Cost-Benefice Analysis

Case Study - Grand Paris Express (GPE)

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1 Context and Problem Definition

1.1 Background and Objectives of the Project

With over 12 million inhabitants, Île-de-France is Europe's largest urban region and one of the world's leading economic hubs. Accounting for around 30% of France's GDP and attracting hundreds of thousands of new residents and workers each year, the region faces increasing pressure on its transport infrastructure, whose radial organization centered on Paris no longer meets contemporary mobility needs. Most commuter traffic still converges on the capital, making inter-suburban travel inefficient and time-consuming. According to the Paris Region Institute, nearly 70% of daily trips now take place between suburbs, yet these journeys remain poorly served by existing public transport, which is often saturated during peak hours. This structural saturation entails heavy economic and social costs: it prolongs travel times, reduces productivity, and limits access to employment and essential services for residents of peripheral areas. The aging network, plagued by delays and technical incidents, also pushes more people toward private car use, fueling congestion and greenhouse gas emissions.

This unbalanced transport geography reinforces spatial and social inequalities within the region. Well-connected areas benefit from economic growth, job creation, and rising property values, while poorly served municipalities accumulate disadvantages. Many residents of outer suburbs are compelled to rely on their cars, bearing high financial and time costs while enduring heavy traffic. These disparities in accessibility hinder social mobility by restricting access to employment for low-income populations. Moreover, sustainable mobility policies such as low-emission zones, while environmentally necessary, risk deepening inequalities if not accompanied by strong improvements in public transport options capable of providing affordable, efficient alternatives to car dependency.

At the same time, the current mobility model, dominated by private car use, is environmentally and socially unsustainable. The transport sector produces nearly one-third of regional CO emissions, 95% of which come from private cars. Chronic road congestion exacerbates these emissions and contributes to air pollution, which remains a major health threat. According to Airparif, several thousand premature deaths each year are linked to fine particles and nitrogen dioxide, disproportionately affecting disadvantaged populations living near major roads. Transitioning to low-carbon mobility is therefore essential to meet climate goals, improve air quality, and reduce health costs. Achieving this requires a significant modal shift toward public transportation, backed by major investments in network capacity, coverage, and service quality.

1.2 Problem Without Policy

Without decisive action, Île-de-France risks worsening congestion, declining productivity, growing inequalities, and rising pollution. To address these interrelated challenges, the Grand Paris Express (GPE) project represents a strategic response. Spanning nearly 200 kilometers of new automated metro lines, the GPE aims to fundamentally reshape metropolitan mobility by connecting suburban areas directly, reducing travel times, easing congestion on existing lines, and facilitating the transition toward carbon-free transport. Beyond infrastructure, it is a lever for rebalancing the metropolis, promoting territorial cohesion, and fostering ecological transition, thereby laying the foundations for a mobility model adapted to the economic, social, and environmental challenges of the 21st century.

2 Description of the Policy and Analytical Scope

2.1 Policy Description and Implementation Phases

The GPE is a vast transport and regional development project in the Île-de-France region initiated by the French government in 2010. Led by the Société du Grand Paris (SGP, which became the 'Société des grands projets' in 2023) , it aims to create an automatic orbital metro network, connecting suburbs to suburbs, avoiding the need to pass through central Paris. The GPE will extend and add rapid automated lines around Paris. Line 14 is being extended north to Saint-Denis–Pleyel and south to Orly; it already opened in 2024 with eight new stations. Line 15 will form an inner-suburban ring through Hauts-de-Seine, Val-de-Marne and Seine-Saint-Denis, with an eastern branch toward Champs-sur-Marne; it is intended to relieve central RER and metro corridors. Line 16 will serve Seine-Saint-Denis from Saint-Denis–Pleyel toward Clichy-Montfermeil and Noisy-Champs. Line 17 will run from Saint-Denis–Pleyel via Le Bourget to Charles-de-Gaulle Airport and the surrounding airport zone. Line 18 will link Orly to Versailles–Chantiers via the Saclay plateau, serving business and research hubs in Essonne and Yvelines. The Line 11 eastward extension (Rosny–Noisy-Champs) is being integrated into the SGP programme. In total, the GPE will add about 68–72 accessible stations, roughly 80 percent of which will interchange with the existing network. Trains will be automated, average 55–65 km/h (peaking near 110 km/h), and run every 2–3 minutes at peak times. The rollout runs from 2024 to 2031, with key milestones: end-2026 (southern Line 15 and central Line 18); mid-2027 (northern Lines 16 and 17, southern Line 18); end-2028 (final part of Line 16 and eastern Line 17); end-2030 (remaining sections of Lines 17 and 18); and 2031 (final Line 15 connections).

In total, it comprises 200 km of new automatic lines (lines 15, 16, 17 and 18) as well as extensions to the metro (lines 11 and 14). This network will connect 72 stations interconnected with existing transport systems (metro, RER, tram, etc.) More than just infrastructure, the GPE is presented as a major urban, social and economic project designed to unite the region's strategic areas and support sustainable development and employment. The Senate Finance Committee estimated the project to cost 36 billion€.

2.2 Scope of the Analysis: Standing and Time Horizon

The cost-benefit analysis considers the potential users of the new transport network, local residents and inhabitants of the areas served, companies in the Île-de-France region and nationally participating in the project, as well as public authorities, due to their role in the financing, management, and taxation associated with the Grand Paris Express.

Specifically, the project aims to create an automated metro network with 200 km of lines and 68 new stations in the Île-de-France region.

The 68 station districts concerned will host nearly 934,000 salaried jobs (end of 2022), representing 21% of the jobs in the Greater Paris Metropolis and approximately 17% of its population (approximately 1,500,000 inhabitants). Residential neighborhoods will benefit from a doubling of access to employment (+105%) by 2030 (*Atelier Parisien d'Urbanisme (APUR)*), thanks to the reduction in travel times to regional economic hubs.

Economically, in 2021, the project involved 4,524 companies, including 2,408 in the Île-de-France region (81% very small businesses (VSEs) and small/medium-sized enterprises (SMEs)), 1,829 in other French regions (82% VSEs/SMEs), and 287 foreign companies. In 2024, there were over 7,000 people working on construction sites, spread across all lines and stations under construction. Furthermore, cumulative payments to VSEs and SMEs reached €2.36 billion by the end of 2022, including €1.38 billion for French companies.

The geographical scope of the analysis covers the entire Île-de-France region, in order to integrate the direct and indirect effects of the project (mobility, attractiveness, employment, environment). The timeframe extends from the construction phase (2015-2030) to the operational phase (2024-2060). The time horizon for the cost-benefit analysis of the Grand Paris Express is set at 2060, as it covers the entire construction period (until 2030) and approximately 30 years of operation after commissioning, in accordance with the official recommendations of the CGDD (2023) for heavy transport infrastructure. Cumulative investments have reached approximately €29.3 billion since 2010 according to *Société du Grand Paris*. This timeframe includes the entire project lifecycle, i.e., from design to full operation, in order to assess environmental costs, benefits, and externalities (emission reduction, nuisances, urban impacts).

The assessment adopts a primarily regional scope, centered on the Île-de-France region, where the majority of the project's costs, benefits, and external effects are concentrated. However, certain extraregional effects, such as the mobilization of companies located in other

French regions or national macroeconomic benefits (in terms of innovation, production, and employment), are mentioned qualitatively, without being included in the main calculation of the analysis.

3 Identification and Quantification of Effects

The launch of the Grand Paris Express will have a major impact on transport, regional planning, the environment and the regional economy. It will offer new rapid suburban connections (avoiding detours through Paris), significantly reducing commuting times. Nearly 3 million daily passengers are expected, which will greatly relieve pressure on the RER and central metro lines. The metro route is reshaping economic activity zones and guiding future urbanisation. Studies (*LIEPP*) show that the GPE should promote densification around stations and reduce urban sprawl. The 68 stations will be surrounded by urban projects: 180 urban projects (housing, offices, facilities) have already been launched around the stations that will be in service by 2025. The project is also linked to the revitalisation of 53 priority neighbourhoods that will be directly served by the metro, helping to rebalance development between Paris and its suburbs. In the longer term, the GPE should stimulate the Île-de-France economy by bringing together businesses, universities and research centres (Saclay plateau, airport hubs, etc.). The SGP emphasises that the metro facilitates access to employment, culture and health, and creates new links and new opportunities for residents. Academic studies suggest that such a project can increase the region's international attractiveness (foreign direct investment) and create agglomeration economies due to the proximity of economic players. In addition, the construction of the GPE is generating thousands of jobs (more than 7,000 people on construction sites by the end of 2022) and many hours of professional integration (3,632 people in integration since the start of the project).

The GPE aims to have an overall positive carbon footprint in the long term. Once operational, the automated (electric-powered) metro is expected to save around 755,000 tonnes of CO per year in the Île-de-France region (by replacing car journeys). In addition, as 90% of the network is underground, the project preserves natural spaces (low fragmentation). However, the construction itself is very resource-intensive: around 4.4 million tonnes of CO will be emitted to build the GPE (mainly due to concrete and steel). The SGP is implementing mitigation measures: extensive use of low-carbon concrete (25% reduction in carbon footprint), river/rail transport of excavated material (13.5% transported by barge/train in Q1 2025), and reuse of excavated material (56% of excavated material reused in Q1 2025). A target of 70% of land reused has been set. The GPE will improve access to everyday services: it is estimated that 95% of residents in the Paris metropolitan area will be less than 2 km from a GPE station (10 minutes by bicycle or bus). Frequent and comfortable trains (air-conditioned and accessible to people with reduced mobility) will make inter-suburban travel easier. This will save an average of 30 minutes in travel time for the future 3 million daily passengers who will use the

GPE, which provides a total gain of 1.5 million hours per day. Finally, the project will be accompanied by the reorganisation of bus routes and cycle paths, and new urban developments around stations to promote sustainable modes of transport.

4 Quantification and Aggregation of Costs and Benefits

4.1 General assumptions

We will now try to monetize each of the consequences that we previously presented. The time horizon on which we will estimate those consequences is from 2015 (year t=0 as it is the start of the work on the Grand Paris Express) to 2060 (because the average lifespan of lines without maintenance work is 30 years). Each estimated benefit from the project will be considered non-risky to simplify computations and avoiding giving estimates with probability distributions that would be too difficult to evaluate. The discount rate r used to discount project costs and benefits follows the standard specification used in French cost–benefit evaluations:

$$r = r_f + \beta\delta$$

where:

- r_f is the risk-free discount rate,
- δ is the macro-systemic risk premium
- β measures the correlation of the project benefits with the economic growth.

We used the French basic value for these parameters, which are:

$$r_f = 1.2\%, \qquad \delta = 2\%, \qquad \beta = 1$$

Substituting these values yields:

$$r = 1.2\% + 1 \times 2\% = 3.2\%$$

For some of the policy impacts considered in this report, we will use different values for β depending on the benefits correlation with economic growth. All monetary benefits and costs presented below are discounted to present values using annual discount rates depending on β values chosen. We set $t = 0$ in 2015, which corresponds to the base year of the analysis; all subsequent costs and benefits are therefore discounted from this reference point.

For each subsection of this part, the objective is to compute the Net Social Value (which is NSV = PV of Benefits − PV of Costs) associated with the corresponding component, in order to aggregate them later in the conclusion and derive the overall net social value of the Grand Paris Express project.

4.2 Monetization of time earnings

In order to highlight the time savings associated with the project, we use weightings based on time spent according to the reason for travel, which are considered more relevant for measuring the value of time saved.

Based on mobility surveys for the Île-de-France region (Institut Paris Région, 2023), approximately 5% of travel time is spent on business trips during working hours, 45% on commuting or education-related travel, and 50% on other reasons (shopping, leisure, etc.).

Applying the reference time values (VoT) from Quinet and Meunier (2013), respectively €22.3/hour for business travel, €12.6/hour for commuting and education, and €8.7/hour for other reasons, we obtain an average time value of:

$$V = 0{,}05 \times 22{,}3 + 0{,}45 \times 12{,}6 + 0{,}50 \times 8{,}7 = €11{,}14/h$$

Based on an estimated 1.5 million hours saved per day and assuming 365 days, the annual benefits associated with this time saving would amount to:

$$B = 1{,}5\,\text{million} \times 365 \times 11{,}14 = €6{,}099{,}150{,}000/year$$

According to mobility survey data (Institut Paris Région, 2023), the value of the parameter β varies depending on the purpose of travel: business trips are highly pro-cyclical with $\beta = 1.3$, commuting and education-related trips are moderately pro-cyclical with $\beta = 1.0$, while leisure and other personal trips are weakly correlated with the economic cycle, with $\beta = 0.5$. The weighted average is therefore:

$$\beta_{\text{time}} = 0.05 \times 1.3 + 0.45 \times 1.0 + 0.50 \times 0.5 = 0.78$$

Applying the standard parameters $r_f = 1.2\%$ and $\delta = 2\%$, the specific discount rate becomes:

$$r_{\text{time}} = 1.2\% + 0.78 \times 2\% = 2.76\%$$

Therefore we can compute the net social value of time earnings :

$$\text{NSV}_{\text{time}} = \sum_{t=15}^{45} \frac{6,099,150,000}{(1+0.0276)^t} = €81{,}987{,}553{,}666$$

4.3 Monetize the climate-related costs and benefits

We value CO_2 emissions using a willingness-to-pay and a willingness-to-accept estimate of €70 per tonne. This value is taken from hedonic pricing techniques: hedonic pricing infers the implicit price of CO_2 by observing the mean market prices for the tonne of CO_2 on the market of permits. Hedonic methods, therefore, provide an empirical estimate of the social value individuals place on marginal changes in CO_2 emissions even when no explicit market price exists.

Total construction emissions are estimated at 4.4 million tonnes CO_2 spread over 16 years (2015–2030 inclusive). We assume these emissions occur linearly over the construction period, i.e. $4{,}400{,}000/16 = 275{,}000$ tCO_2 per year. Annual social cost of these construction emissions is:

$$275{,}000 \text{ t/year} \times €70/\text{t} \; = \; €19{,}250{,}000/\text{year}.$$

On the other hand, emissions avoided thanks to the Grand Paris Express are worse 755,000 tCO_2/year. The annual benefits from avoided emissions are therefore:

$$755{,}000 \text{ t/year} \times €70/\text{t} \; = \; €52{,}850{,}000/\text{year}.$$

In literature, climate β was estimated with Monte Carlo simulation $\beta_{50} = 0{,}7$ (Dietz, Gollier 2017), $\beta_{50} = -3{,}5$ (Galoso) but there is no universal value for it. In addition, we found arguments in favor of a positive value for β (growth of consumption and growth of emissions are correlated) but also supporting the idea of a negative value (climate change will make future generations poorer so investing now to reduce emissions will have high returns in a bad state of the world). This is why choosing $\beta = 0$ for CO_2 emissions seemed relevant, it is a mean value between literature findings, consistent with our hypothesis and an easy value to manipulate. With $\beta = 0$ the discount rate for climate flows reduces to the risk-free rate:

$$r \; = \; r_f + \beta\delta \; = \; r_f \quad (\text{since } \beta = 0).$$

We take $r_f = 1.2\%$, hence $r = 1.2\% = 0.012$ and:

$$\text{NSV}_{\text{CO}_2\text{emissions}} \; = \; \sum_{t=9}^{45} \frac{52{,}850{,}000}{(1+0.012)^t} \; - \; \sum_{t=0}^{15} \frac{19{,}250{,}000}{(1+0.012)^t} = €1{,}146{,}000{,}000.$$

Hence, the Net Social Value (NSV) related to the climate is positive and is worse €1,146,000,000.

4.4 Monetizing the costs and benefits associated with noise

We set $\beta = 0$ since the benefits (or costs) related to noise reduction (or increase) are not correlated with economic growth and mainly reflect changes in health and well-being. Consequently, the appropriate discount rate is $r = 1.2\%$.

4.4.1 Benefits associated with noise

According to *Bruitparif* (2021), in Île-de-France, the social cost of road traffic noise is estimated at approximately €18.1 billion per year. Relative to *DRIEAT* forecasts (MODUS model) for 2030, the modal share of private cars is expected to decrease only slightly due to the GPE: about -0.9% in the morning and -1.4% in the evening. Assuming this reduction remains constant over time, the average decrease can be written as:

$$\bar{\Delta} = \frac{0.9 + 1.4}{2} = 1.15\%$$

There are approximately 14 million daily car trips in Île-de-France, including 12.8 million outside Paris proper based on *omnil*. We take 12.8 million as the relevant value, as the project primarily targets individuals living outside the central Paris area. The reduction in car trips per day due to the GPE is therefore:

$$\Delta N = 12{,}800{,}000 \times (-0.0115) = -147{,}200 \text{ trips per day.}$$

The annual social cost of noise per car trip can be estimated as:

$$C_{\text{trip}} = \frac{18.1 \times 10^9}{365 \times 14 \times 10^6} \approx €3.54\,/\text{trip/year.}$$

Hence, the annual reduction in the social cost of noise (RscN) is:

$$RscN = 365 \times 147{,}200 \times C_{\text{trip}} \approx €190{,}308{,}571.$$

Assuming a constant discount rate $r = 0.012$ and benefits starting from year t=15 (2030, as 2015 is t=0) to t=45 (2060), the present value of benefits is:

$$B_{noise} = \sum_{t=15}^{45} \frac{RscN}{(1+r)^t} = €4{,}148{,}333{,}835.$$

4.4.2 Costs associated with noise

Noise from future transport

According to *Bruitparif* (2021), railway noise in Île-de-France represents about €3.8 billion per year, or 9% of the total regional cost. The region contains approximately 12,952 kilometres of rail lines based on many sources such as the *SNCF, the RATP or Île-de-France Mobilités*. The unit cost of annual railway noise per kilometre is thus:

$$C_{\text{rail}} = \frac{3.8 \times 10^9}{12{,}952} \approx €293{,}390/\text{km/year.}$$

The Grand Paris Express will add around 200 km of new lines, generating an additional annual cost of:

$$addC_{\text{rail}} = 200 \times 293{,}390.58 = €58{,}678{,}196.$$

However, this cost is only considered from the end of the construction period (2030 onwards). In addition, the extension of line 11 and 14 (21.6 km) represents an additional cost of approximately $C_{\text{rail}} \times 21.6 \approx €6{,}337{,}245.21$ million per year from 2025 onwards, given that its construction was completed in 2025. The present value of the cumulative cost is then: 19 835 219.3

$$CV_{\text{transport}} = \sum_{t=10}^{14} \frac{6{,}337{,}245.21}{(1+r)^t} + \sum_{t=15}^{45} \frac{58{,}678{,}196.42}{(1+r)^t} = 27{,}464{,}150 + 1{,}279{,}063{,}501 = €1{,}306{,}527{,}651.$$

Noise from Construction Sites

The total regional social cost of noise related to construction sites is estimated at €2.4 billion per year, or about 5% of the total, as indicated by *Bruitparif* (2021). With a regional population of 12.3 million inhabitants (*INSEE*, 2021), the average cost per inhabitant per year is:

$$C_{\text{inhabitant}} = \frac{2.4 \times 10^9}{12{,}317{,}279} \approx €194.85\,/\text{inhabitant/year}.$$

The 68 GPE station districts include about 1.2 million inhabitants (*APUR*, 2021), or roughly 17,800 inhabitants per station within an 800 m radius. Assuming a uniform spatial density and that the population exposed to noise is within a radius of 300 m, we have:

$$N_{300m} = 17{,}800 \times \left(\frac{300}{800}\right)^2 \approx 2{,}503\,\text{inhabitants}.$$

Assumption on Duration and Intensity of Noise

The construction of each station generally spans several years, but the most intense noise emissions occur during the heavy civil engineering phase (excavation, tunneling, foundations). We assume that this phase lasts, on average, around three years, in line with the durations observed at several sites (such as Bagneux–Lucie Aubrac or Saint-Denis Pleyel), after which noise levels decrease sharply. For the linear works (tunnels, tracks, technical equipment), the noise is more diffuse and considered not high enough to generate a measurable social cost.

Given this, we assume that 68 station sites generate noise-related costs spread over 15 years (2015–2030), divided into four 3-year periods with approximately 17 sites active per period:

$$CV_{\text{construction}} = \sum_{t=0}^{15} \frac{(2{,}503 \times 194.85 \times 17)}{(1+r)^t} = \sum_{t=0}^{15} \frac{8{,}291{,}062}{(1.012)^t} \approx €121{,}487{,}805.$$

4.4.3 Net Social Value (NSV) associated with noise

Finally, the net social value associated with noise is computed as:

$$NSV_{noise} = B_{noise} - (CV_{\text{transport}} + CV_{\text{construction}})$$

$$\Leftrightarrow 4{,}148{,}333{,}835 - 1{,}306{,}527{,}651 - 121{,}487{,}805 = €2{,}720{,}318{,}379.$$

Thus, considering both benefits and costs, the Net Social Value of the noise component is positive, suggesting that reduced road traffic noise outweighs the noise impacts from new rail infrastructure and construction. Moreover, this result may overestimate the actual cost, since future rail technologies and better noise insulation could substantially reduce the effective sound emissions compared to current infrastructure.

4.5 Monetizing health and mortality effects (VSL / QALY)

The assessment of the health effects of the GPE is based on the two main channels identified in the Airparif and Road Safety reports: the reduction in mortality linked to air pollution and the improvement in road safety.

In the Île-de-France region, fine particulate matter ($PM_{2.5}$) pollution is responsible for around 6,200 premature deaths per year, 24% of which are attributable to road traffic. The GPE would lead to a reduction in car traffic of around 1.15%. Assuming that the reduction in emissions is proportional to the reduction in traffic and that the effects on mortality follow the same proportion, this would result in a total reduction in regional mortality of:

$$6\,200 \times (0.24 \times 0.0115) = 6\,200 \times 0.00276 = 17.1.$$

Added to this is the effect on road safety. In 2022, there were 281 deaths on the roads of the Paris region. A 1.15% reduction in car traffic means that the number of lives saved can be estimated at:

$$281 \times 0.0115 = 3.2.$$

The value of a statistical life (VSL) recommended for French socio-economic analyses is €3 million (Quinet Report, 2013). Monetizing avoided deaths therefore leads to the following benefits:

$$\begin{aligned} \text{Air pollution:} \quad & 17.1 \times 3{,}000{,}000 = 51.3 \text{ million.} \\ \text{Road safety:} \quad & 3.2 \times 3{,}000{,}000 = 9.2 \text{ million.} \end{aligned}$$

The total health benefit of the GPE, for the central scenario alone, is therefore around €60.5 million per year. These results confirm that the GPE, by reducing car use and urban pollution, generates significant and recurring health co-benefits for the population of the Paris region.

Chronic exposure to current levels of $PM_{2.5}$ in the Paris region is also responsible for a range of non-fatal health effects:

- Asthma attacks and exacerbations of chronic obstructive pulmonary disease (COPD),

- Cardio-respiratory hospitalizations,
- Acute respiratory symptoms,
- Reduced lung capacity and impaired quality of life.

Economic assessments of air pollution (e.g., WHO, OECD reports) generally consider these non-fatal effects to represent a significant portion of the total health cost. According to the methodology of the Clean Air for Europe program (CAFE, 2005), pollution-related morbidity accounts for 10 to 30% of the damage associated with mortality.

Assuming a ratio of 20% (the median value in this range), morbidity therefore accounts for 20% of the health benefit linked to mortality. In the central scenario, the GPE's "mortality pollution" benefit was estimated at €60.5 million per year, applying the 20% coefficient for morbidity:

$$B_{\text{morbidity-pollution}} = 0.2 \times 60.5 = \text{€}12.1 \text{ million/year}.$$

In other words, the reduction in air pollution brought about by the GPE would prevent several hundred hospitalizations and asthma attacks each year, representing an economic gain of around €12.1 million per year, in addition to the mortality benefits already accounted for.

The GPE will also lead to a substantial increase in physical activity for its users, due to the additional walking involved in accessing stations, making connections, and traveling on foot. According to the report *Health Effects of the Grand Paris Express in Île-de-France* (Airparif & Santé publique France, 2024), a public transport user walks an average of 27 minutes per day, compared to 8 minutes for a motorist, representing a net gain of around 19 minutes/day of moderate activity.

In its article *HEAT for Walking and Cycling* (2017), which serves as the official guide for the economic evaluation of walking and cycling, the WHO proposes a range of 0.003–0.006 QALY/year for a gain of approximately 20 min/day. Assuming that around 210,000 motorists would switch to public transport thanks to the GPE, which corresponds to around 1.15% of journeys, and an average gain of 0.005 QALY per user per year for this level of activity, we obtain:

$$210{,}000 \times 0.005 = 1{,}050 \text{ QALY/year}.$$

By monetizing these QALYs at €150,000, the French reference value, the annual health benefit from increased physical activity is estimated at:

$$B_{\text{activity}} = 1{,}050 \times 150{,}000 = \text{€}157.5 \text{ million/year}.$$

Health and mortality benefits, including reduced air pollution, improved road safety, and increased physical activity, are only weakly correlated with economic growth. Following the Quinet (2013) recommendations for low-cyclicity benefits (health, safety, environment), we adopt:

$$\beta_{\text{health}} = 0.2.$$

The total annual benefit is :

$$B_{\text{health total}} = 60.5 + 12.1 + 157.5 = €230.1 \text{ million/year}.$$

Adopting $\beta_{\text{health}} = 0.2$, the corresponding discount rate is:

$$r_{\text{health}} = r_f + \beta_{\text{health}}\,\delta = 1.2\% + 0.2 \times 2\% = 1.6\%.$$

Assuming benefits start 15 years after the base year and remain constant at $B = 230.1$ million per year, the net social present value of health is:

$$\text{NSV}_{\text{health}} \;=\; \sum_{t=15}^{45} \frac{230,000,000}{(1+0.06)^t} = €4,294,088,379$$

4.6 Monetizing economic impacts

4.6.1 Employment

To estimate the employment-related net social value of the Grand Paris Express we adopt an accounting of three labour channels: direct construction employment, insertion hours, and indirect employment, and we distinguish temporary (construction-period) from permanent (post-opening) effects. Value added per job is the share of economic output attributed on average to a job over the course of a year. We will use it to estimate the contribution of these new employments to GDP instead of just summing wages because a cost-benefit analysis seeks to measure the total economic surplus generated by a project, not just household income. The value-added per job used is €107,760 per person year (regional GDP/value-added per job estimates in Paris, *choose paris region*). Direct construction employment is represented by an average on-site workforce of 5,000 workers per year (5,000 person-years) over the construction window 2015–2030 (*grand paris express*). This gives a VA of 107,760 x 5,000 = €538,800,000 per year from 2015 to 2030.

For indirect employment we apply an input-output style multiplier so that total indirect person-years equal direct person-years × (multiplier − 1), with a central multiplier of 1.5 which is consistent with regional IO evidence for construction and associated services. (*European Commission*). It gives a total of (80,000 x 0.5) / 16 = 2,500 person-years. This reflects employments created during the construction phase in response to demand generated by the construction project such as jobs with suppliers and subcontractors (concrete, steel, prefabrication, equipment, design offices, etc.) or jobs induced by local demand, because employees consume locally (catering, retail, services). The value added from indirect employment is 107,760 x 2,500 = €269,400,000 per year from 2015 to 2030.

To reflect the fact that most induced jobs fade after the construction impulse, we assume that 20% of indirect jobs structuralise and become permanent from IO-based analyses of persistent value-added effects (*European Commission*). It gives an amount of 500 permanent person-years after 2030. The value added associated is 500 × 107,760 = €53,880,000 per year from 2030 to 2060. In addition, a baseline stock of 500 permanent operations/maintenance jobs is credited from 2024 onward (RATP / IDFM). Annual value added = 500 × €107,760 = €53,880,000 per year from 2024 to 2060.

We also tried to give an estimate for permanent employments created by the economic dynamic of the Grand Paris Express. We considered jobs that result from a structural change in the local economy caused by improved accessibility (increased productivity, attractiveness, establishment of businesses). These are sustainable jobs created because the area is becoming more productive and attractive (business setting up near a railway station, creation of an R&D centre, new SMEs providing services linked to an increased customer base, etc.). *LIEPP* (Sciences Po, Grand Paris Express and territorial dynamics 2019) estimates that the GPE could generate an additional 0.2 to 0.4% of annual Gross Value Added (GVA) at the regional level in the long term. For a central scenario, we took ΔGVA = €300 million/year which is approximately 0.03% of regional GVA. To avoid double counting with permanent indirect jobs, we subtract the value added already taken into account in permanent indirect jobs. €300,000,000 - (2 x €53,880,000) = €192,240,000 per year from 2030 to 2060 (assuming that those employments will start being created just at the opening of all lines in 2030).

We discounted these benefits using a β=1, assuming that these employment benefits are correlated with economic growth. This gives us a discount rate of 3.2%.

$$\mathrm{NSV}_{\text{employment}} = \sum_{t=0}^{15} \frac{538,800,000}{(1+0.032)^t} + \sum_{t=0}^{15} \frac{269,400,000}{(1+0.032)^t} + \sum_{t=15}^{45} \frac{53,880,000}{(1+0.032)^t}$$

$$+ \sum_{t=9}^{45} \frac{53,880,000}{(1+0.032)^t} + \sum_{t=15}^{45} \frac{192,240,000}{(1+0.032)^t} = €14,303,744,227$$

4.6.2 Benefits associated with property value

According to the *APUR* (2021), the 68 station districts of the GPE are defined as the areas located within an 800-meter radius around each future station. These districts concentrate approximately 17% of the total population of the "Métropole du Grand Paris" (MGP).

The MGP population counts 7,115,576 inhabitants and 3,254,532 households, resulting in an average household size of 2.186 persons (*INSEE*, 2021). From this, we estimate the population living within the 68 station districts as:

$$P_{800m} = 0.17 \times 7{,}115{,}576 \approx 1{,}209{,}648 \text{ inhabitants.}$$

Assuming a uniform population density, the population within a 500-meter radius around each station can be estimated by the ratio of areas:

$$P_{500m} = P_{800m} \times \left(\frac{500}{800}\right)^2 = 1{,}209{,}648 \times \frac{25}{64} \approx 472{,}519 \text{ inhabitants.}$$

Given the average household size, this corresponds to approximately:

$$N_{\text{apartments}} = \frac{472{,}519}{2.186} \approx 216{,}157 \text{ dwellings.}$$

Property value per dwelling

We assume that all real estate around train stations consists of apartments.

According to the *Notaires du Grand Paris* (2024), the average apartment price in Île-de-France is approximately €4,873 per m^2. The median surface area of apartments in the departments of Hauts-de-Seine, Seine-Saint-Denis and Val-de-Marne is 56.66 m^2 (*Chambre des Notaires de Paris*, 2023). The average property value per apartment is therefore:

$$V_{\text{avg}} = 4{,}873.33 \times 56.66 = €276{,}155$$

Price differential due to transport proximity

According to *Le Journal de l'Agence* (2023), there exists on average a 7.7% price premium for properties located within 500 meters of a metro station compared to more distant properties. The average value increase per dwelling can thus be estimated as:

$$\Delta V = 0.077 \times 276{,}155.55 = €21{,}264$$

and the total gross capital gain for all dwellings within 500 meters of GPE stations is:

$$B_{\text{Immo, gross}} = 21{,}264 \times 216{,}157 = €4{,}596{,}357{,}552$$

Adjustment for double counting

As suggested by the *International Transport Forum* (ITF/OECD, 2021), the capitalization of accessibility, noise reduction, and time savings in property values leads to potential double counting if these benefits are also valued separately in the CBA. To address this, and following the conservative assumption used in several hedonic-pricing studies (e.g., Zhou et al., 2022; Mikula & Molnár, 2022), we assume that only 15% of the observed increase in property value reflects benefits not already captured by the other components (urban renewal, amenities, social attractiveness). Therefore:

$$B_{\text{Immo, net}} = 0.15 \times 4{,}596{,}357{,}552 = €689{,}453{,}632$$

Assuming the capitalization effect occurs when the network becomes operational (year $t = 15$, i.e., 2030) and a social discount rate of $r = 0.032$ (as β is positively correlated with the economic growth in this case), the net present value of the property-related benefit is:

$$NSV_{\text{Immo}} = \frac{B_{\text{Immo, net}}}{(1+r)^{15}} = \frac{689{,}453{,}632}{(1.032)^{15}} \approx €429{,}842{,}748$$

4.7 Monetizing construction costs

According to *Delisle* (2024), the initial cost of the Grand Paris Express project was estimated at €19 billion, but this figure gradually increased over time, reaching €22.6 billion in 2013, €29 billion, then €38.5 billion in 2017, and finally €39.6 billion in 2023. In line with this upward trend, *Karoutchi* (Senate report, 2024) estimates that the total cost could ultimately reach up to €50 billion, even under optimistic assumptions. We therefore retain Karoutchi's optimistic estimate of €50 billion as the upper bound for the total cost of the project, knowing that according to *94.Citoyens* (2015), around €6 billion had already been paid by 2015 for the initial stages of the network, including the construction of lines 15 South, 15 West, and 14 South. In these facts, we assume that:

- €6 billion are paid immediately in 2015 (year $t = 0$), and thus are not discounted.
- The remaining €44 billion are spread evenly between 2016 and 2030, representing the gradual continuation of construction works and equipment installation.

The cost of construction is highly correlated with macroeconomic growth and investment cycles in the infrastructure sector. Following our general assumption of $\beta = 1$, the corresponding discount rate is $r_f + \beta\delta = 1.2\% + 1 \times 2\% = 3.2\%$.

The present value of the construction costs is therefore:

$$PV_{\text{cost construction}} = 6{,}000{,}000{,}000 + \sum_{t=1}^{15} \frac{44{,}000{,}000{,}000/15}{(1+0.032)^t}.$$

$$\Leftrightarrow PV_{\text{cost construction}} = 6{,}000{,}000{,}000 + 34{,}516{,}700{,}221 = €40,516{,}700{,}221.$$

So, the Net Social Value (NSV) for the construction costs is equal to $-PV_{\text{cost construction}} = -€40,516{,}700{,}221 = NSV_{\text{cost construction}}$.

5 Overall Net Social Value and Conclusion

Before aggregating all components, it is important to recall the fundamental decision rule used in cost–benefit analysis. A public policy or investment project should be accepted if and only if its Net Social Value (NSV) is strictly positive, i.e.:

$$\boxed{\text{NSV}_{\text{total}} > 0 \quad \Rightarrow \quad \text{Accept the policy (socially and economically beneficial).}}$$

In the previous subsections, we find the following Net Social Values (NSVs) :

$$\begin{aligned}
\text{NSV}_{\text{time}} &= €81{,}987{,}553{,}666, \\
\text{NSV}_{\text{CO}_2} &= €1{,}146{,}000{,}000, \\
\text{NSV}_{\text{noise}} &= €2{,}720{,}318{,}379, \\
\text{NSV}_{\text{health}} &= €4{,}294{,}088{,}379, \\
\text{NSV}_{\text{employment}} &= €14{,}303{,}744{,}227, \\
\text{NSV}_{\text{Immo}} &= €429{,}842{,}748, \\
\text{NSV}_{\text{construction}} &= -€40{,}516{,}700{,}221.
\end{aligned}$$

The total net social value of the Grand Paris Express project is thus:

$$NSV_{total} = 81{,}987{,}553{,}666 + 1{,}146{,}000{,}000 + 2{,}720{,}318{,}379 + 4{,}294{,}088{,}379$$
$$+14{,}303{,}744{,}227 + 429{,}842{,}748 - 40{,}516{,}700{,}221 = €64{,}364{,}847{,}178.$$

The overall Net Social Value (NSV) is therefore positive and substantial, at approximately €64.36 billion. This result indicates that the total discounted benefits significantly exceed the discounted costs of the project.

From a socio-economic perspective, the Grand Paris Express constitutes a socially profitable investment, expected to generate a considerable net gain for the Île-de-France region. The project's long-term impacts, including improved accessibility, enhanced productivity, reduced pollution, health co-benefits, and increased urban attractiveness, confirm that the decision to undertake it was economically justified and socially desirable.