysis and discussion

The empirical findings can be interpreted through the lens of cognitive sustainability, reflecting a broader transformation in how urban space is perceived, evaluated, and utilised. The introduction of the tram not only alters physical accessibility but also modifies the cognitive structure of the metropolitan system by reducing uncertainty, travel complexity, and perceived distance. These changes influence household-level decision-making and contribute to the observed patterns of socio-spatial reorganisation.

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The results suggest a partial and heterogeneous relationship between the introduction of tramline D in the Bordeaux agglomeration and socio-spatial restructuring in the surrounding municipalities, rather than a uniform process of gentrification. The observed increase in density in peripheral municipalities, particularly after the launch phase, is consistent with the idea that fixed rail investments can reshape urban residential attractiveness by improving accessibility and reinforcing metropolitan decentralisation dynamics (Mohammad et al., 2013). However, the absence of a comparable acceleration in the more central municipality suggests that the effects are spatially selective and are possibly due to pre-existing saturation (Higgins et al., 2014).

The evolution of socio-professional categories provides more direct, yet nuanced, evidence of socio-economic metamorphosis. The increasing share of higher-income groups and the decline of the number of "blue-collar" workers in municipalities crossed by the tramline are consistent with transit-induced socio-economic restructuring in TOD contexts (Bardaka et al., 2018). Nevertheless, attributing these changes solely to the tramline remains methodologically limited.

Regarding the indicators of the standard of living, the results are more ambiguous. While average household income increases along the tram corridor, particularly in peripheral municipalities, the number of low-income households does not exhibit a clear or consistent decline. This divergence suggests that income growth may be the consequence of wealthier households settling more than of direct displacement effects. The absence of a clear reduction in low-income households may also reflect the relatively short post-implementation observation window, as transport-induced neighbourhood change is often slow and may unfold over one or two decades rather than a few years (Rietveld et al., 2007).

In addition, the quantitative indicators used in this study do not capture residents' lived experiences or the micro-level mechanisms driving neighbourhood change. Qualitative approaches, such as interviews with residents, analysis of housing market actors, or ethnographic observations, could provide valuable insights into perceptions of accessibility, neighbourhood desirability, and potential displacement pressures. Integrating such methods would enable a more comprehensive understanding of the social dynamics associated with transit infrastructure development.

Taken together, the results suggest that transport infrastructure investments may function as catalysts of cognitive reconfiguration within urban systems. By expanding the range of feasible choices and lowering the cognitive cost of mobility, such investments can indirectly shape socio-economic dynamics and spatial distribution patterns. This perspective complements traditional economic and spatial explanations and highlights the importance of integrating cognitive dimensions into the analysis of urban transformation processes.

5. Conclusion

This study demonstrates that the introduction of a tram service contributes to a reconfiguration of socio-spatial dynamics that can be interpreted not only through improvements in physical accessibility but also through the lens of cognitive sustainability. The findings indicate that transport infrastructure modifies the cognitive environment in which households make residential and mobility decisions, thereby influencing patterns of density, socio-professional composition, and income distribution.

Overall, the findings support a cautious interpretation: the tramline serving the French city of Bordeaux and its suburb appears to contribute to a certain reconfiguration of spatial attractiveness and the socio-economic profile of the area, but the evidence for full gentrification, being the displacement and socio-spatial replacement of the original population, is not fully established.

A key limitation of this study lies in both its temporal scope and its methodological approach. The relatively short observation period following the tramline's implementation limits the ability to identify long-term displacement dynamics, while the descriptive-analytical framework limits causal attribution. Consequently, the findings should be interpreted as evidence of emerging socio-spatial restructuring patterns rather than definitive proof of transit-induced gentrification. This is consistent with recent empirical studies on rail investments in European contexts, which emphasise that accessibility improvements are a necessary but not sufficient condition for gentrification, as outcomes depend strongly on land-use regulation, housing supply elasticity, and broader metropolitan economic trends (Delmelle, 2021; Padeiro et al., 2019). A key limitation of this study lies in its

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temporal scope and in the inability to isolate the effect of this investment from other urban dynamics (independent evolution of housing prices in the area and neighbourhood remodelling).

Future research could benefit from other modelling tools, such as difference-in-differences analysis comparing municipalities that received new infrastructure with socially similar municipalities that did not, combined with longer-term data to analyse reliable dynamics.

Future research should aim to combine longitudinal quantitative analysis with causal inference techniques and qualitative investigations to better capture the complexity of transit-induced urban transformations. Extending the temporal horizon and incorporating comparative case studies across different metropolitan contexts would also contribute to a more generalisable understanding of how transport infrastructure interacts with socio-economic and spatial dynamics.

The integration of cognitive sustainability into the analysis of transport infrastructure provides a novel perspective that bridges transport engineering, urban studies, and sustainability science. By emphasising the role of information, perception, and decision-making processes, this approach offers new avenues for understanding how mobility systems contribute to long-term urban development and socio-economic transformation.

Ackonwledgement

The author has used generative AI for grammatical polishing.

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