

Gentrification Degree Index (GDI) for Paris (2013–2021)

Conceptual Background of Gentrification

Gentrification refers to the socio-spatial transformation of a historically working-class urban area by an influx of more affluent residents (the “gentry”), resulting in displacement of lower-income populations and an upgrading of the neighborhood’s physical and social environment ¹. The term was coined by Ruth Glass (1964) to describe how middle-class homebuyers were “invading” modest districts in London and rapidly changing their social character ² ³. This process is driven by both **demand-side** factors – the preferences and actions of the middle class returning to the city – and **supply-side** factors – investment flows and real-estate dynamics. Neil Smith’s theory, for example, emphasizes uneven development and the “rent gap,” viewing gentrification as a reinvestment frontier whereby capital (and the middle class) “colonizes” disinvested neighborhoods ⁴. In this frontier metaphor, gentrification is a deliberate “*social conquest*” of working-class space by upper classes ⁵ ⁶. Chris Hamnett and others, in contrast, stress structural shifts like the rise of professional and service-sector jobs (post-industrial economy) that expanded the urban middle class, which then seeks housing in the city’s inner neighborhoods ⁷ ⁸. This expansion of a highly educated middle class with greater earning power is seen as the driver of neighborhood “filtering up” through new demand for urban residences ⁷ ⁹.

Crucially, gentrification is **measurable** through changes in socio-economic indicators. It is commonly defined by a rapid increase in a neighborhood’s relative socio-economic status (income levels, education, etc.) from a previously low base ¹⁰. Quantitative studies operationalize this by tracking metrics such as rising median incomes, an influx of college-educated or high-income residents, escalating property values, and declines in poverty rates ¹¹. For example, one approach is to label a tract “gentrified” if its median income was initially low but then rose dramatically (e.g. by two deciles in rank within the city) over a decade ¹². These metrics capture the **upgrading** aspect of gentrification. At the same time, scholars note that gentrification can involve “**transitional polarization**”: during the process, an area may temporarily exhibit higher internal inequality as both new affluent and remaining poor residents share the space ¹³. Hwang and Sampson (2014), for instance, observed that in Chicago, gentrification often unfolded along racial lines—predominantly white middle-class in-movers avoiding areas with high minority populations—resulting in uneven outcomes and leaving some segregated low-income districts “bypassed” by reinvestment ¹⁴. Similarly in Paris, certain immigrant-heavy quarters have been comparatively “skipped” or slower to gentrify, despite adjacent areas upgrading; these districts tend to have deteriorated housing and a large share of non-European immigrant residents, factors which initially deter middle-class buyers ¹⁵. Gentrification must therefore be understood as a **gradual process** affecting different neighborhoods unevenly, rather than an overnight change. In sum, theories converge that gentrification entails a *rise in local affluence* and *social recomposition* (more highly educated/professional residents) at the expense of the prior working-class population ¹⁶ ¹⁷. We can draw from this consensus the key measurable dimensions of neighborhood change – income, social class mix, and demographic profile – that signal a gentrifying neighborhood.

Interpreting Available Variables for Gentrification Measures

To construct a Gentrification Degree Index (GDI) for Paris at the IRIS level (the French infra-urban statistical unit of roughly 2,000 inhabitants ¹⁸), we rely on variables that capture the mechanisms above. The **available data (2013, 2017, 2021)** include census socio-demographics and FiLoSoFi income indicators. Each variable is examined through the lens of gentrification theory to determine its relevance:

- **Median Disposable Income (DISP_MEDYY)** – *Socio-economic status*: A higher median income indicates greater affluence in the neighborhood. Rising median income is a hallmark of gentrification as wealthier residents move in ¹⁰. Many studies use growth in median income as a primary indicator of neighborhood upgrading ¹². We interpret a high or rising DISP_MED as evidence of socio-economic uplift. Conversely, stagnant low median income would suggest the area remains low-status or is undergoing little change. This variable directly proxies the improved economic well-being of residents in a gentrifying area ¹⁰. We will use median income as a core component of GDI to represent general *upward economic change*. (We exclude the related income quartile metrics DISP_Q1 and DISP_Q3, as well as poverty rates, because the median effectively captures the central tendency, and extreme poverty is indirectly captured by other variables like social assistance share. The interquartile range or poverty rate could be pertinent for inequality analysis, but gentrification is better signaled by a shift in the median and overall class structure ¹¹.)
- **Socio-professional Category Shares**: The census provides counts of residents by socio-professional class (PCS) – notably **executives and higher intellectual professions (CS3)**, and **manual workers (CS6)**, among others. These map to the class transformation inherent in gentrification. An increasing share of **CS3 (cadres, professionals)** reflects an influx of the educated middle-class “gentrifiers,” while a declining share of **CS6 (ouvriers, manual laborers)** reflects the out-migration or displacement of the working class ¹⁶ ¹⁷. Indeed, gentrification has been described as the replacement of blue-collar workers by white-collar professionals in inner-city neighborhoods ¹⁷. We therefore include the **percentage of population aged 15+ in CS3** (as a positive indicator) and **percentage in CS6** (as a negative indicator) in the GDI. A higher CS3 share means the neighborhood has a concentration of managers, professionals, and intellectual occupations – a group characterized by high cultural and economic capital who are typical gentrifiers ¹⁹ ²⁰. A lower CS6 share (fewer manual workers) indicates the erosion of the traditional working-class presence ¹⁷. For Paris, Clerval (2011) showed clearly that between 1982 and 1999 the map of increasing “cadres” and the map of declining “ouvriers” were spatial mirror images, tracking the advance of gentrification from the affluent West into the formerly blue-collar East ²¹ ¹⁷. We exclude intermediate categories (CS4 “intermediate professions” and CS5 “employees”) because these middle groups are not as unambiguous in meaning – they often form a transitional class that can be present in both modest and upscale areas. In fact, French studies often group **employés** (white-collar clerical and service workers) with **ouvriers** as “working classes” due to their relatively similar income levels and their co-residence patterns ¹⁷. Including every class would make the index redundant (since the class shares sum to 100%). Focusing on the two poles – *upper professionals vs. manual workers* – gives a clear measure of class turnover associated with gentrification ¹⁷. This approach is supported by sociological research showing gentrification’s essence is the rise of the professional middle class and the decline of the blue-collar class in a neighborhood ¹⁶ ¹⁷.
- **Age Structure (Young Adult and Senior Populations)**: We use the **share of 25–39 year-olds (POP2539)** and **share of 65+ year-olds (POP65P)** in the IRIS population as demographic markers of gentrification. Gentrifying neighborhoods characteristically attract young adults (often with

higher education and stable employment) and see a relative decrease in the elderly population ²². The influx of “*young, affluent professionals*” is well documented in urban change research ²² – indeed, analysts sometimes speak of “*youthification*” as a subset of gentrification, wherein 25–34 year-olds concentrate in revitalized urban districts (often preceding family formation) ²³. A high or rising POP2539 signals this trend of young professional in-migration. On the other hand, gentrification often coincides with fewer longtime elderly residents: either because original older residents are displaced (or pass away), or because the area’s amenities and housing market become oriented toward younger demographics. Thus, a low or falling POP65P (proportion of seniors) is expected in gentrifying areas, relative to more stable or declining areas that retain an aging population. We include **% age 25–39 (positive)** and **% age 65+ (negative)** in the index to reflect these shifts. (We exclude the 18–24 age group: although student populations (18–24) can cluster in certain neighborhoods, “studentification” is a different phenomenon. A high 18–24 count might indicate proximity to universities or inexpensive student housing, which doesn’t necessarily imply gentrification-driven affluence or long-term displacement of working-class families. In fact, students often have low incomes and temporary residence. Given our focus on sustained socio-economic upgrading, POP2539 is more telling of young professionals settling with purchasing power, whereas POP1824 is not used to avoid conflating student presence with gentrification ²³.)

- **Immigrant or Foreign Population (POP_IMM, POP_ETR):** The dataset includes counts of immigrants (foreign-born) and foreign nationals. We **do not include immigrant share directly in the GDI formula**. While there is often an inverse correlation between immigrant concentration and gentrification (many traditionally working-class, immigrant neighborhoods have been slower to gentrify, as noted in Paris and Chicago) ²⁴ ²⁵, immigrant percentage is not a direct mechanism of gentrification but rather a contextual factor. A high immigrant share has at times *delayed* gentrification (due to discrimination or tightly-knit ethnic community retention) ²⁴, and conversely a falling immigrant share may *result* from gentrification-driven displacement. However, using ethnicity/nativity as an input risks mislabeling neighborhoods – for instance, a multicultural but stable low-income area might score “high gentrification” if we simply penalize immigrant presence, which would be conceptually wrong. To keep the index focused on economic and class criteria (and to avoid conflating ethnicity with gentrification level), we exclude POP_IMM and POP_ETR. Their effects are indirectly captured by the socio-economic variables (since many immigrant communities in Paris correlate with lower incomes and higher social assistance rates, which our index does include). We note, though, that a dramatic decline in immigrant share can be an *outcome* of gentrification (as seen in parts of Paris’s 18th or 19th arrondissements), but this outcome will be reflected through rising income and changing occupations anyway.

- **Income Source Structure:** Gentrification changes not just how much income residents have, but *where their income comes from*. Three FiLoSoFi variables describe the composition of household disposable income in each IRIS: **share of labor and activity income (including salaries, self-employment, and unemployment benefits)**, **share of pensions/retirement income**, and **share of social transfer benefits** in total disposable income (often labeled in data as TP60, TP61, TP62 respectively). These indicate the prevalent economic profile of residents ²⁶ ²⁷. In a gentrified or upwardly mobile neighborhood, we expect a higher proportion of income to come from active work (salaries) and a lower proportion from pensions or social welfare. A rising **labor income share** means more working-age, employed (and likely higher-earning) residents are present, boosting earned incomes as the main resource. A high **pension income share** typically points to an older population of retirees; such neighborhoods may be stable middle-class enclaves or declining aging areas, but not *dynamic gentrifiers*. Similarly, a high **social benefits share** (income from social aid like minimum income support, unemployment assistance beyond

insurance, housing benefits, etc.) indicates a concentration of low-income households reliant on welfare – a sign of poverty or “pauperization,” essentially the opposite of gentrification ²⁸ . Therefore, we incorporate these as follows: **% labor income (positive), % pension income (negative), % social benefits (negative)**. In practical terms, a gentrifying IRIS should show increasing labor income share (because new residents are working professionals) while the shares of pensions and social assistance drop (fewer retirees and fewer very poor households). For example, in 2021 data across France, on average about 74% of disposable income comes from work, ~28% from pensions, and ~5% from social benefits ²⁷ . A gentrified Paris neighborhood would likely exceed 74% in labor income and have well below 28% from pensions, whereas a retiree-dominated area might have the opposite balance. By including these, we capture the **economic life-cycle profile** of the neighborhood. (We acknowledge these three shares are interrelated – if one rises, others fall, since total = 100%. To avoid overweighting this aspect, we will combine them in a balanced way in the index formula. We exclude *capital income share* – not explicitly given here – but note that very affluent areas might also have higher capital or property income. However, this is a minor component in most IRIS; the provided variables focus on main income sources, which suffice to distinguish “yuppie” workforce-heavy areas from pensioner or welfare-dependent areas. If needed, one could approximate capital income share as residual, but we do not use it directly.)

- **Inequality Measures (Gini, D9/D1):** The FiLoSoFi data include **the Gini index of inequality** and **D9/D1 ratio** (the ratio of the upper decile to lower decile income) within each IRIS. These measure the **internal income disparity** in the neighborhood ¹³ . A rising Gini or D9/D1 in a neighborhood could indicate a “transitional” phase of gentrification where affluent newcomers increase top incomes while some low-income residents remain, stretching the local income gap. However, in a fully gentrified area, inequality might actually *decline* if the neighborhood becomes homogenously affluent (the poorest residents having been displaced). Conversely, some long-stable poor areas also have low internal inequality (everyone is similarly low-income). Thus, high inequality is *not a straightforward indicator* of gentrification level; it is context-dependent. We treat these **dispersion metrics as supplementary** rather than core components of GDI. Following the literature, they can be used as a **modifier or diagnostic**: for example, identifying neighborhoods that are undergoing partial gentrification with mixed populations (high Gini) versus those uniformly transformed. We opt *not to include Gini or D9/D1 in the core formula* for simplicity and to keep the index focused on the level of “gentrified” status (which is more about the center of the distribution shifting upward than about the spread). Instead, we note that **a very high D9/D1 or Gini** alongside a moderate GDI score might flag a neighborhood in early transition (some upscale influx but many low-income remain), whereas a high GDI score with low inequality might denote a fully stabilized middle-class area. The GDI formula itself will capture the primary drivers (income, class composition, etc.), and Gini can be checked separately for nuanced analysis ¹³ .

In summary, the subset of variables we'll use and their expected relationship to gentrification are:

- **Median income per UC** – higher = more gentrified ¹⁰ .
- **Share of executives (CS3)** – higher = more gentrified ¹⁹ .
- **Share of manual workers (CS6)** – higher = *less* gentrified (we will use its inverse) ¹⁷ .
- **Share of 25–39 years** – higher = more gentrified (young professionals) ²² .
- **Share of 65+ years** – higher = *less* gentrified (aging, little influx) ²² .
- **Labor income share** – higher = more gentrified (more working professionals) ²⁶ .
- **Pension income share** – higher = *less* gentrified (many retirees) ²⁶ .
- **Social benefits share** – higher = *less* gentrified (concentration of poverty) ²⁶ .

(Each “less gentrified” indicator will be used negatively in the index.) Other provided variables have been excluded due to either redundancy or weak theoretical linkage (e.g., employees/intermediate classes, 18–24 age, immigrant share, etc., as justified above). We now turn to how these selected measures combine into a single index.

Derivation of the Gentrification Degree Index (GDI) Formula

Objective: Derive a transparent formula that aggregates the key dimensions of gentrification into one score per IRIS, for each year (2013, 2017, 2021). The formula should reflect the **degree of gentrification** (from low to high) in a way that is interpretable, literature-grounded, and comparable across time. To ensure comparability over time, we will use *year-specific standardization* for each component.

Standardization: Because absolute values (e.g., euros of income) change over time (due to inflation, overall growth, etc.), GDI is based on **relative standings within Paris for each year**. In practice, for each variable we compute a z-score or percentile within the distribution of all residential IRIS in Paris for that year. This yields a normalized value indicating how extreme that IRIS is compared to the city average that year. For example, an IRIS with median income in the top 10% of Paris in 2017 would get a high positive standardized score on that component. Using year-specific normalization removes temporal trends and focuses on *relative change*: an IRIS that maintains the same city rank in income from 2013 to 2021 will have a roughly stable contribution, whereas one that jumps from well below average to above average will show a large index increase. This approach follows the practice of benchmarking neighborhood indicators to citywide averages or distributions ²⁹, enabling meaningful comparison of a neighborhood’s status over time despite external changes. Essentially, we treat each component as a *position indicator* (e.g., percentile) rather than raw value. This ensures, for instance, that “rising median income” means rising relative to the city’s median each year, which is a true sign of gentrification (as opposed to a general rise in all incomes).

Linear Additive Form: We construct GDI as an *additive index* of the selected variables, each reflecting a mechanism from theory. Additive (or linear weighted) indices are common in socio-economic indices for their transparency and ease of calculation. Each component will be entered either positively or negatively, according to whether a higher value indicates more or less gentrification:

Let for a given year t (2013, 2017, 2021):

- $Z_{\text{medinc}}^{(t)}$ = standardized (e.g., z-score) of median income (DISP_MED) in IRIS i for year t .
- $Z_{\text{CS3}}^{(t)}$ = standardized share of executives (CS3).
- $Z_{\text{CS6}}^{(t)}$ = standardized share of manual workers (CS6).
- $Z_{25-39}^{(t)}$ = standardized share of age 25–39 population.
- $Z_{65+}^{(t)}$ = standardized share of age 65+ population.
- $Z_{\text{labor}}^{(t)}$ = standardized share of labor (work) income in disposable income.
- $Z_{\text{pens}}^{(t)}$ = standardized share of pension income.
- $Z_{\text{social}}^{(t)}$ = standardized share of social benefits income.

Now we define **GDI** as a weighted sum of these components:

$$\text{GDI}_{i,t} = +w_1 Z_{\text{medinc}}^{(t)} + w_2 Z_{\text{CS3}}^{(t)} - w_3 Z_{\text{CS6}}^{(t)} + w_4 Z_{25-39}^{(t)} - w_5 Z_{65+}^{(t)} + w_6 Z_{\text{labor}}^{(t)} - w_7 Z_{\text{pens}}^{(t)} - w_8 Z_{\text{social}}^{(t)}.$$

Here each w_j is a weight (a positive number). To keep the index **simple and transparent**, our **primary recommended formulation** uses **equal weights** for all components (after standardization). Essentially,

we assume each selected dimension contributes equally to the overall gentrification status, an approach that treats the various symptoms (income, class, age, etc.) as comparably important. Equal weighting is often favored in index design when there is no strong evidence that one factor should dominate and to avoid arbitrary bias ¹¹. With equal weights, and for convenience, we can set each $w_j = 1$. The formula then simplifies to the **mean** of the standardized indicators (with appropriate sign reversals):

$$\mathbf{GDI}_{i,t} = \frac{1}{N} \left(Z_{\text{medinc}}^{(t)} + Z_{\text{CS3}}^{(t)} - Z_{\text{CS6}}^{(t)} + Z_{25-39}^{(t)} - Z_{65+}^{(t)} + Z_{\text{labor}}^{(t)} - Z_{\text{pens}}^{(t)} - Z_{\text{social}}^{(t)} \right),$$

where N is the number of terms included (in this case, $N = 8$ terms). Each term corresponds to one mechanism: income level, professional class mix, working-class presence, young adult concentration, senior concentration, workforce activity, retiree presence, and welfare dependence.

Plain-English interpretation: The GDI thus constructed can be seen as an average of *several z-scores*: how affluent the IRIS is (median income z-score), how professional vs. working-class it is (cadres z-score minus ouvriers z-score), how youthful vs. aged (young-adult z minus senior z), and how employment-driven vs. pension/welfare-driven its income is (labor income z-score minus pension and social income z-scores). A higher GDI means an area scores high on affluence, high on professional occupations, low on working-class population, high on young adults, low on retirees, high on labor incomes, and low on pensions/welfare – in short, it exhibits the profile of an upscale, gentrified neighborhood. A low (negative) GDI means the area is relatively poor, with more working-class (fewer professionals), an older or economically inactive population, and reliance on social support – the profile of an ungentrified or even disadvantaged neighborhood. By construction, GDI will be near zero for an IRIS that is “average” on all these dimensions in that year (z-scores ~ 0). An IRIS scoring, say, +1.5 on GDI in 2021 is significantly above the Paris average in gentrification markers (likely among the more gentrified quartile of neighborhoods), whereas one scoring -1.0 is significantly below average (a low-income or socially stagnant area).

Justification of linear combination: Each included term has a clear literature basis, and we avoid complex interactions or non-linear weights to keep the index transparent. This aligns with best practices that indices of neighborhood status should be explainable and reproducible by policy analysts or researchers without requiring obscure computations. The additive method also implicitly assumes that different aspects of gentrification can compensate each other to some extent. For example, an IRIS might have an extraordinarily high share of young professionals but only average median income (perhaps because some public housing remains); the index would balance these, potentially still ranking the area as moderately gentrified. This is sensible because gentrification often is multifaceted – one symptom can signal it even if another lags. Nonetheless, because the components are correlated (affluent areas tend to also have more professionals, etc.), we are not simply averaging noise: they generally reinforce one another for true cases of gentrification. If an area scored high on median income but still had many manual workers and elderly poor on social benefits, those conflicting signals would produce a middling GDI – which correctly flags that the area is not uniformly gentrified (perhaps a partially transformed neighborhood). This additive structure thereby encodes the **“concordance across components”** idea: a high GDI emerges only when *most* of the indicators point towards gentrification, whereas if some indicators suggest gentrification and others do not, the score will be moderate. This approach echoes multivariate analyses (like principal components) where typically one dominant factor distinguishes affluent vs. working-class areas ³⁰. Indeed, Clerval’s multivariate analysis of Paris found a primary axis contrasting high-income, professional, young areas against low-income, working-class, older areas ³⁰ – our GDI effectively reconstructs that axis in an easily interpretable formula.

Optional weighted variant: While equal weights are straightforward, one could argue for slight adjustments based on theory or empirical variance. For instance, **median income** might deserve a higher weight since income integrates various advantages (education, job type) and is a direct measure of material uplift. Some studies define gentrification using income alone (with thresholds) ¹², highlighting its importance. Alternatively, one might weight **social composition** (CS3/CS6) more, as the classical definition is fundamentally about class replacement ³¹ ¹⁷. A literature-justified tweak could be: give *median income and occupational mix* double weight relative to the other factors, on the premise that economic and class change are the core of gentrification, while age and income-source structure are secondary manifestations. For example, we could set $w_1 = w_2 = w_3 = 2$ and $w_4, \dots, w_8 = 1$, then divide by the sum of weights. This would slightly boost the influence of median income and class composition on the final GDI. The effect is that a neighborhood with an influx of wealth and professionals would rank a bit higher than one where, say, many young adults are present but incomes haven't risen as much. We recommend, however, to **keep the index in its equal-weight form** unless a specific reason or validation suggests re-weighting. The equal-weight GDI is easier to defend to stakeholders (each component is deemed equally essential) and, given the correlations between components, the index will be robust to modest weight differences (sensitivity tests can be done to confirm this). In any case, whether equal-weighted or lightly weighted, both formulations will be **monotonic transformations** of each other, so they will agree on the ranking of neighborhoods almost all the time. For transparency, our final reported GDI uses equal weighting (essentially the simple average of standardized indicators). This formula is parsimonious, includes no superfluous variables, and every term can be traced to a gentrification mechanism identified in academic studies.

Before proceeding, we ensure the **year-specific standardization** is understood: for each year, Paris-wide mean and standard deviation (or percentile scale) of each variable are used to compute Z . This means a GDI of, say, +1 in 2013 is not directly an absolute level comparable to +1 in 2021 (since each is relative to that year's context). However, to analyze change over time, we compare *the GDI of the same area across years*, which reflects whether its relative position improved or declined. (In effect, we are using a *norm-referenced* index each year and then looking at the trajectory of each area in that normed space.)

GDI Categorization into Four Classes

With a continuous GDI score computed for each IRIS and each year, it is often useful to categorize neighborhoods into ordinal classes of gentrification degree for interpretation and mapping. We propose a **four-class scheme**: for example, *Low*, *Lower-Intermediate*, *Upper-Intermediate*, and *High gentrification*. These categories correspond to increasing levels of the GDI. A simple and defensible way to define these classes is by using citywide **quantiles (quartiles)** of the GDI distribution in each year ²⁹. This approach assigns roughly 25% of IRIS to each category (assuming a reasonably symmetric distribution), which is intuitive and ensures each class represents a distinct segment of the city's neighborhoods. Specifically:

- **Low Gentrification** – IRIS with GDI in the bottom ~25% citywide for that year. These are strongly characterized by low incomes, working-class or welfare-dependent profiles, and little sign of influx of affluent groups. They might be stable low-income or even experiencing ongoing *paupérisation*. In Paris, such IRIS may include outer banlieue-type pockets within the city or still-disadvantaged quarters in the northeastern arrondissements.
- **Lower-Intermediate** – IRIS in the 25th–50th percentile of GDI. These are below median but not the very lowest. They might be modest neighborhoods with some slight uptick or incipient change but still predominantly lower-middle or working class. They could represent either slowly

improving former blue-collar areas that have not (yet) heavily gentrified, or formerly average areas possibly in slight decline relative to the rest.

- **Upper-Intermediate** – IRIS in the 50th–75th percentile. These are above the city median GDI but not at the top. Such neighborhoods show clear signs of socio-economic ascent: they likely have higher incomes and more “bobo” populations than the city median. Many **actively gentrifying** areas in mid-process would fall here – places that are significantly changed from a decade prior, but not (or not yet) as elite as the traditional wealthy neighborhoods.
- **High Gentrification** – IRIS in the top ~25% of GDI. These are the most gentrified or affluent urban neighborhoods. They score very high on all gentrification metrics (wealthy, dominated by professionals, few original low-income residents remaining). In Paris, this category would include not only historically bourgeois areas (western districts), but also fully transformed neighborhoods in the east or center that have completed the gentrification cycle and now resemble bourgeois areas in socio-economic profile. A “High GDI” label means an IRIS is among the urban elite in terms of social composition ³².

We will set the precise cut-offs based on the distribution (they could be the quartile break values of GDI each year). This quartile method is analogous to practices in other research: for instance, measuring neighborhood socioeconomic status often uses quartiles or quintiles to label areas as disadvantaged or affluent ²⁹. It also resonates with definitions of gentrification that require a neighborhood to move from a lower bracket to a higher bracket of rank. (One study defined a tract as gentrified if it went from the bottom quartile of income to above the city median or into the upper quartiles over time ³².) Using the **top quartile** as a threshold for “high” aligns with the idea of identifying the neighborhoods that stand out as truly gentrified relative to the rest ³².

We justify this classification on both conceptual and practical grounds: Conceptually, gentrification is not a binary but a gradient; however, creating a few categories helps communicate the concept of “degree” more clearly. Empirically, quartiles are a non-arbitrary choice that ensures each class has a substantial number of cases, aiding statistical comparison. Additionally, Paris urban studies often discuss “popular neighborhoods” versus “bourgeois/gentrified neighborhoods” with an implicit rank ordering – our four classes formalize such groupings. While one might alternatively choose specific GDI score cut-offs or standard-deviation based thresholds (e.g., $>1\sigma$ above mean as “high”), the quartile method is simpler for stakeholders to grasp (e.g., “this IRIS is among the top 25% gentrified in Paris” is an easy message). It also corresponds loosely to commonly understood divisions: roughly, the bottom quartile could be likened to “priority neighborhoods” (though not exactly the Politique de la Ville definition) and the top quartile to “privileged neighborhoods”, with two tiers of middling status in between.

In practice, we would label each IRIS each year with one of the four classes based on its GDI that year. It is important that this annual classification is done **after** standardizing within that year – thus it reflects the neighborhood’s standing in that year’s urban context. For example, an IRIS might be “Low” in 2013 (relative to 2013 city conditions) and move to “Upper-Intermediate” by 2021, illustrating substantial gentrification. The class labels are thus year-specific snapshots, not fixed categories carried over time.

Temporal Change Classification (2013–2017–2021)

Defining GDI for multiple time points allows us to characterize **temporal trends** in each neighborhood’s gentrification level. The task is to label each IRIS’s trajectory from 2013 to 2021 as either “stable,”

“intensifying,” or “declining” gentrification. We base this on changes in the GDI score between 2013→2017 and 2017→2021, and overall 2013→2021. The procedure is as follows:

1. **Calculate GDI for 2013, 2017, 2021** as described. Ensure IRIS comparisons over time are valid (see next section on boundary consistency).
2. **Determine changes:** Let $\Delta_1 = \text{GDI}(2017) - \text{GDI}(2013)$ and $\Delta_2 = \text{GDI}(2021) - \text{GDI}(2017)$. These represent the change in the index in the first and second interval respectively. Also consider the total change $\Delta_t = \text{GDI}(2021) - \text{GDI}(2013)$.
3. **Apply thresholds for significance:** Because even normalized data can have minor fluctuations (due to measurement noise or marginal demographic shifts), we establish a **minimum threshold to consider a change meaningful**. Drawing on literature definitions, a neighborhood might be considered to have “gentrified” only if it jumps a substantial amount in rank or value ¹². We can use a threshold such as **0.5 standard deviation of GDI** (which is a moderate effect size) or an equivalent percentile jump (e.g., 20 percentile points) as the cutoff for a notable change. This choice is informed by prior studies like Freeman’s, where a rise of two deciles (20 percentage points in rank) over a decade signified gentrification ¹². We will use this as a ballpark: roughly, $\Delta_t > 0.5$ (in standardized units) or a rise of at least one quartile in class would count as a significant increase. Similarly, $\Delta_t < -0.5$ would be a significant decrease. Changes smaller than this (within ± 0.5) are considered essentially *stable* (no major change). The exact threshold can be fine-tuned (for example, 0.5σ corresponds to moving from median to ~70th percentile, which is a notable climb).
4. **Classification rules:**
5. **Intensifying Gentrification:** The IRIS shows a consistent and significant upward trend in GDI. Concretely, we require *both* sub-periods to show non-trivial increases ($\Delta_1 > 0$ and $\Delta_2 > 0$), and the overall rise Δ_t to exceed the threshold (e.g., > 0.5). In other words, the neighborhood steadily “climbed” in gentrification level from 2013 to 2021. This would often correspond to moving up at least one class (say from Low to Lower-Intermediate, or Intermediate to High) over the period. If an IRIS jumped two classes (e.g., Low in 2013 to Upper-Intermediate or High by 2021), that clearly is intensification. We label it **“intensifying”** to indicate that gentrification pressures are growing there. These are neighborhoods in the throes of change – for instance, a quartier that was modest in 2013 but attracted considerable middle-class influx by 2021 (perhaps due to new transport links, redevelopment, etc.).
6. **Declining (or Reversing) Gentrification:** The opposite pattern – GDI has consistently and significantly decreased, indicating the area has become relatively less affluent/upscale over time. This could happen if a neighborhood experienced out-migration of the gentrifiers or an influx of lower-income residents (perhaps through new social housing or economic downturn). Requirements: $\Delta_1 < 0$ and $\Delta_2 < 0$, and overall Δ_t below -0.5 (a notable drop). This is less common in inner-city contexts, but not impossible (sometimes termed “degentrification” or a return of lower-income households, or simply stagnation while the rest of the city improves faster). In Paris, widespread decline is rare in recent decades, but a few cases of relative decline could be areas that were moderately affluent but did not keep pace with citywide gains, or experienced aging-in-place of original residents without renewal. We label these **“declining”** to signify a reduction in gentrified characteristics.
7. **Stable:** All other cases. Typically, if an IRIS’s GDI changes only slightly or inconsistently (perhaps up then down, or hovering within ± 0.3 for example), we consider it **“stable”** in terms of gentrification status. This means its relative socio-economic position did not markedly change; it neither significantly gentrified further nor markedly reverted. Many neighborhoods fall in this category – either long-gentrified areas that remained high (with minor fluctuations), or

persistently low-income areas that have not yet gentrified, or solid middle-class areas that stay middle-class. For instance, an IRIS that was high-gentrification in 2013 and remains high in 2021 with minimal change would be “stable” (it was already gentrified and stayed so). Likewise, a low-GDI area that sees little improvement stays stable (still largely ungentrified). We include in “stable” any ambiguous trajectories, such as one sub-period up and one down (unless the net change still breaches a threshold). This rule ensures we don’t overinterpret short-term bumps. Essentially, if the trend isn’t clearly monotonic and large, we default to saying the neighborhood’s gentrification level remained relatively stable.

This scheme aligns with the idea of identifying “gentrifying neighborhoods” vs. others in many policy studies, which often classify tracts as *not gentrified*, *gentrifying*, or *gentrified*. Here, “intensifying” corresponds to actively gentrifying (in the time window), “stable” corresponds either to not gentrifying or already gentrified and not changing, and “declining” is a marginal category for any counter-trend. The requirement of *concordant changes in both sub-periods* for intensifying/declining is to filter out noise: if a neighborhood’s index jumped up by 2017 then fell back by 2021 (or vice versa), it’s likely influenced by transient factors or data artifacts, and we would call that overall stable (unless the net change is still huge, which would be unusual without monotonicity). This echoes the need for a sustained trend to declare a genuine trajectory ¹².

Illustrative example: Suppose an IRIS had GDI = -0.8 in 2013, -0.2 in 2017, and +0.5 in 2021. It went from well below average to slightly above average – a significant rise ($\Delta_t = +1.3$). It likely moved from Low to Upper-Intermediate class. Both sub-periods were upward ($\Delta_1 = +0.6$, $\Delta_2 = +0.7$). We classify it **intensifying**. Conversely, another IRIS started at +1.2 (High) in 2013, then +1.0 in 2017, then +0.9 in 2021 – a gentle decline ($\Delta_t = -0.3$) but not crossing our threshold. That area is still very affluent and only slightly less so; we’d call it **stable** (its gentrification happened earlier, before 2013, and now it’s just plateaued at a high level). Another IRIS might start at -0.5, rise to -0.1, then drop back to -0.4; net change is negligible (and one up, one down), so it’s **stable**. If an IRIS dropped consistently (say from +0.3 to -0.2 to -0.7), $\Delta_t = -1.0$ and both periods down, we’d label it **declining** – perhaps reflecting a socio-economic downturn in that micro-neighborhood.

This temporal classification method is consistent with approaches in the literature where neighborhoods are tracked over decades: for instance, identifying census tracts that “gentrified” vs “did not gentrify” based on threshold criteria of change ¹² ³³. We are essentially doing the same, but also allowing for identifying those that **remained at the top** (stable-high) or **remained at the bottom** (stable-low) as “stable” rather than forcing everything into a binary gentrified/not. The introduction of “declining” adds nuance for any cases of reversal. Using our index over two intervals provides a built-in check: requiring consistency across 2013–2017 and 2017–2021 reduces the chance of false positives due to one-off anomalies. It’s a conservative approach, which is warranted since labeling a neighborhood as “gentrifying” often carries policy implications (e.g., need for anti-displacement measures) ³⁴.

Harmonizing IRIS Units Over Time

One practical consideration is that the **IRIS geographic boundaries** or definitions might change slightly between 2013, 2017, and 2021. The INSEE IRIS system is largely stable – “almost all IRIS have kept the same boundaries as in 1999”, according to INSEE ³⁵ – but occasionally IRIS are split or merged (often as population grows, an IRIS exceeding ~5,000 people may be split into two). For accurate temporal comparisons of GDI, we must ensure we compare like with like spatial units. Two issues arise: (1) if an IRIS was split or merged between these years, and (2) if the underlying population data collection methods changed (INSEE did adjust some methodologies around 2017–2019, e.g., improving geocoding of tax data ³⁶).

Our strategy is to create a **consistent spatial framework**: use the 2017 IRIS boundaries as a base (since 2017 is mid-point) or the latest 2021 boundaries, and *recompute or aggregate* 2013 data to that geography. In practice, if an IRIS from 2013 was later split into IRIS A and B by 2021, we would **aggregate A and B** in 2021 back into the single unit for comparison with 2013. Aggregation of socio-economic variables requires care: counts (like population or number of executives) are summable, but medians and ratios need to be recomputed. We can perform a population-weighted interpolation: for example, to get the 2013 median income for the combined area corresponding to A+B in 2021, we could use the population-weighted average of their medians *if* distribution shapes are similar, or ideally reconstruct the income distribution by combining micro-data (if available). Similarly, percentages like CS3 share could be derived by summing the numerators (CS3 persons) and denominators (population 15+) of A and B. By doing this, we maintain a “**stable unit**” across time. If instead an IRIS merged or boundaries shifted in a minor way, one could allocate data from one to the other proportionally (e.g., by area or address points). The **interpretability is preserved** because we’re tracking the same approximate population cluster over time ³⁵. In essence, we either **harmonize all years to the 2021 IRIS geography** (which INSEE actually does when releasing historical data – the 2021 Filosofi data, for instance, is on the Jan 2022 geography ³⁷, and previous years can often be converted to that) or define custom aggregated units if needed.

For Paris specifically, IRIS changes from 2013–2021 were minimal. Should any occur, they likely involve new housing developments (e.g., a large development on former industrial land might create a new IRIS). In such a case, an IRIS in 2013 might cover a larger area than in 2021. **Our approach**: use the intersection of geographies – if IRIS X in 2013 became X1 and X2 in 2021, we combine X1 and X2 for computing 2021 GDI comparable to 2013’s X. Alternatively, we could split 2013 data into X1 and X2 if we have a basis (like assuming each had half the population and similar profiles, or using 2013 census block data if available). The simplest is aggregation to larger units so that each 2013 unit has a direct counterpart in 2021. This may slightly reduce spatial resolution but ensures that the **change in GDI reflects real neighborhood change, not a redrawing of boundaries**.

An additional minor adjustment is needed because of the **methodological improvements in income data** in Filosofi 2019 and 2021 (INSEE warns that local income changes may partly reflect data improvements ³⁶). Since we are not working with raw data files here, we simply note that caution and perhaps smoothing could be applied if we saw an anomalous jump in GDI due to data artifact. But assuming consistency, our harmonized IRIS approach holds.

By aggregating/splitting where necessary, we ensure that GDI trends are not artifacts. If an IRIS’s boundaries change significantly (which, again, is rare intra-muros Paris post-2010), we might drop it from the trend analysis or treat it qualitatively. Fortunately, according to INSEE’s documentation, “*an indicator identifies IRIS that have undergone modifications... almost all have kept same boundaries*” ³⁵, so for the majority we can treat the IRIS as temporally stable. Where we do need to merge for analysis, interpretability remains: the merged unit still represents a coherent neighborhood, just a slightly larger one, and its GDI is an average appropriate to that neighborhood’s overall gentrification level. This way, spatial boundary issues do not mislead our temporal labeling of intensifying/stable/declining – any real changes reflect actual socio-demographic evolution, not a statistical artifact.

In summary, **we preserve interpretability by using consistent IRIS units**: either through INSEE’s harmonized data or by our own aggregation method, so that each area’s GDI trajectory is measured on the same spatial footprint. This is a standard approach in longitudinal neighborhood studies (analogous to using consistent tract definitions in U.S. census research, sometimes employing crosswalks or weighted area interpolations to handle boundary changes).

Limitations and Robustness Considerations

While the proposed GDI formula and classification scheme are grounded in literature and data, a few limitations and robustness checks are noteworthy:

- **Composite Index Simplification:** By collapsing multiple variables into one index, we lose some nuance. Two neighborhoods could end up with the same GDI for different reasons (one might score moderately on everything, another might have very high incomes but also a mix of ages that bring its score down a bit). For policy and analysis, looking at the individual components alongside GDI is advised. GDI should be seen as a summary, not a replacement for detailed profiles. However, because all included components correlate with the underlying concept of gentrification, the index effectively captures a common signal (akin to the first principal component of these variables) ³⁰. In fact, a **principal component analysis (PCA)** on these variables would likely show one dominant axis explaining a large variance share – differentiating affluent/professional vs. poor/working-class IRIS – which validates using a single index ³⁰. We essentially constructed GDI to represent that axis in a more interpretable weighted sum form. As a robustness check, one could perform PCA on the 2013 data to derive weights and see if any significantly differ from equal weights. If, say, median income and cadre share have the highest loadings in PCA, one might tweak weights to reflect that. But we expect fairly uniform contributions, given prior analyses of social space in Paris ³⁰.
- **Weighting and Omitted Variables:** The equal-weight approach assumes each selected indicator is equally important. If the user or further research finds that certain factors are more strongly associated with known gentrification outcomes (like displacement or property values), weights could be adjusted. Our optional weighted variant already suggests a route for that. The effect of modest re-weighting on classification is generally small – neighborhoods that rank high in one formulation tend to rank high in another, because an area that is truly gentrified scores well on most inputs. To test robustness, we could calculate GDI under different weighting schemes or even try an alternative index like a simple **ratio of “gentrifiers to original residents”** (e.g., $(CS3)/(CS3+CS6)$ or so) and see if it tells a similar story. The proposed GDI is more comprehensive than any single such ratio, but it’s reassuring if simpler metrics agree on which areas are top or bottom.
- **Threshold Sensitivity:** The choice of quartiles for class breaks and ± 0.5 std for trend is somewhat heuristic. If the distribution of GDI is highly skewed, quartiles might cluster many cases in one or two categories. In that event, one could switch to defined **absolute thresholds** – for example, $GDI > +1$ (meaning roughly one std above city mean) could be labeled “high” gentrification, and $GDI < -1$ as “low”, with the rest split as intermediate. This would emphasize extreme cases. However, in Paris, socio-spatial inequalities are pronounced but continuous, so quartiles offer a balanced segmentation. We cite similar approaches where top-quartile changes indicate “intense gentrification” ³⁸ to give precedent. For the trend classification, if we set 0.5σ as the threshold and very few neighborhoods cross that, we might consider lowering it to capture more subtle change. Alternatively, one could define “intensifying” as simply any upward class movement (e.g., from one quartile class to the next). That rule might label slightly more areas as changing. Ultimately, the threshold should be chosen to reflect what magnitude of change is **policy-relevant**. Given that Freeman (2005) considered a two-decile income rank jump significant ¹², our ~two-quartile (or one quartile) criterion is on the safe side. We can fine-tune it by examining the distribution of ΔGDI : e.g., if the standard deviation of GDI change is 0.3, then 0.5 is quite high; we might lower to 0.3 for “significant”. This can be decided empirically. In any case, we will clearly document the chosen threshold and test a range to see if the classification of many areas changes drastically (a form of sensitivity analysis).

- **Distinguishing Ongoing vs. Historic Gentrification:** Our index at a single year doesn't distinguish whether a high-GDI area was always wealthy (historic elite enclave) or recently gentrified from a low base. For example, Paris's 7th arrondissement and parts of the 20th arrondissement might both rank as "High" in 2021, but the former has been bourgeois for a century, while the latter might be a product of 20 years of gentrification. Our trend labels partly address this: the 7th would be "stable" (high all along), whereas the 20th might be "intensifying" (if it climbed from moderate to high). Thus, using the **combination of the annual class and the trend classification is important**. A "High & intensifying" area is likely a case of super-gentrification (already affluent and getting more so, if possible) ³⁹, whereas "High & stable" is an established affluent area, and "Upper-Intermediate & intensifying" is a classic gentrifying neighborhood on its way up. This context should be considered in analysis.
- **Data Quality and Scale:** IRIS-level data is quite detailed (districts of a few thousand people). Small-area data can be noisy, especially for income (the FiLoSoFi data at IRIS level is modelled from tax data and comes with warnings about reliability in annual changes ⁴⁰ ³⁶). We mitigated this by focusing on broad periods (2013 to 2021) and requiring consistent changes over multi-year spans. Still, some blips might occur. If an IRIS has a small population or unusual composition, the median income might fluctuate due to a few households moving. A robustness step could be to **smooth** the data or use five-year averages (though here we only have specific years). Alternatively, applying the classification at a slightly higher spatial aggregation (like grouping adjacent IRIS or analyzing the *quartier* level – the city's administrative quarters) could reduce volatility. However, that loses spatial granularity. Our approach strikes a balance: IRIS is the finest unit for which these stats are published, and by not reacting to small changes (via our stability threshold), we implicitly smooth out minor noise.
- **External Validation:** To build confidence in the GDI, we can compare it with known qualitative categorizations. For instance, City of Paris or APUR reports often identify areas regarded as gentrified or gentrifying (e.g., the Goutte d'Or, Belleville, etc. as gentrifying; the Marais as gentrified; historically rich areas like Passy as not a result of recent gentrification) ⁴¹ ⁴². Does GDI align? If our 2021 "High GDI intensifying" list includes Goutte d'Or, that matches Bacqué & Fijalkow's observations of that area's transformation ⁴². If "Low GDI" includes peripheral public housing clusters (e.g., Porte de la Chapelle sector) and indeed those are known to be still low-income, that's a good sign. We could also correlate GDI with independent measures like real estate price increases (often a marker of gentrification). A strong correlation would validate the index. Prior research in Paris by the Institut Paris Région (formerly IAU) created typologies of communes or IRIS by income change ⁴³ ⁴⁴; we expect our GDI intensifying list to correspond to their identified "upgrading" areas. Any discrepancies could highlight either data issues or conceptual differences (e.g., an area where GDI didn't move much but housing prices did – possibly indicating incoming wealthier residents displacing poorer ones one-for-one, keeping median income static initially but driving up property values – a complex scenario to explore).
- **Use of GDI in Practice:** Policymakers could use the four-class annual state to target areas for different interventions (e.g., protection from displacement in intensifying areas, investment in amenities in low-stable areas, etc.), and the trend classification to monitor dynamics. It's important to note that GDI is relative *within Paris*. If one wanted to compare Paris IRIS to suburbs, the standardization would need to be redone for a larger region. Also, a "Low gentrification" class in Paris might still be higher on an absolute scale than an average neighborhood in another city – our index is city-specific. This is fine for internal urban analysis, but one should avoid comparing GDI values between cities or regions without re-basing.

- **Ethical and Social Implications:** By focusing on socio-economic measures, the GDI implicitly values certain changes (rising income, etc.). One should recall that a high GDI, while it signals less material deprivation, also often means *displacement or exclusion* of vulnerable populations. GDI does not measure displacement directly; it measures the outcome of who lives in the area at each time. Two areas could end up with similar GDI increases, but one might have achieved it through “*replacement*” of population and the other through *gradual uplift without displacement*. Our index cannot distinguish those scenarios. For a fuller picture, one could incorporate data on population turnover or housing eviction rates if available. But that’s beyond our scope – GDI focuses on the neighborhood’s compositional change, consistent with how gentrification is usually operationalized in quantitative work ⁴⁵ ⁴⁶ .

In conclusion, the GDI formula provides a **literature-grounded, multi-factor measure** of gentrification at the micro-neighborhood level. It is simple enough to compute with available data and interpret (each component has real-world meaning), and our classification scheme translates the numbers into categories that resonate with urban study narratives (from low-income enclave to highly gentrified district). By tracking GDI over 2013, 2017, 2021, we capture the temporal evolution – identifying not just where neighborhoods stand, but how they are changing. This approach is in line with contemporary urban analyses which emphasize both status and change, for instance distinguishing long-gentrified “established elite” areas from “ongoing gentrification frontiers” ⁴⁷ ⁴⁸ . Our method for trend (requiring sustained index increase) aligns with the need to isolate genuine gentrification processes from short-term fluctuations ¹² .

Final note: All source variables come from official INSEE definitions – *population, socio-professional categories, and FiLoSoFi income indicators*. Disposable income per UC is well-defined by INSEE as total income after taxes/transfers, including earnings, pensions, unemployment, and social benefits ²⁶ . The PCS categories distinguish clearly the social class of residents ¹⁶ . By basing GDI on these, we ensure it rests on transparent, reputable data. The use of IRIS (residential IRIS only, type “H”) as the spatial unit is appropriate for capturing neighborhood-level phenomena in Paris ¹⁸ . Each IRIS is relatively homogeneous and delineated by INSEE to reflect local communities (grouping city blocks with similar housing characteristics) ¹⁸ . This granularity is necessary to detect gentrification, which often operates at the level of a few blocks or a quarter. The approach of harmonizing IRIS across time means our analysis truly follows the *same neighborhoods*.

We acknowledge that any index like GDI is a reductive summary – it won’t convey everything (for example, cultural changes or subjective perceptions of “trendy” vs “up-and-coming”). But it focuses on measurable structural shifts identified by urban theory: **income uplift, class recomposition, demographic turnover, and dependency shifts**. These are the crux of what Glass, Smith, Hamnett, and others have described in qualitative terms ⁴⁹ ³¹ . In applying GDI to Paris 2013–2021, we would expect to see, for instance, areas like south-central Paris and certain eastern IRIS increasing their scores (intensifying gentrification) as documented by observers in the 2010s, while traditional wealthy west-side IRIS remain high but stable, and some peripheral or dense low-income pockets remain low GDI (stable ungentrified). This would confirm known patterns ⁵⁰ ⁵¹ and provide a quantitative backbone for them. By citing the scholarly and official sources throughout this derivation, we ensure every choice – from variable inclusion to how to classify changes – is backed by either theoretical reasoning or precedent in the literature.

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