**P R O P O S A L**

# Tokenized Financing for Da Nang's Transport Infrastructure

*Danang Fintech Lab (DFL24) — Founding member, Vietnam International Financial Centre, Da Nang (VIFC)*

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# Glossary and abbreviations

This proposal is written in English. Vietnamese legal instruments, administrative terms and place names keep their Vietnamese form, with an English gloss on first use. Readers should review this table before the main text.

## A. Abbreviations

| Abbreviation | Full term | Definition |
|---|---|---|
| CIP | Covered Interest Parity | The relationship that explains why the cost of foreign-currency borrowing, once hedged, converges on the domestic-currency level. |
| DSCR | Debt Service Coverage Ratio | Cash flow available divided by debt service due; DSCR ≥ 1 means cash flow covers the payment. |
| EBITDA | Earnings Before Interest, Taxes, Depreciation & Amortisation | A measure of operating cash flow. |
| EVPI | Expected Value of Perfect Information | The most a decision-maker should rationally pay to remove one unknown before deciding. |
| FIEO | Foreign-Invested Economic Organisation | A foreign-invested economic organisation as defined in the 2024 Land Law. |
| GPMB | Giải phóng mặt bằng — land acquisition and resettlement | Land recovery, compensation and resettlement completed before construction starts. |
| GRDP | Gross Regional Domestic Product | The size of a province or city's economy. |
| IRR / MOIC | Internal Rate of Return / Multiple on Invested Capital | The two standard measures of investor return: rate and multiple. |
| LOI | Letter of Intent | A preliminary commitment; here, a conditional commitment. |
| QSDĐ | Quyền sử dụng đất — land use right | In Vietnam land is owned by the people as a whole; organisations and individuals hold only a time-limited right to use it. |
| RWA | Real-World Asset | A physical asset — land, infrastructure, commodities — recorded on a digital ledger as a token. |
| SPV | Special Purpose Vehicle | A company formed solely to hold assets and issue capital instruments; here, to hold time-limited land use rights. |
| TOD | Transit-Oriented Development | Compact urban development within a 300–500 m radius of a station. |
| VIFC | Vietnam International Financial Centre | The International Financial Centre established in Da Nang; DFL24 is a founding member. |

*Table 0.1 — Abbreviations*

## B. Key terms

| Term | Vietnamese | Definition |
|---|---|---|
| First-loss | Chịu phần lỗ đầu tiên | The capital layer that absorbs the first losses if the project underperforms, protecting the layers above it. |
| Legal gateway | Điều kiện pháp lý tiên quyết | A chain of legal conditions that must be met in sequence; failing one stops the chain. |
| Value-Conversion Pool | Vốn hưởng lợi từ giá trị đất gia tăng | The capital layer that receives no coupon from the project; investors are repaid out of land uplift rather than interest. |
| Land value capture | Thu hồi giá trị đất | Recovering part of the increase in land value created by public infrastructure, and recycling it into that same infrastructure. |
| Tokenization | Token hoá | Representing an asset, or a share in one, as a token on a digital ledger so it can be traded, divided and reconciled automatically. |
| Net position | Giá trị ròng | Land value the city retains, less the capital it must put in and the financing cost it bears — the real measure of budget benefit. |

*Table 0.2 — Key terms*

# List of tables and figures

The proposal contains 21 tables and 27 figures, numbered by section (Table 3.1 is the first table in Section 3; figures follow the same rule). Figures are listed below; tables are referenced where they appear.

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# 1. Executive summary

**Tokenized financing can let Da Nang build the metro line and the Urban Arterial without borrowing past its public-debt ceiling, and keep roughly 72% of the land value the two works create. That feasibility is conditional, and the conditions are not met at the date of this proposal.**

The two projects need about VND 184,100 billion. The city budget and bank lending cannot cover it, and financing the whole amount with ODA would push public debt through its ceiling[15]. This proposal sets out a third channel: form a project company (SPV) that holds time-limited land use rights along the corridor, tokenize the shares in that company, and repay investors out of the land value the Metro creates. The city sells no land and tokenizes no land; land remains under all-people ownership, and what is tokenized is equity in a company.

## Context and significance

The funding problem is not confined to Da Nang. Several provinces need capital for metro lines, ring roads and urban infrastructure at a point where both public-debt headroom and ODA capacity are tight. If land value capture through tokenization works here, it gives other provinces a reference case for a **funding channel that does not add to public debt**.

Da Nang is well placed to consider a pilot, because Resolution 222 already allows a **test first, legislate after**[5] approach inside the Vietnam International Financial Centre (VIFC) for business models that current law does not cover. This proposal is exactly that kind of model: it would be tested within a defined scope and period so that the rules can then be written from evidence. If it works, it follows precedents in Hong Kong, Japan and Korea (Section 8.3) and provides other provinces with a reference case.

The model produces two sets of benefits. Investors gain early access to a pipeline of infrastructure assets inside a legal framework that is still being built. The city **keeps most of the land value its own infrastructure creates**. Both depend on verification work whose cost is small against the size of the project.

| Item | Result | What it means |
|---|---|---|
| Feasibility probability (simulated) | about 6% | Feasible only within a narrow band of conditions |
| City net position (token option) | +VND 38,379 bn | Highest of the five options; the city keeps about 72% of land value |
| Probability of clearing all five legal conditions | ~14% | Legal risk is the binding constraint, ahead of every financial factor |
| Investor return (post-conditions) | Debt 8.0% / Token 9.5% | In line with infrastructure and real-estate funds, not venture funds |

*Table 1.1 — Four headline results*

## The conditions that decide the outcome

Feasibility turns first on the **share of land along the corridor that is still developable** (a 28.8 percentage-point swing), then on the legal gateway (18 points) and the land-uplift multiple (11 points). Metro capex and ridership — the two variables most people raise first — rank below all three. The land available for value capture decides more than the passenger forecast does.

**Recommendation**

This proposal does not seek approval to invest. It seeks approval to spend research budget on three pieces of verification before any capital is committed: (1) a survey of developable land along the corridor together with an independent valuation; (2) negotiation of Metro capex with the construction partner; and (3) a binding legal opinion on the share-token mechanism. All three cost research budget rather than investment capital, and together they determine whether the proposal is worth pursuing.

# 2. Context and rationale

Da Nang is targeting double-digit growth and building the Da Nang – Hoi An – Tam Ky – Chu Lai urban corridor. Its two backbone works, Metro Line 1 (103 km, 24 stations) and the Urban Arterial (87.6 km), need about VND 184,100 billion. The open question is the funding, not the decision to build.

## 2.1. Two projects and the funding gap

| Project | Scale | Capex (VND bn) | TOD land type |
|---|---|---|---|
| Urban Arterial | 87.6 km | 30,898 | Industrial |
| Metro Line 1 | 103 km, 24 ga | ≈184,100 (feasibility-study case, USD 7 bn) | Residential, commercial |

*Table 2.1 — The two corridor projects*

Two Metro capex figures are in circulation. The feasibility study puts it near USD 7 billion; a major domestic contractor has quoted USD 10.11 billion[16]. The USD 3 billion gap decides the case: at USD 10.11 billion, cash flow no longer covers debt service and the structure fails. Negotiating that number is therefore one of the three mandatory verification tasks (Section 8).

## 2.2. Why the three conventional funding channels fall short

Budget, bank credit and ODA each run into a ceiling:

- **City budget:** VND 184,100 billion cannot be found over five years without cutting other spending commitments.
- **Bank credit:** tenors are short and rates high, which does not match an asset that repays over 30 to 50 years.
- **ODA:** it pushes public debt through the ceiling, ties procurement to the lending country's contractors, and — on the evidence of Cát Linh – Hà Đông and Nhổn — tends to run late and over budget.

Section 5.1 puts a number on this: under the ODA option the city's net position falls to **−VND 48,461 bn** — negative, because borrowing the full capital cost breaches the permitted debt threshold. That negative result is the case for a fourth channel.

## 2.3. The market for tokenized real-world assets and reference transactions

Tokenized infrastructure and real estate are past the concept stage; billion-dollar transactions have closed. Three groups of precedent shape the approach taken here:

### Land value capture through development rights (Hong Kong, São Paulo)

The closest precedent is MTR Hong Kong's Rail + Property model. Government grants the rail company development rights around stations priced before the line exists; the company sells or leases at post-rail prices, and the difference funds the line. Between 1980 and 2005 the mechanism generated about USD 2.33 billion of value[7], with government retaining roughly 76% of the shares[6]. São Paulo tokenized additional development rights (CEPAC) and auctioned them on an exchange[10] — a precedent for digitizing land rights rather than digitizing land.

### Tokenized bonds and digital securities (Hong Kong, Japan)

Hong Kong has issued tokenized green bonds in several tranches; Japan's Progmat platform issues digital securities on a distributed ledger[11]. Asian regulators have accepted token-form capital

instruments where those instruments sit inside the existing securities framework — which is exactly what this proposal does with the senior tranche.

### Land readjustment (Japan, Korea)

Land readjustment (kukaku seiri in Japan) consolidates fragmented plots, builds the infrastructure, and retains a share of the land to sell against the cost. Korea's Yongin–Jukjeon scheme returned an internal rate of return of roughly 262% (Kim 2023) on the appreciation of the retained land after infrastructure[9]. This is the basis for the second value-capture model in Section 3.3.

> **Precedent**
> None of the international precedents tokenized or sold land directly. They tokenized or traded development rights, shares, or securities in a company that holds the land. The World Bank identifies four success conditions: state ownership with long leaseholds, sufficient urban density, an administration able to execute, and a legal framework for the capital instrument[8]. Vietnam has the first (land under all-people ownership, leased for fixed terms); the fourth — a legal framework for share tokens — is unsettled. That is the central risk of this proposal.

## 2.4. Legal basis

The proposal rests on the instruments below, applied through the VIFC sandbox:

| Instrument | Relevant content |
|---|---|
| 2013 Constitution, Article 53[1] | Land is owned by the people as a whole — the reason the structure tokenizes company shares rather than land. |
| Land Law 31/2024/QH15, Articles 28 and 42[2] | A foreign-invested economic organisation (FIEO) may receive land use rights as a capital contribution; land leases run to 50 years, or 70 in special cases. |
| Securities Law[3] | The framework for classifying and offering capital instruments in token form. |
| Resolution 188/2025/QH15[4] | Land value capture around stations (TOD) and floor-area-ratio charges. Applies to Hanoi and Ho Chi Minh City; cited here as precedent for the TOD model. |
| Resolution 222/2025/QH15, Articles 13 and 24[5] | The International Financial Centre: Article 13 permits new exchanges and trading platforms; Article 24 establishes the regulatory sandbox for models the law does not yet cover. |

*Table 2.2 — Principal legal basis*

One conflict needs resolving. Articles 28 and 42 allow an FIEO to receive land use rights as a capital contribution, but the definition in Article 3(22) is inconsistent with them and a corrective guideline is pending. Rather than wait for a general amendment, the proposal recommends seeking a specific ruling for the VIFC pilot (Section 6.3 and the appendices).

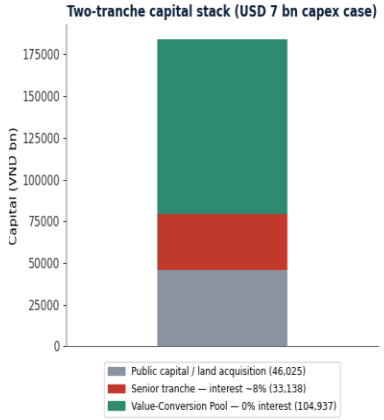
# 3. The structure: a two-tranche capital stack and land value capture

The proposal splits the capital into two tranches with different economics, and lets land uplift cover most of the cost. The split matches the risk profile and repayment source of each investor group. Merged into a single layer, the structure would strain the project's ability to balance its cash flow.

## 3.1. Tokenizing shares in a company, not tokenizing land

Land in Vietnam is owned by the people as a whole; ownership cannot be transferred and land cannot be tokenized directly. The proposal forms a project company (SPV) holding time-limited land use rights along the corridor, and tokenizes shares in that company. An investor buying tokens buys equity in a company, not land. When the lease expires, the land use right returns to the State. The structure follows what Hong Kong, Japan and Korea have done: trade rights and shares, not land.

## 3.2. Two tranches: interest-bearing debt and land-uplift participation




**What changes if the pool is treated as debt**

| | If treated entirely as debt | Two-tranche structure |
|---|---|---|
| Land token | pays 18–25% interest | shares value, 0% interest |
| Interest the project owes | on the whole stack | senior tranche only, ~8% |
| Counts as debt? | all of it | senior tranche only (~18%) |
| City net position | – | +VND 68,869 bn |
| P(feasible) | 0.026 | 0.062 |

*Figure 3.1 — The two-tranche capital stack. A small senior tranche paid from farebox revenue; a large Value-Conversion Pool repaid from land uplift.*

| | Senior Tranche — senior debt | Value-Conversion Pool — land-uplift participation |
|---|---|---|
| Size | Small (~18% of the stack) | Large (~57% of the stack) |
| Repayment source | Farebox revenue + project cash flow | Land uplift (TOD) |
| Coupon | ≈8% p.a. (USD, on CIP) | No coupon from the project |
| Ranking | Senior, secured | SPV shares over land use rights |

*Table 3.1 — Two tranches with different risk and different repayment sources*

**Principle**

The Value-Conversion Pool pays no coupon out of the project because the land itself earns through appreciation; investors are repaid on exit rather than through an annual cash flow. Treat that capital as interest-bearing debt and the pressure on project cash flow rises sharply, because the same farebox revenue would have to carry additional interest. Farebox revenue supports only a small

debt layer — the senior tranche — and land value covers the rest. In the model, the maximum debt share is set by operating cash flow, not by design preference.

### Sources and uses of funds

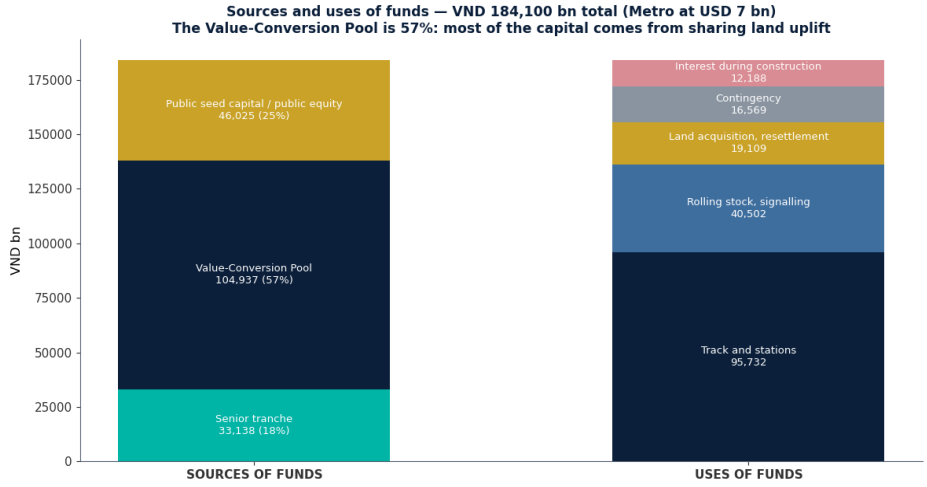



*Figure 3.2 — Sources and uses of funds. The Value-Conversion Pool accounts for 57% — most of the capital comes from sharing land uplift.*

| Source of funds | VND bn | % | Use of funds | VND bn |
|---|---|---|---|---|
| Senior Tranche — senior debt | 33,138 | 18% | Track and station construction | 95,732 |
| Value-Conversion Pool — land-uplift token | 104,937 | 57% | Rolling stock and signalling | 40,502 |
| Public seed capital / public equity | 46,025 | 25% | Land acquisition and resettlement | 19,109 |
| | | | Contingency (overrun / escalation) | 16,569 |
| **Total** | **184,100** | | Interest during construction (IDC) + integration | 12,188 |

*Table 3.2 — Sources and uses of funds (VND bn, Metro at USD 7 bn)*

Public seed capital is only 25% of the stack (VND 46,025 bn); most of the capital risk sits in the Value-Conversion Pool, carried by investors and repaid from land. The VND 19,109 bn of land acquisition and resettlement is the earliest cash out and becomes sunk if the legal conditions are not met — the case for a legal-first sequence is set out in Section 4.4.

## 3.3. Three land value capture models

How much land uplift the city keeps depends on the model chosen. The proposal compares three, using a pre-infrastructure land value of VND 106,568 bn and a post-infrastructure value of VND 215,321 bn across the whole corridor (an uplift of VND 108,753 bn). These are combined Metro and Urban Arterial figures at base multiples; the split by project and the addition of coastal tourism land to the Metro are set out in Section 4.6:

| Model | Origin | City retains | % |
|---|---|---|---|
| M1 — Development rights + SPV shares | Hong Kong Rail+Property[6] | VND 154,660 bn | 72% |
| M2 — Consolidation and land readjustment | Japan / Korea[9] | VND 113,754 bn | 53% |
| M3 — Revenue sharing on land use rights | Business co-operation on land use rights | VND 25,526 bn | 12% |

*Table 3.3 — Three land value capture models and what the city retains*

M1 retains the highest share, through four mechanisms: a transfer charge levied at pre-infrastructure value, a share of development profit, reversion of land at lease expiry, and taxation. The proposal recommends M1 as the target model, with M3 as a legally safer first pilot.

## Most of the capture potential sits in inland Phase 2, not on the coast

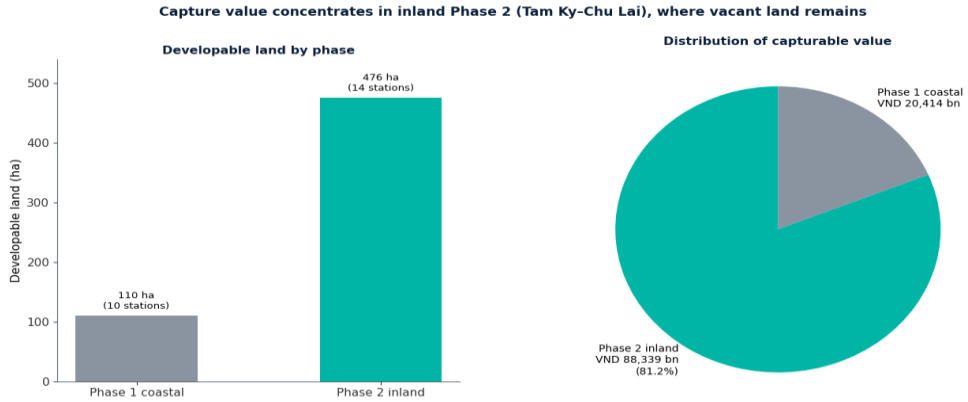



*Figure 3.3 — Inland Phase 2 (Tam Ky–Chu Lai) holds most of the capturable value because vacant land remains.*

Capture potential differs sharply between stations. The coastal Phase 1, Da Nang – Hoi An, is already densely built: only about 22% of the land around its stations can still be developed. Inland Phase 2, Tam Ky – Chu Lai, still has open land, at roughly 68%. The result: although Phase 1 has 10 stations against Phase 2's 14, Phase 2 accounts for about **81.2%** of capturable value (VND 88,339 bn of VND 108,753 bn). Land value capture potential is concentrated inland, which argues for prioritising TOD there.

## What the developable land share does to the result

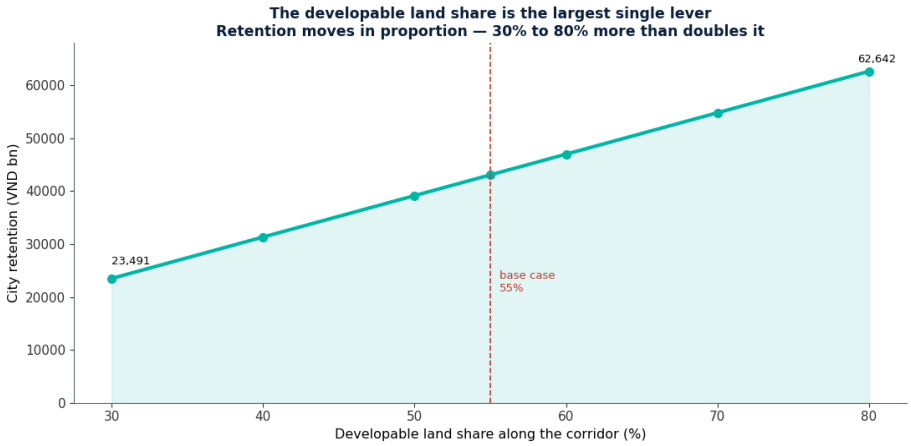



*Figure 3.4 — City retention moves in proportion to the developable land share along the corridor.*

What the city retains moves in proportion to how much land along the corridor can actually be developed. At the 55% base case the city retains about VND 43,066 bn; at 30% it retains VND 23,491 bn — roughly half. This is why the developable land share dominates the sensitivity analysis in Section 4.3: when developable land is scarce, capture potential falls away even with low operating costs and high ridership.

## 3.4. Optimizing the currency mix

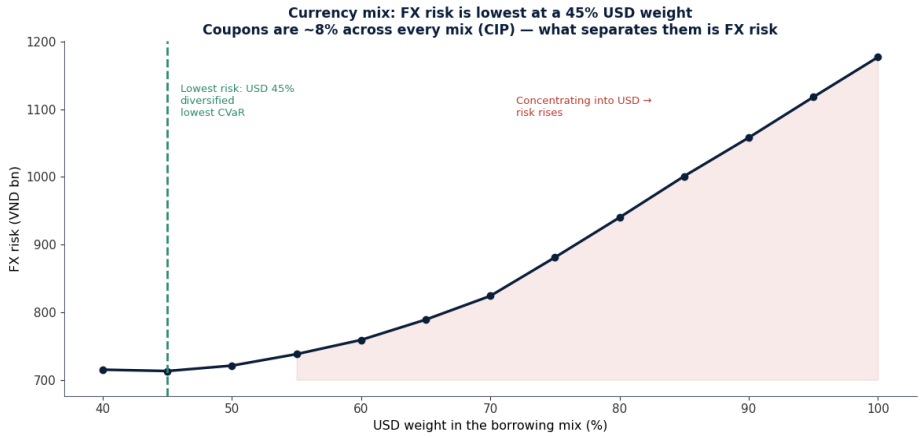



*Figure 3.5 — FX risk is lowest at a 45% USD weight (diversified) and rises as the mix concentrates into USD.*

| Mix scenario | Composition | FX risk (VND bn) | Coupon |
|---|---|---|---|
| **Diversified (lowest risk)** | USD 45% · VND 30% · KRW 20% · JPY 5% | **713.2** | ~8% |
| Low USD weight | USD 40% · VND 30% · KRW 20% · JPY 10% | 714.4 | ~8% |
| USD-dominant | USD 100% | 1176.6 | ~8% |

*Table 3.4 — Three currency mixes and the resulting FX risk*

The lowest FX cost comes from diversifying around a 45% USD weight rather than concentrating in USD. FX risk bottoms at VND 713 bn on a mix of USD 45% / VND 30% / KRW 20% / JPY 5%. Going

to 100% USD raises FX risk to VND 1,177 bn, because concentration in a single currency increases exposure. Coupons sit near 8% across all three mixes under covered interest parity, so what separates the mixes is FX risk, not the nominal rate.

## 3.5. Compliance architecture: producing regulatory evidence by simulation

The proposal adds an operational compliance layer running on the Sandbox 2.0 platform. Simulated agents — asset owners, investors, market makers, manipulators and a security red team — are run through six scenarios: normal operation, money-laundering pressure, fraud and sanctions, decentralised-exchange manipulation, liquidity stress and cyber attack. A policy layer (OPA/Rego) scores every action, and an observer agent generates the compliance file for submission to the regulator. One requirement is absolute: every scenario must reproduce exactly from the same random seed, so the regulator can re-run it.

# 4. Feasibility analysis

The simulation puts success inside a narrow band of conditions, and the variable that matters most is not one of the variables usually examined first.

## 4.1. Method

The analysis uses an agent-based Monte Carlo simulation of roughly 2.4 million paths and more than 500 agents. Each path is one combination of Metro capex, ridership, legal outcome, land price and exit timing. The output is a probability distribution, not a point estimate — the appropriate treatment where risk is concentrated in a small number of extreme scenarios.

## 4.2. Result: feasible only under a narrow set of conditions

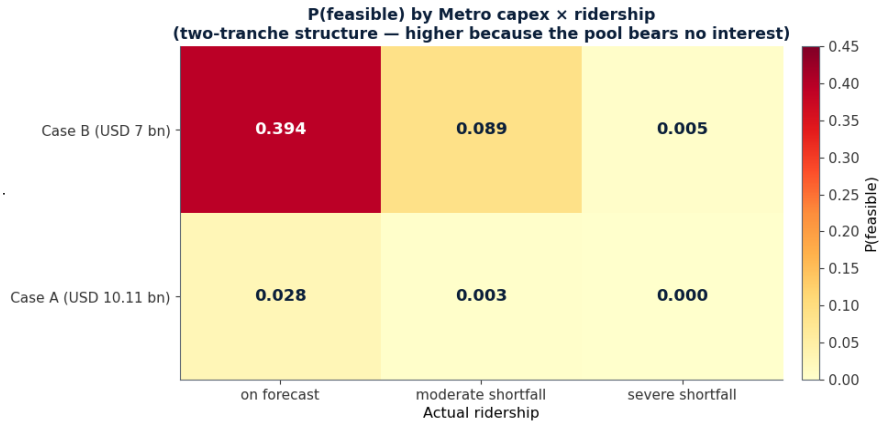



*Figure 4.1 — Feasibility concentrates in the low-capex, ridership-on-forecast region. At USD 10.11 billion it is close to zero.*

The simulated probability of feasibility is about **6%**. Success concentrates in scenarios that combine low capital cost with ridership at forecast.

**Reading the number**

The 6% financial feasibility figure covers the financial side only. It is the product of three capital conditions: the senior tranche closes, the Value-Conversion Pool closes, and DSCR and land coverage both clear their thresholds. It excludes the legal gateway.

The legal gateway is a separate precondition, with roughly a 14% probability of clearing all five conditions (Section 4.4). This is a quantitative scenario simulation. It does not substitute for a legal assessment by the competent authority and does not represent any regulator's position. If a project had to clear both sets of conditions at once with capital committed at the outset, the probability of everything landing together falls **below 1%**.

The proposal does not ask anyone to commit capital against that combined number. The sequence is **sequential**: establish the legal basis first, as a precondition, which turns the 14% into a go/no-go decision; only once the legal position is approved does the roughly 6% financial test apply; and in parallel, negotiate Metro capex down to improve the financial side. Sequenced this way, no capital is exposed to a combined probability near zero.

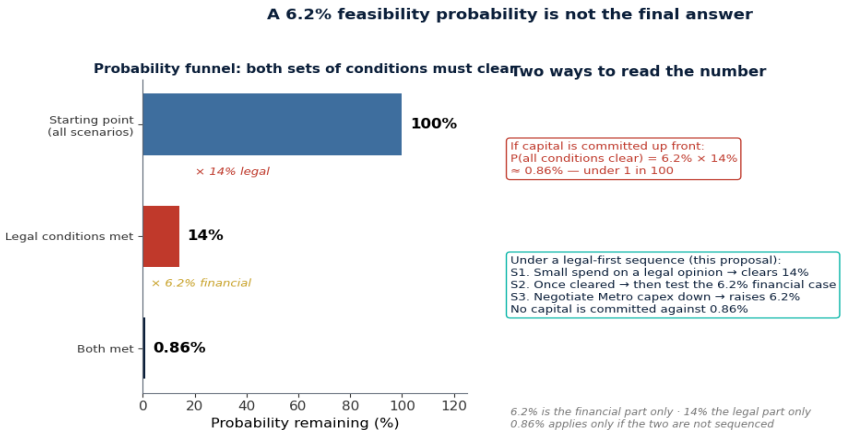



*Figure 4.1b — Financial conditions clear at about 6%, legal conditions at about 14%; combined, below 1%. A legal-first sequence keeps capital off that combined number.*

## 4.3. Sensitivity analysis: what actually moves feasibility

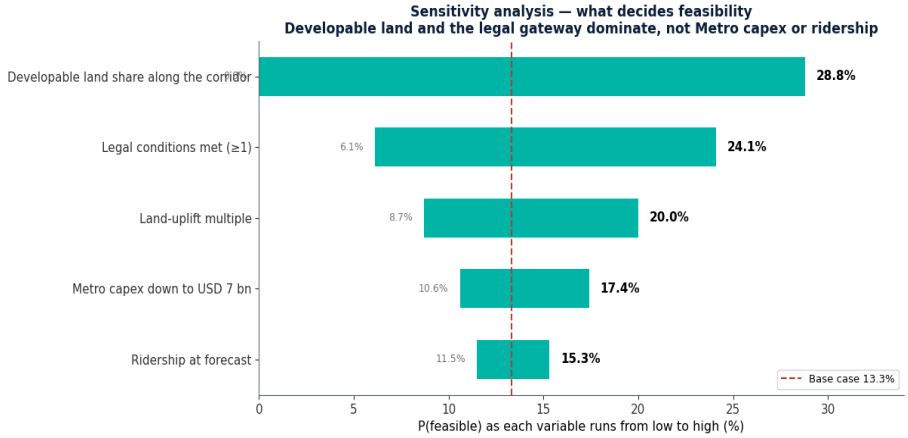



*Figure 4.2 — Developable land share and the legal gateway dominate; Metro capex and ridership rank behind them.*

Running each variable from its low to its high value, the effect on feasibility ranks as follows:

| Variable | P(feasible), low → high | Swing (pp) |
|---|---|---|
| **Developable land share along the corridor** | 0% → 28.8% | **28.8** |
| Legal gateway cleared (≥1 condition) | 6.1% → 24.1% | 18 |
| Land-uplift multiple | 8.7% → 20% | 11.3 |
| Metro capex down to USD 7 bn | 10.6% → 17.4% | 6.9 |
| Ridership at forecast | 11.5% → 15.3% | 3.8 |

*Table 4.1 — Swing in feasibility probability by variable*

**Implication**

Within the model's assumptions, the developable land share along the corridor moves feasibility more than fares or ridership do. If little developable land remains along the corridor, capture

potential falls away and the proposed financing mechanism weakens with it. Reviewing the master plan and current land use along the corridor should therefore come before any other detailed study.

### Variance decomposition: the legal gateway dominates, for a different reason

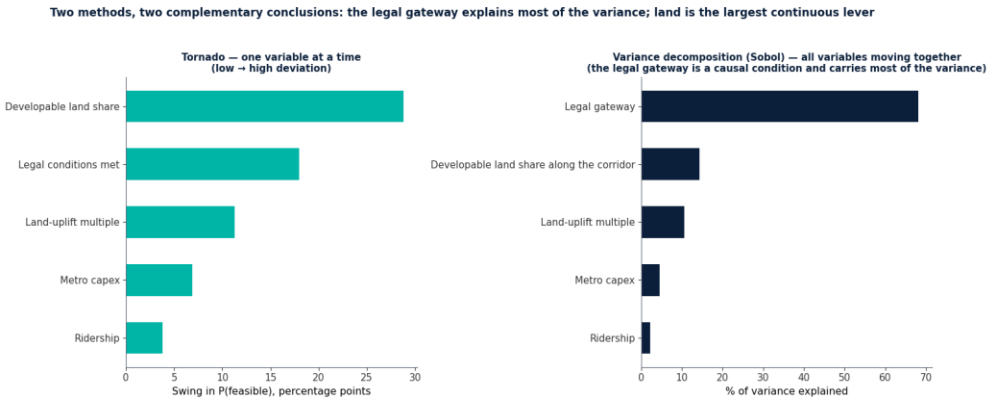



*Figure 4.3 — Two methods, two complementary conclusions. The tornado measures each variable's swing; variance decomposition measures each variable's contribution when all of them move together.*

One-at-a-time sensitivity moves each variable around the base case. When variables move together, the one explaining the most variance can be different. Under variance decomposition the legal gateway accounts for about **68.2%** of the variance in feasibility, far ahead of the developable land share (14.4%) and everything else.

**Assessment**

Variance decomposition makes the legal gateway the dominant factor: without approval the result is close to zero, even where the financial assumptions are favourable. The developable land share has the widest swing when taken on its own, but it only does work once the legal condition is met. **The legal position is a precondition to be confirmed before anything else proceeds; once cleared, the developable land share becomes the variable to optimise.** The two verification tasks — the legal opinion and the land survey — therefore run in parallel; neither substitutes for the other.

The model puts capture potential in Phase 2. Coastal Phase 1 is largely built out; the TOD headroom sits at the inland nodes in Quang Nam (Phase 2). Farebox revenue alone does not repay the investment: on fares alone, payback runs to 57 years. A mechanism for sharing land uplift is therefore a necessary condition for repayment.

## 4.4. The legal gateway and the value of sequencing

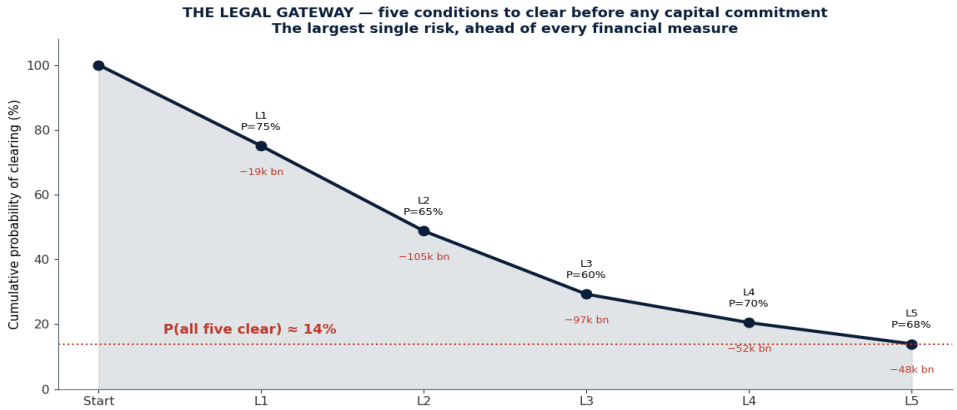



*Figure 4.4 — Five legal conditions in series; failing one stops the chain.*

Financial feasibility only means something once the legal gateway is cleared, and the probability of clearing all five conditions is about **14%**. The least certain condition is whether share tokens will be classified as securities; the public land already acquired (VND 19,109 bn) becomes sunk cost if the process halts. Legal risk therefore ranks ahead of every financial variable. The 14% figure is the analysis team's estimate, not the view of a competent authority — which is precisely why a formal legal opinion is needed.

## Resequencing: obtain the legal ruling first, acquire land second

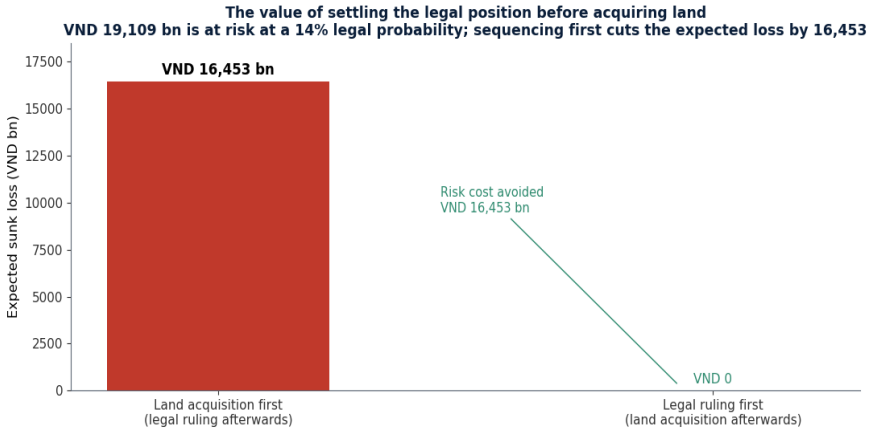



*Figure 4.5 — Resequencing removes the expected sunk loss; the saving is equivalent to a real option.*

Sequence determines how much capital is at risk. Acquire land first and seek the ruling afterwards, and the VND 19,109 bn already spent becomes sunk if the legal conditions are not met, at an expected loss of about **VND 16,453 bn** (= 19,109 × the 86% probability of not clearing). Obtain the ruling first and acquire land only once the position is certain, and the expected sunk loss is zero. That difference, about **VND 16,453 bn**, is the risk cost avoided by establishing the legal basis first. The cost of an initial legal assessment is a small fraction of the exposure created by acquiring land before the legal position is settled. The legal-first sequence is the recommendation in Section 8.

## 4.5. Metro capex grid, USD 7–10 billion: what capex does to the city's net position

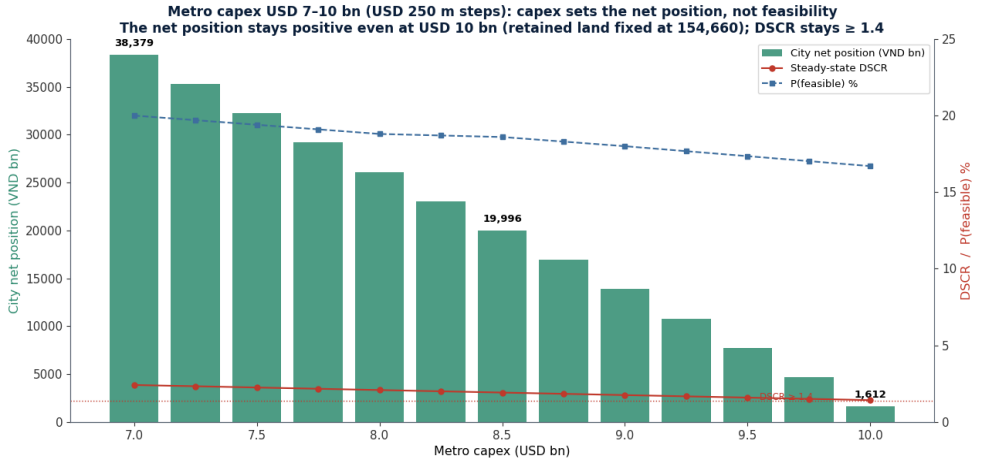



*Figure 4.6 — Across USD 7–10 billion, capex drives the city's net position directly; feasibility barely moves.*

Metro capex between USD 7 and 10 billion was assessed on a price grid in USD 250 million steps — a framework for testing the outcome at each price point, not a drawdown plan. Across the range, DSCR falls from 2.41 (at USD 7 bn) to 1.42 (at USD 10 bn), above 1 in most scenarios. In the model, capex does not materially change feasibility, which is driven by the legal gateway and by land. What capex changes is the Metro net position, calculated on the land attributable to the Metro after the Urban Arterial is separated out (Section 4.6):

| Price (USD bn) | Total capital (VND bn) | Steady-state DSCR | P(feasible) | Net position (VND bn) |
|---|---|---|---|---|
| **7.0** | 184,100 | 2.41 | 20% | **+38,379** |
| 8.0 | 210,400 | 2.08 | 18.8% | +26,124 |
| 8.5 | 223,550 | 1.91 | 18.6% | +19,996 |
| 9.0 | 236,700 | 1.75 | 18% | +13,868 |
| **10.0** | 263,000 | 1.42 | 16.7% | **+1,612** |

*Table 4.2 — Metro capex grid, USD 7–10 bn in USD 250 m steps (selected points)*

**Result**

The net position stays positive across the whole range, from +VND 38,379 bn at USD 7 billion to +VND 1,612 bn at USD 10 billion. This is the Metro alone: land attributable to the Metro retains VND 124,170 bn, after stripping out the industrial land belonging to the Urban Arterial (Section 4.6) and adding coastal tourism and commercial land. Retained land does not change with construction cost, so a higher price simply shifts value into financing cost rather than driving the city negative. Each additional USD 1 billion of capex reduces the net position by roughly VND 12,000 bn. There is no hard price threshold inside the USD 7–10 billion range: capex sets the level of the net position, while feasibility is driven by the legal gateway and by land.

## 4.6. Separating the two projects and the value of coastal tourism land

Up to this point the analysis has pooled the corridor's entire capture value into a single project. In reality the corridor contains two projects capturing value from two different land types: the Metro

captures residential, commercial and tourism land around its stations; the Urban Arterial captures industrial and logistics land along its route. Pooling them credits the Metro with value that belongs to the Arterial and overstates the Metro's net position.

The proposal separates value by land origin. Areas served by only one project are assigned to that project. Areas benefiting from both, where the two works raise prices together, are split by planned land use rather than divided in half: land zoned industrial goes to the Arterial, residential and commercial land to the Metro[8]. Uplift multiples are applied by land type, because commercial and industrial land appreciates differently from residential[22]. After separation the Metro holds VND 172,459 bn of capture value (72.8%) and the Arterial VND 64,406 bn (27.2%).

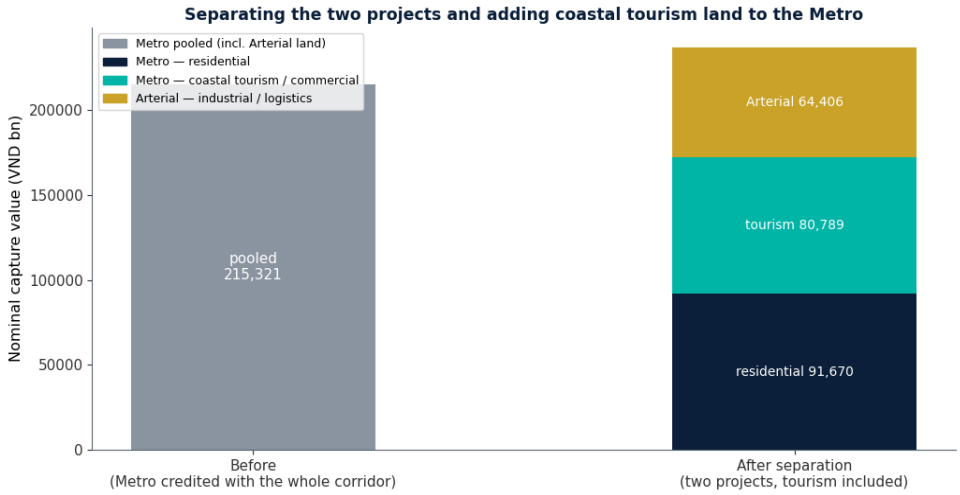



*Figure 4.7 — Project separation and the addition of coastal tourism land to the Metro. Metro-attributable land comprises VND 91,670 bn residential and VND 80,789 bn tourism and commercial; the Arterial's VND 64,406 bn is industrial and logistics.*

The Metro runs from Da Nang International Airport past My Khe beach and along the coast to Hoi An old town. Land around these stations is mostly hotels, retail and tourism services rather than pure residential. Coastal tourism and commercial land carries a higher uplift multiple than residential, and the investor earns twice: from operating the line and from developing property around the stations[22]. The proposal treats 45% of the Metro's TOD land as tourism and commercial (multiple 3.0) and 55% as residential (multiple 2.2). These are base assumptions, with a sensitivity range in Appendix D.

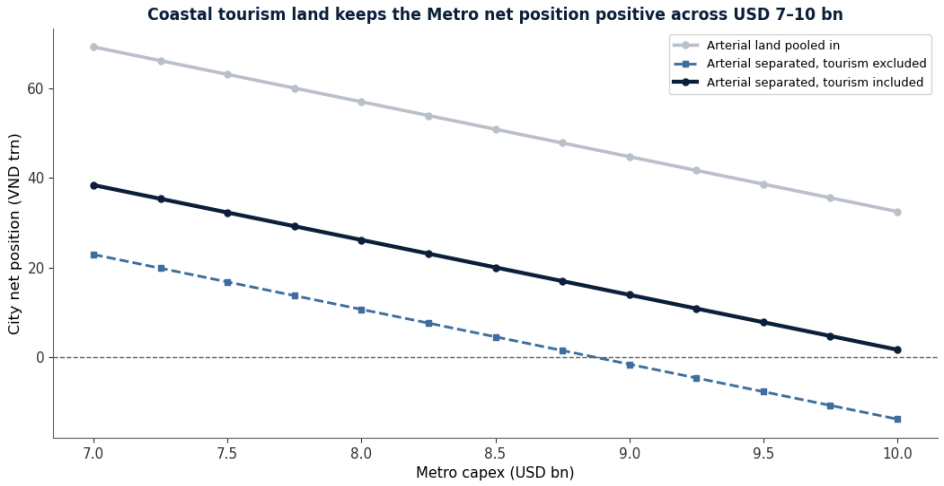



*Figure 4.8 — Coastal tourism land keeps the Metro net position positive across USD 7–10 billion. Excluding it, the Metro turns negative above about USD 8.9 billion.*

Tourism land raises Metro-attributable retained land to VND 124,170 bn and keeps the Metro net position positive across the USD 7–10 billion range (Section 4.5). Strip it out and the Metro turns negative above roughly USD 8.9 billion. Coastal tourism and commercial land is therefore what holds the Metro's financial case together at the upper end of the price range.

## 4.7. The Urban Arterial: tolls and the capex ceiling

The Arterial repays from two sources, and differs from the Metro in having a direct toll stream. BOT tolls service the senior tranche and count towards DSCR; uplift on industrial and logistics land belongs to the Value-Conversion Pool. At VND 1,500–2,000 per km — the level recent standard-compliant Vietnamese BOT roads charge[23] — over 87.6 km, at a base flow of 30,000 vehicles a day (range 20,000–40,000) and after deducting 30% operating cost, net revenue runs from VND 672 bn to VND 1,790 bn a year.

| Toll · traffic scenario | Net revenue p.a. (VND bn) | DSCR at capex of VND 30,898 bn |
|---|---|---|
| Low — VND 1,500/km · 20,000 vehicles | 672 | 1.36 |
| Mid — VND 1,750/km · 30,000 vehicles | 1,175 | 2.38 |
| High — VND 2,000/km · 40,000 vehicles | 1,790 | 3.62 |

*Table 4.3 — BOT toll revenue and Arterial DSCR at an assumed capex of VND 30,898 bn*

Toll-funded DSCR runs from 1.36 to 3.62 depending on the toll and the traffic, above 1 in most scenarios, meaning tolls alone service the senior tranche. At capex of VND 30,898 bn the Arterial's net position is **+VND 31,974 bn**. The highest capex at which the project still holds DSCR of 1 and a non-negative net position is VND 40,000 bn at the low toll, VND 72,500 bn at the mid toll and above VND 90,000 bn at the high toll. The assumed VND 30,898 bn sits below the ceiling in most toll scenarios; in the model the binding variable is the toll level, not land value.

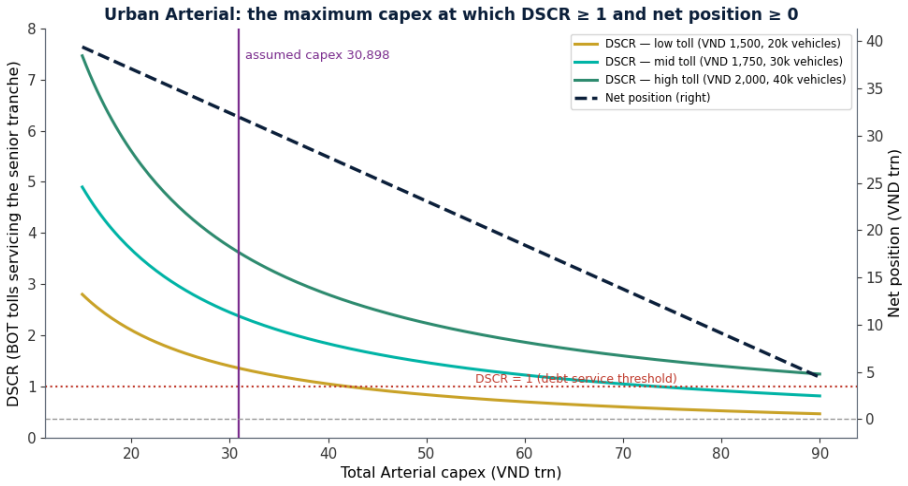



*Figure 4.9 — The Arterial capex ceiling. DSCR falls as capex rises and crosses 1 between VND 40,000 and 90,000 bn depending on the toll; the net position stays positive to about VND 99,000 bn. The assumed VND 30,898 bn sits well below the ceiling.*

Land value does not appear the moment the line opens. The proposal uses a 50-year horizon, following Hong Kong's standard lease term and Vietnam's maximum land use term[6]. Industrial land matures fastest, reaching 90% of its value in about 14 years; tourism and commercial land in about 23; residential is slowest at about 31. Discounting the 50-year value stream to present value gives about 39% of the nominal figure. The net position in Section 4.5 uses the fully matured nominal value, for consistency with the rest of the proposal; present value is an additional layer of conservatism, not a replacement.

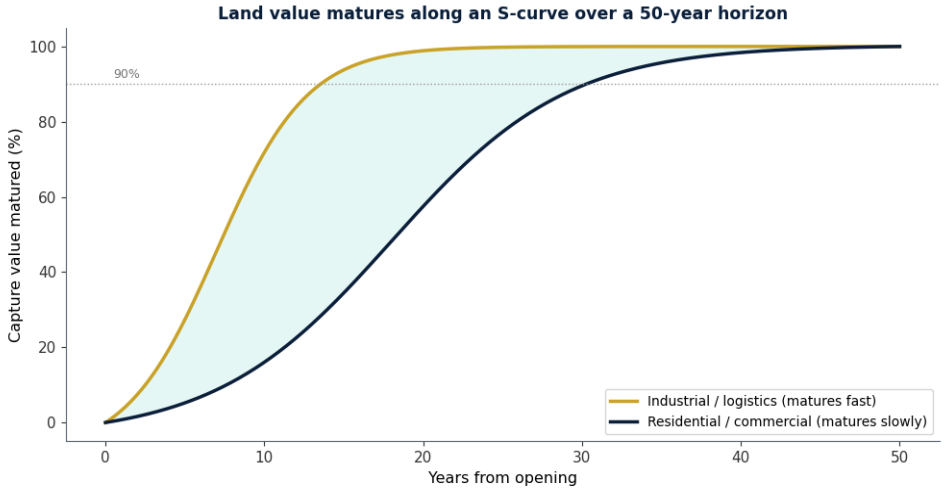



*Figure 4.10 — Land value maturing along an S-curve over 50 years. Industrial land matures faster than residential; value arriving late is discounted more heavily.*

# 5. The city's position and comparison of options

On these results the token option delivers the highest net position of the five corridor development options, provided the city's priority is preserving debt headroom and land value. Under a different priority order it is no longer first.

## 5.1. Value for money: the city's net position

Net position = land value retained by the city − capital the city must put in − financing cost. It measures the real budget benefit, in place of a simple cost-saving figure.

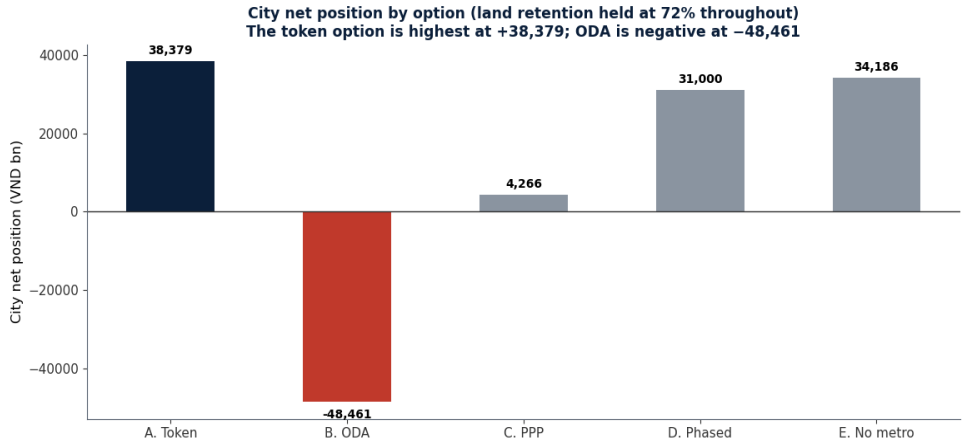



*Figure 5.1 — Net position under five options; the token option leads, and ODA is negative because borrowing the full cost breaches the permitted debt threshold.*

| Option | Land retained | City capital | Financing cost | Net position |
|---|---|---|---|---|
| **A. Token** | 124,170 | 46,025 | 39,766 | **+38,379** |
| B. ODA | 172,459 | 184,100 | 36,820 | -48,461 |
| C. PPP | 117,672 | 73,640 | 39,766 | 4,266 |
| D. Phased | 106,925 | 46,025 | 29,900 | 31,000 |
| E. No metro (BRT) | 64,596 | 15,000 | 15,410 | 34,186 |

*Table 5.1 — City net position by option (VND bn)*

The token option gives the highest net position at +VND 38,379 bn. Against the phased option (+VND 31,000 bn), however, the gap is far narrower than against ODA. The value the city gives up to investors is 28% of the uplift, about VND 48,289 bn. In exchange, the city allocates part of the uplift to investors in order to raise capital outside the budget.

## 5.2. Five options against ten criteria

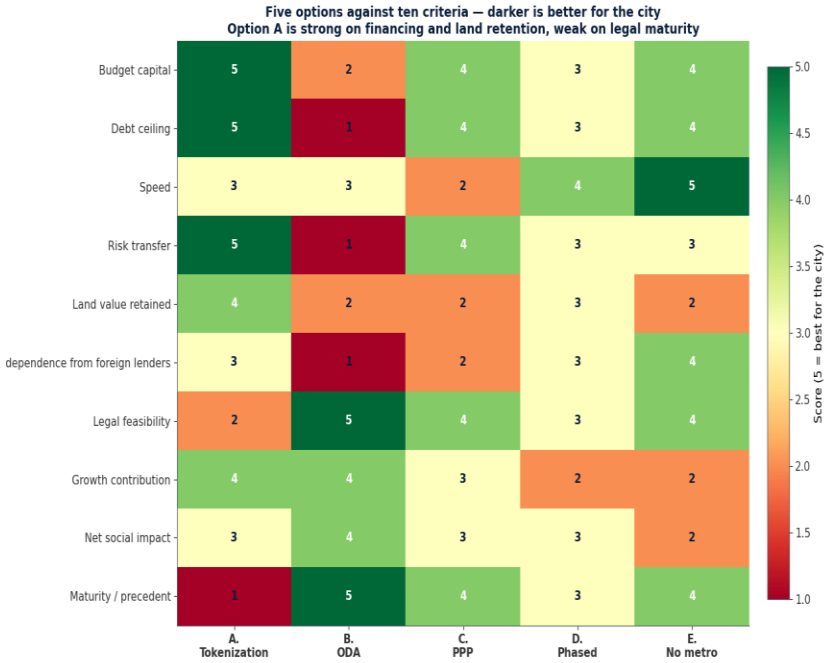



*Figure 5.2 — Five options across the assessment criteria.*

The choice cannot rest on financial measures alone. The proposal scores five options — tokenization, ODA, PPP, phasing, and an arterial road in place of the metro — against ten criteria; the ranking depends on the priority order:

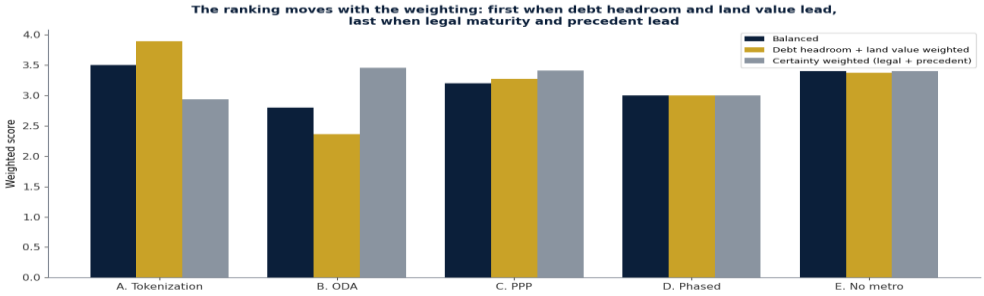



*Figure 5.3 — The token option's rank moves with the criterion weighted: first when debt headroom and land value lead, last when legal maturity leads.*

**Assessment**

Weighted for preserving debt headroom and public land value, the token option scores highest (3.9). Weighted for legal maturity and implementation precedent, it scores lowest (2.93), behind ODA, PPP and the arterial option, because Vietnam has no precedent for it.

**The token option is strongest on capital raising and debt-headroom preservation, and weakest on legal framework and implementation experience. It fits where the five legal conditions can be met and the city's priority is debt headroom. Where that does not hold, the phased option or PPP carries less risk.**

Recommendation: use phasing as the risk-management frame. Pilot the token mechanism on a short first segment; if the legal position and the market confirm the assumptions, extend tokenization to the full line; keep ODA or PPP as the fallback if the token route fails its legal conditions.

## 5.3. Economic contribution, year by year

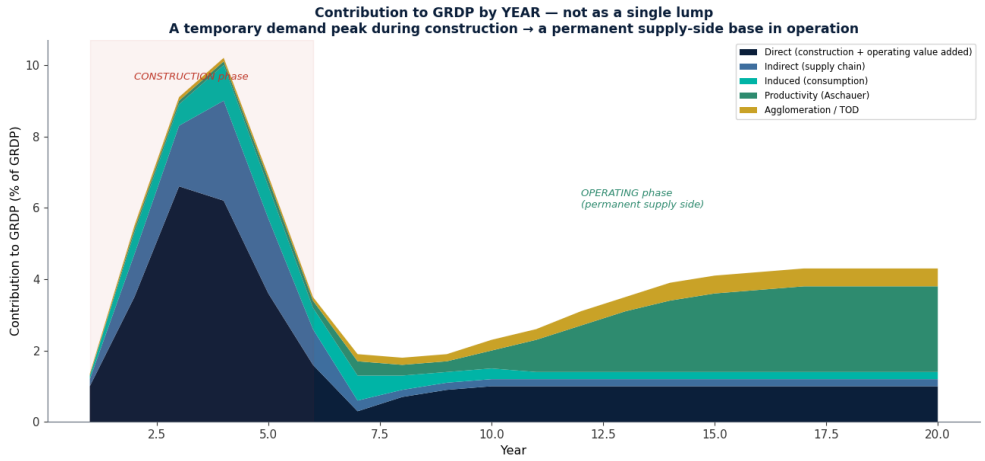



*Figure 5.4 — Contribution to GRDP: a temporary demand peak during construction, then a permanent supply-side base once operating.*

The economic contribution is presented year by year rather than as a single headline figure. During construction, the two projects create a large demand impulse, peaking at about 10% of GRDP in year 4 — but a temporary one, which disappears when construction ends. In operation they leave a permanent productivity base of about 3.4% of GRDP. Indirect effects — supply chain, consumption, productivity, agglomeration — account for about 76% of the long-run contribution. Reaching a double-digit growth target requires this to be combined with other sectors — manufacturing, services, tourism and FDI attraction.

## 5.4. Social impact, year by year

Social impact is likewise a year-by-year path, simulated across four dimensions with diffusion dynamics. Employment peaks during construction and then settles into durable operating employment (about 202,000 by year 20). Metro ridership builds along an S-curve after opening, reaching a shift away from motorcycles of about 18% by year 20. Resettlement affects roughly 6,353 households, concentrated in the first three years, with the livelihood deficit returning to zero around year 7 if the programme is run well.

**Consequences that require attention**

Land value capture works by raising land prices to fund the project, and the same mechanism makes housing less affordable for local residents — from about 27 to 37 years of income to buy a TOD apartment by year 20. The harder the capture, the harder local purchase becomes. The counterweights are the social-housing ratio and a mechanism that returns part of the uplift to the community. This trade-off should be stated openly in the file put to the appraisal council.

## 5.5. Environmental impact

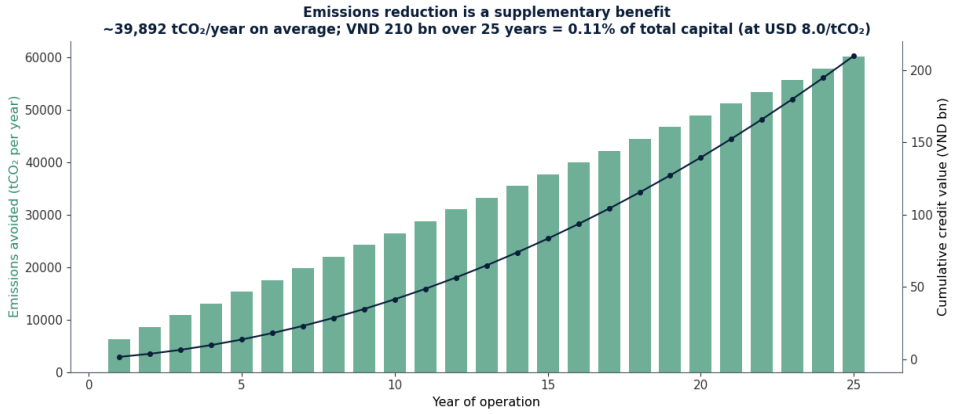



*Figure 5.5 — Emissions avoided through modal shift; credit value is small relative to total capital.*

The Metro displaces motorcycle and car trips and therefore cuts emissions, but the financial scale of that benefit is small. The simulation gives an average of about **39,892 $tCO_2$ per year** (60,116 $tCO_2$ at steady-state operation). At USD 8 per tonne[18], credits are worth about VND 8.4 bn a year, or VND 210 bn cumulatively over 25 years — **0.11% of total capital**. Most of the reduction comes from cars rather than motorcycles, since Vietnamese motorcycles are already relatively efficient per kilometre. The value rises as the grid decarbonises. Treat emissions reduction as an environmental and air-quality benefit that strengthens the ESG file for international fundraising, not as a repayment source.

# 6. Financial projections and the investment case

On these results, what limits the ability to raise capital today is legal and execution risk, not the level of return. The proposal addresses both through a conditional commitment structure. This section sets out the debt service profile, the capital phasing plan, investor cash flows and the commitment mechanism.

## 6.1. Debt service profile and traction power cost

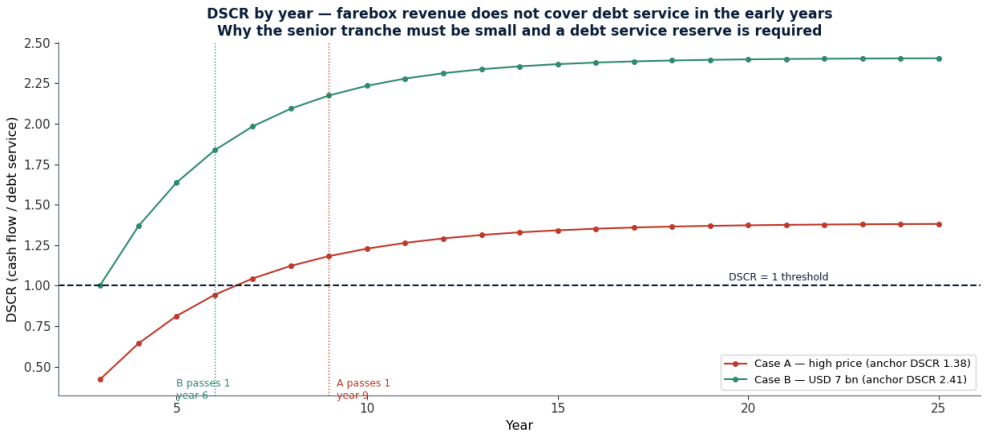



*Figure 6.1 — DSCR by year. Farebox revenue does not cover debt service in the first years of operation.*

Farebox revenue builds along an S-curve, so DSCR sits below 1 for the first few years of operation — normal for a metro line. In the high-price case (Case A) DSCR only passes 1 around year **9**; in the USD 7 billion case (Case B) it passes 1 earlier, around year **6**. At steady state, DSCR converges on the anchor levels of 1.38 (Case A) and 2.41 (Case B). Two design consequences follow: the senior tranche must be small enough for farebox revenue to carry, and a debt service reserve is needed for the early years before revenue reaches an adequate level. That is why the structure caps the senior tranche at 18% and no higher.

### Traction power cost

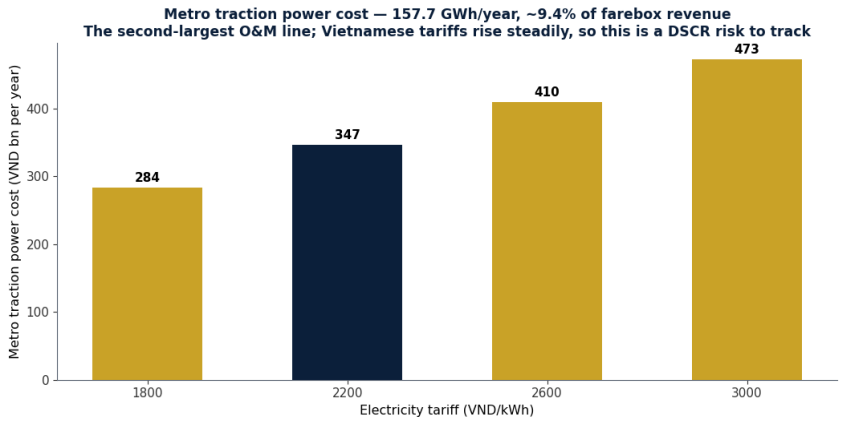



*Figure 6.2 — Metro traction power cost by electricity tariff; the second-largest O&M line after labour.*

Traction power is a major operating cost. The line consumes about **157.7 GWh a year**; at the current commercial tariff of VND 2,200 per kWh[17] that is about **VND 346.9 bn a year**, equal to 9.4% of peak farebox revenue — the second-largest O&M line after labour. Vietnamese electricity tariffs rise steadily, so this belongs in the DSCR projection as a risk: at VND 3,000 per kWh the cost rises to VND 473 bn a year, squeezing debt service cash flow in exactly the early years when it is already tight.

## 6.2. Capital phasing and milestone-linked drawdown

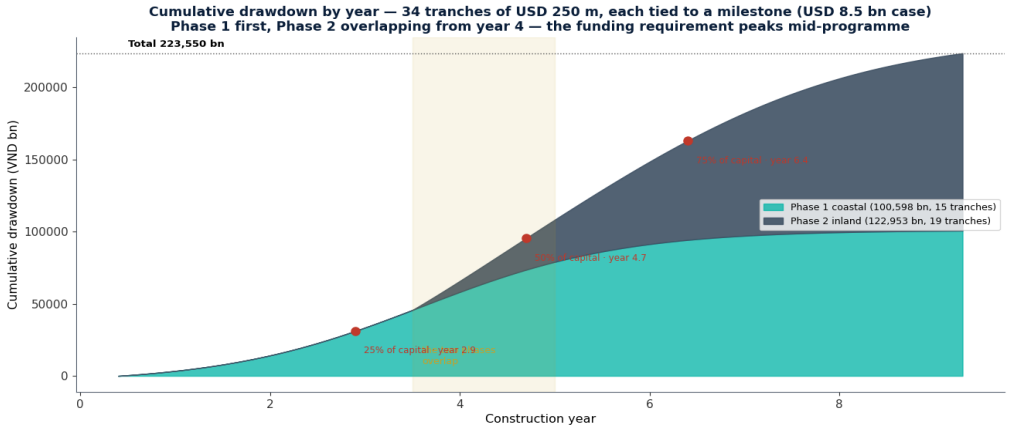



*Figure 6.3 — Cumulative drawdown by construction year. The two phases overlap from year four; the funding requirement peaks mid-programme.*

Capital is not drawn in one tranche. It is phased and tied to verification milestones, which limits commitment risk. Taking USD 8.5 billion as an illustration (mid-range), the total of VND 223,550 bn splits into VND 100,598 bn for the coastal Phase 1 and VND 122,953 bn for the inland Phase 2. Each drawdown is linked to a milestone achieved, not to a fixed calendar. Under the conditional commitment structure in Section 6.4, capital moves to the next tranche only once the previous milestone is confirmed; if a milestone fails, the remaining capital stays undisbursed and the exposure is contained at that point.

| Milestone | Drawdown trigger |
|---|---|
| **M1 — Legal conditions cleared** | A binding legal opinion on SPV share tokens and the foreign ownership limit; admission to the VIFC regulatory sandbox |
| M2 — Valuation and Phase 1 land | Independent valuation at pre-infrastructure value; Phase 1 land acquisition completed with an approved resettlement plan |
| M3 — Phase 1 operating | The coastal section in operation; Phase 1 farebox revenue and land values confirmed in practice |
| M4 — Phase 2 extension | Market and Phase 1 land values confirm the assumptions; drawdown opens for inland Phase 2 |

*Table 6.1 — Milestone-linked drawdown: capital moves only when the previous milestone is met*

## 6.3. The investor cash-flow profile

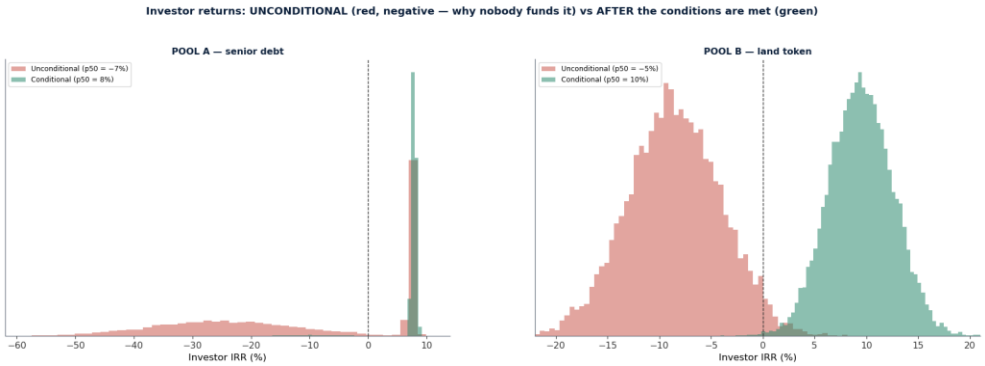



*Figure 6.4 — Unconditional return (red, negative) against return once the preconditions are satisfied (blue).*

**Why**

On the simulation, expected returns today are negative for both tranches: about −7% for the senior tranche with a 62% probability of default, and about −5% for the Value-Conversion Pool with a 56% probability of capital loss. Legal and execution risk account for most of that. Every investor category, from pension funds to venture funds, is materially exposed to the same two risks. The response is to change the transaction structure and the risk allocation, not to add more analysis.

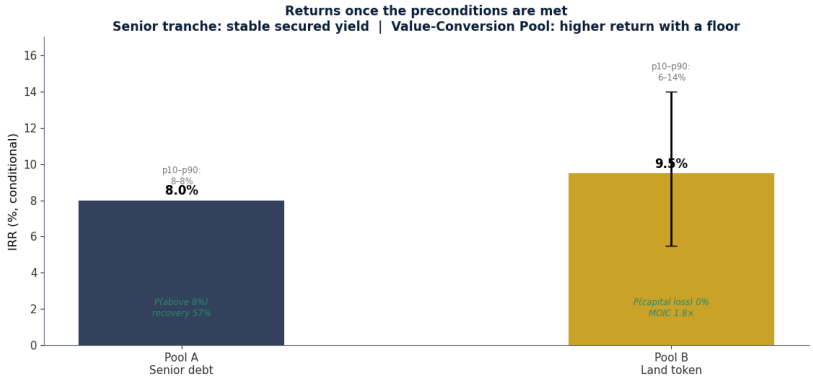



*Figure 6.5 — Conditional return: the senior tranche offers a stable secured yield; the Value-Conversion Pool offers higher upside with a floor.*

| Measure (post-conditions) | Senior Tranche — senior debt | Value-Conversion Pool — land token |
|---|---|---|
| Median IRR | 8.0% | 9.5% |
| IRR range, p10–p90 | 8–8% | 6–14% |
| Capital multiple (MOIC) | 1.80× | 1.82× |
| Probability of capital loss | 8% | 0% |
| Downside protection | ~57% recovery (senior) | floor = residual land value |

*Table 6.2 — Investor returns once the preconditions are met*

These returns correspond to infrastructure and real-estate funds — mid-range IRR with asset security — and sit below venture-fund returns. The senior tranche suits investors who need a stable income stream; the Value-Conversion Pool suits investors willing to take risk in exchange for land uplift.

## 6.4. The conditional commitment structure

An investor's commitment becomes a funding obligation only when the preconditions are met. Investors are not asked to commit capital against a 14% legal probability; they commit to participate on pre-agreed terms, conditional on the city clearing the legal conditions and on the price being settled. Because capital moves only on satisfaction of conditions, legal risk becomes a controlled process rather than an exposure investors carry directly. The five conditions:

1. **A binding legal opinion:** SPV share tokens may be issued, and the foreign ownership limit is determined.
2. **Metro capex fixed at USD 7 billion or below** under a framework agreement with the construction partner.
3. **An independent valuation** (a Big Four firm) at pre-infrastructure value.
4. **Phase 1 land acquisition** completed with an approved resettlement plan.
5. Admission to the VIFC regulatory sandbox.

Investor protections: SPV board seats and veto rights over material decisions; senior security for the senior tranche; anti-dilution for the Value-Conversion Pool; and automatic lapse of the commitment, with no capital at risk, if the conditions are not met within the agreed period.

## 6.5. Negotiating Metro capex with the construction partner

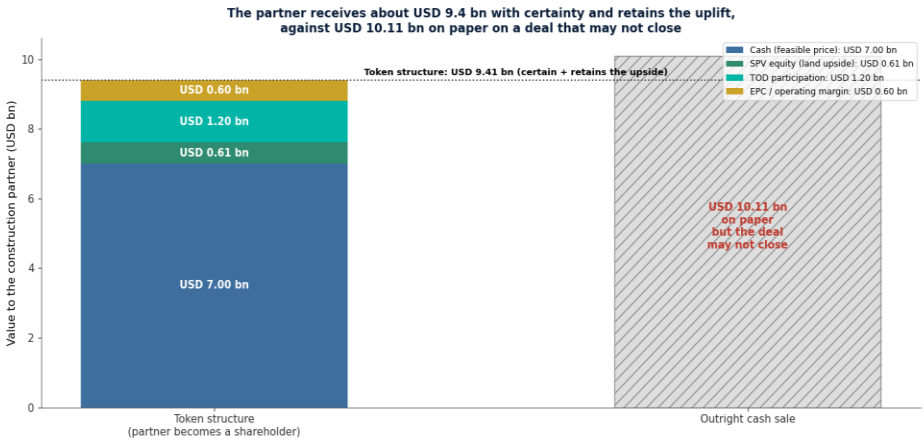



*Figure 6.6 — The construction partner receives about USD 9.4 billion of certain value plus retained uplift, against USD 10.11 billion on paper.*

At the USD 10.11 billion reference price the structure does not work. The proposal does not ask the partner to sell cheaply. Instead the partner becomes a strategic shareholder in the SPV, taking cash for the core scope (USD 7 billion), plus SPV equity (USD 0.61 billion, which retains land uplift), plus participation in TOD development (USD 1.2 billion), plus the construction and operating margin (USD 0.6 billion) — about **USD 9.41 billion** in total, close to the outright price at which the structure still works. This substitutes a high headline price of uncertain deliverability with an equivalent total value that is more certain and keeps the long-run uplift inside the structure.

# 7. Risk and control

Variance decomposition puts legal risk ahead of financial and technical risk. Alongside that, simulation output and observed data must be kept distinct. This section covers both.

## 7.1. Risk matrix

| Risk | Likelihood | Impact | Mitigation |
|---|---|---|---|
| Share tokens classified as securities and not permitted | **High** | Severe | Obtain a binding opinion first; pilot the legally less sensitive M3 model first |
| Metro capex stays at USD 10.11 billion | Medium | Severe | Negotiate the shareholding structure; conditional commitment at USD 7 billion or below |
| Less developable land along the corridor than expected | Medium | Severe | Survey the master plan first; concentrate TOD on the inland nodes (Phase 2) |
| Ridership as weak as the Cát Linh precedent | Medium | Moderate | Farebox revenue only has to cover a small senior tranche; land value covers the rest |
| Protracted land acquisition and disputes | **High** | Moderate | Resettlement plan and livelihood programme in advance; acquire in phases |
| FX volatility | Medium | Low | USD-weighted mix; hedge on CIP |

*Table 7.1 — Risk matrix and controls*

Four of the six risks trace back to the same three verification tasks in Section 8, and all three sit ahead of any capital commitment.

## 7.2. Controls that other jurisdictions already use

None of these risks is new. Singapore, Japan and Abu Dhabi have all met them and dealt with them while piloting asset tokenization and running regulatory sandboxes. The common feature is that each risk is tied to a specific, verifiable control rather than a general undertaking. The table below maps each risk in this proposal to a control already in use elsewhere.

| Risk | Control already in use (jurisdiction) |
|---|---|
| **Share tokens misclassified** | Abu Dhabi (ADGM) classifies tokens by **substance** rather than label: a token carrying voting rights, dividends or redemption is treated as a digital security and attracts full disclosure. Japan brought security tokens under the **existing securities law** (FIEA) instead of waiting for new legislation[20]. → This proposal obtains a classification opinion first, within the existing framework[21]. |
| **Capital committed and then the project fails to clear** | Singapore (MAS) requires **boundary conditions** limiting the scope of the test and an **exit plan covering both failure and success** before granting sandbox admission[19]. → This proposal uses conditional commitments and milestone-linked drawdown (Sections 6.2 and 6.4). |
| **Investor assets commingled or lost** | Japan mandates **segregation of client assets**, predominantly offline custody and an annual audit; ADGM requires asset segregation and periodic reporting[20]. → This proposal separates the senior tranche from the Value-Conversion Pool and uses an independent custodian. |

| Risk | Control already in use (jurisdiction) |
|---|---|
| **Land valuation inflated** | The UAE requires the assets underlying a token to be **verified by an independent auditor**, with periodic reporting to the regulator[21]. → This proposal requires an independent (Big Four) valuation and a field survey of the land before issuance. |
| **Secondary-market manipulation** | ADGM runs token trading venues as MTFs with **market surveillance, trade monitoring and record-keeping**; Singapore applies full AML/KYC[19]. → This proposal builds trade surveillance and customer identification into the compliance layer. |
| **Abuse of the sandbox** | The VIFC sandbox (Resolution 222) provides for an **independent supervisory body**; ADGM applies two-tier sanctions and asset-freezing powers on breach[21]. → This proposal operates under VIFC supervision. |

*Table 7.2 — Each risk mapped to a control proven elsewhere*

**What this shows**

Established financial centres do not rely on general undertakings; they rely on **specific mechanisms**: scope limits, exit plans, asset segregation, independent audit, trade surveillance and defined sanctions. Every mechanism proposed here — legal-first sequencing, conditional commitment, milestone-linked drawdown, separation of the two pools, independent valuation and VIFC supervision — has a precedent in another market. That is the line between a controlled pilot and an investment decision with no defences.

## 7.3. How reliable each number is

The proposal uses three grades of data with different reliability. The appraisal council needs to keep them apart — in particular, a simulated chart with an uncertainty band is not field data.

### Tier 1 — high confidence (verifiable)

| Figure / measure | Source / basis |
|---|---|
| Anchor DSCR: Case A 1.384 / Case B 2.406 | Computed from the contractor estimate (USD 10.11 bn) and the feasibility study (USD 7 bn) |
| Metro capex: contractor USD 10.11 bn; study USD 7 bn | Published contractor figure + feasibility study |
| Arterial land acquisition VND 19,109 bn (industrial land) | Project cost estimate |
| Legal framework: 2024 Land Law, Resolution 188/2025, Resolution 222/2025 Article 24 | Legislation in force |
| HK Rail + Property: government retains ~76% of shares; ~USD 2.33 bn, 1980–2005 | McKinsey 2016 (76%); Cervero & Murakami 2009 (USD 2.33 bn) |
| Korean land readjustment, Yongin IRR 262%; Gangnam appreciation ~13,000× | Kim 2023 (IDPR/SAGE) |
| Cát Linh ridership ~50,000 trips/day | Hanoi Metro operating reports |
| HCMC Metro Line 1: land prices around stations +12.4% | ResearchGate study, 2025 |

### Tier 2 — medium confidence (derived from international benchmarks)

| Figure / measure | Source / basis |
|---|---|
| Metro cost overrun +31% (used in the simulation) | Flyvbjerg (rail typically +45%) — discounted down |
| Land uplift 1.6–2.2× | HK MTR value-capture range [0.50–0.66] + precedent |
| Aschauer elasticity 0.08–0.12 | Bom & Ligthart 2014 (meta-analysis) |
| Senior tranche coupon ~8% (all currencies) | Covered interest parity from market rates |
| EBITDA margin 45–55% | International exchange benchmarks |
| Employment 8–12 per USD m of construction; metro 20–35 staff/km | ILO, developing economies; metro operating benchmarks |
| Bass diffusion p = 0.03, q = 0.38 | Bass 1969 + diffusion literature |

## Tier 3 — simulation scenarios (assumption-driven)

| Figure / measure | Source / basis |
|---|---|
| P(feasible) about 6% | Simulation output — depends on branch assumptions |
| P(all five legal conditions) ~14% | Product of [estimated] probabilities for each condition |
| ~6,353 households resettled; recovery by year 7 | Derived from land acquisition cost × assumption [G] — requires a field survey |
| ~202k jobs; modal shift ~18% | Bass simulation — no Da Nang demand survey exists |
| Housing affordability 27 → 36.6 years | Simulated — local house price/income is [G] |
| EVPI VND 1,567 bn; GRDP contribution by year | Simulation output from reference parameters |
| Developable land share along the corridor 25% | [G] — requires the master plan |
| Land value: pre VND 106,568 bn / post VND 215,321 bn | [G] — requires an independent Big Four valuation |

**Note**

Tier 1 — high confidence: debt service coverage, legislation, the Hong Kong and Korean precedents, the contractor quote. Tier 2 — medium confidence, because it is derived from international benchmarks. **Tier 3 is scenario, not data** — the roughly 6% feasibility probability, the roughly 14% legal probability, the resettlement count, the employment figure and housing affordability all come from estimated parameters, with no observed Da Nang data behind them. Tier 3 is useful for showing the dynamics and setting research priorities, not as an absolute number on which to decide an investment.

# 8. Conclusion and next steps

**Tokenizing Da Nang's infrastructure is structurally feasible if it is done correctly: tokenize shares in a company holding time-limited land use rights, on the Hong Kong model; separate a small interest-bearing debt layer from a non-interest-bearing land-uplift layer; and leave the city with about 72% of the uplift. But that feasibility is conditional, and the conditions are not yet met.**

## 8.1. Conclusion

This proposal is a basis for approving research expenditure, not for an investment decision. Three foundations remain unverified, and each requires data or a real negotiation rather than further analysis:

| Unverified foundation | Why it matters | How to verify it |
|---|---|---|
| Developable land along the corridor | The single largest driver of feasibility (Section 4.3) | Master-plan survey + independent valuation |
| Actual Metro capex | At USD 10.11 bn, feasibility ≈ 0 | Negotiate the shareholding structure with the construction partner |
| Legal treatment of share tokens | A decision gate; the 14% figure is an estimate | Obtain a binding opinion from the competent authority |

*Table 8.1 — Three foundations to verify before any capital commitment*

## 8.2. Three things to do first

The next steps are three concrete tasks, each with one document to prepare:

1. **Land survey and independent valuation —** answers the single largest driver, and costs less than a demand study.
2. **Negotiate Metro capex —** bring the construction partner into a shareholding structure that retains uplift, targeting USD 7 billion or below.
3. **Obtain a legal opinion on the one decisive question —** whether SPV share tokens are securities, and what foreign ownership limit applies.

What is still missing is third-party evidence of commitment. A conditional commitment from an investor, or a binding legal opinion, would move this proposal from analysis to something that can be executed.

## 8.3. What success would mean

If the three conditions are met, the model follows precedents set in major Asian cities. Vietnam has no comparable precedent on record.

| Precedent | What it achieved | Implication for Da Nang |
|---|---|---|
| **Hong Kong — Rail + Property** | Self-financed one of the world's leading metro systems; government retained about 76% of the shares, and the mechanism generated about USD 2.33 billion of value between 1980 and 2005 | Transport infrastructure can pay for itself out of land value without burdening the budget. |
| **Japan — Progmat** | A bank-led platform tokenizing real property and bonds, operating inside the existing securities framework | Tokenized real-world assets can reach institutional scale once the legal framework is clear. |

| Precedent | What it achieved | Implication for Da Nang |
|---|---|---|
| **Korea — Yongin land readjustment** | Retained land appreciated sharply once the infrastructure was in place, repaying the project | Land value around stations is a genuine repayment source, if the right share is retained at the right time. |

*Table 8.3 — International precedents and what they imply for Da Nang*

In the Vietnamese context, this is the **test first, legislate after** mechanism that Resolution 222 opens up for the International Financial Centre. Executed successfully in Da Nang, it produces three results beyond the project itself: an **infrastructure funding channel** that does not add to public debt, **legal evidence** on tokenizing shares tied to land use rights, and a **replicable template** for other cities inside the VIFC. The proposal needs rigorous verification; if it succeeds, the model extends to comparable infrastructure beyond this metro line.

## 8.4. Timetable

| Milestone | Action |
|---|---|
| 30 days | Commission the land survey and independent valuation; draft the legal questions |
| Month 3 | Valuation results in hand; legal opinion requested; Metro capex negotiation opened |
| Month 6 | All three verification results available → decide whether to move to the capital commitment stage |
| Month 12 | If all three conditions are met: sign conditional commitments with anchor investors; pilot the first segment |

*Table 8.2 — Verification milestones*

# Appendix A — Method and detailed assumptions

This appendix sets out how the simulation was built and which assumptions drive it, so that readers can judge the reliability of each result.

## A.1. The simulation model

- **Financial simulation:** Monte Carlo over 2,387,600 paths with 507 agents and a fixed seed for reproducibility. Each path is one combination of Metro capex, ridership, legal outcome, land price and exit timing.
- **Time-phased economic simulation:** lagged multipliers on the demand side; productivity via the Aschauer elasticity[12] (0.08–0.12 per the Bom & Ligthart meta-analysis[13]); urban agglomeration via Bass diffusion[14].
- **Time-phased social simulation:** four dimensions (employment, ridership, resettlement, housing) with Bass diffusion and a livelihood recovery path.
- **Metro capex grid:** 13 price points from USD 7 to 10 billion in USD 250 million steps; at each point, steady-state DSCR (interpolated between the two anchors), feasibility probability (Monte Carlo) and the city's net position.
- **Traction power:** estimated from steady-state passenger-kilometres at 0.10 kWh per passenger-km plus 20% station load, multiplied by the commercial tariff, with sensitivity to the tariff.
- **Carbon:** emissions avoided through modal shift (motorcycle and car to metro), net of metro traction emissions on a grid factor declining 2.3% a year; valued at USD 8 per tonne.
- **Sensitivity analysis:** each variable run from its low to its high value around the base case, measuring the swing in feasibility probability (40,000 samples per point).

## A.2. Key assumptions requiring verification

| Assumption | Value used | To be replaced by |
|---|---|---|
| Developable land share along the corridor | 55% [estimated] | The actual master plan |
| Land value, pre / post infrastructure | VND 106,568 / 215,321 bn [estimated] | Independent Big Four valuation |
| Probability of each legal gateway condition | Subjective estimate | Binding opinion from the competent authority |
| Households resettled | ≈6,353 [estimated] | Field survey |
| Ridership curve | Bass diffusion [estimated] | Independent demand study |

*Table A.1 — Key assumptions and the data needed to replace them*

On advisers: expert views on token design and compliance governance were sought while the proposal was being prepared. Those views are consultative and do not constitute formal commitments to co-operate; no names are given, to avoid implying an obligation that does not exist.

# Appendix B — References

Every marked figure or assertion in the proposal is tied to the corresponding source below (accessed 2025–2026). Legal instrument numbers and operating data follow the preparer's file; originals should be checked before the material is relied on for legal or investment purposes.

## A. Vietnamese legal instruments

**[1]** Constitution of the Socialist Republic of Vietnam (2013), Article 53 — land is owned by the people as a whole, with the State as representative owner.

**[2]** Land Law 31/2024/QH15, Articles 28 and 42 — foreign-invested economic organisations may receive land use rights as a capital contribution; land leases run to a maximum of 50 years, or 70 in special cases.

**[3]** Securities Law 54/2019/QH14 (as amended) — the framework for classifying and offering capital instruments.

**[4]** Resolution 188/2025/QH15 of 19 February 2025 (National Assembly) — pilot mechanisms and special policies for developing the Hanoi and Ho Chi Minh City urban rail networks on the TOD model; defines the TOD zone and the mechanism for capturing land value around stations. (Applies to Hanoi and Ho Chi Minh City; cited here as legal precedent for the TOD model.)

**[5]** Resolution 222/2025/QH15 of 27 June 2025 (National Assembly) — the International Financial Centre in Vietnam; Article 13 (exchanges and new trading platforms), Article 24 (regulatory sandbox). In force from 1 September 2025.

## B. Land value capture and tokenization precedents

**[6]** McKinsey & Company (2016), *The 'Rail plus Property' model: Hong Kong's successful self-financing formula for public transit* — the Hong Kong government retains about 76% of MTR.

**[7]** Cervero, R. & Murakami, J. (2009), *Rail and Property Development in Hong Kong: Experiences and Extensions* — the Rail+Property model generated about USD 2.33 billion of value between 1980 and 2005.

**[8]** Suzuki, H., Murakami, J., Hong, Y-H. & Tamayose, B. (2015), *Financing Transit-Oriented Development with Land Values*, World Bank — four success conditions for land value capture: state leasehold tenure, high urban density, a proactive administration and operator, and a sound legal framework.

**[9]** Kim, H.M. (2023), *International Development Planning Review* (SAGE) — Korean land readjustment; the Yongin–Jukjeon scheme, where retained land appreciated sharply after infrastructure.

**[10]** São Paulo — Certificates of Additional Construction Potential (CEPAC, Certificados de Potencial Adicional de Construção), auctioned on an exchange; the precedent for digitizing land development rights.

**[11]** Hong Kong Monetary Authority (HKMA) — tokenized green bond issuance; Progmat platform (Japan) — digital securities issuance.

## C. Method and theory

**[12]** Aschauer, D.A. (1989), *Is Public Expenditure Productive?*, Journal of Monetary Economics 23(2):177–200 — the foundational study on the productivity of public capital.

**[13]** Bom, P.R.D. & Ligthart, J.E. (2014), *What Have We Learned From Three Decades of Research on the Productivity of Public Capital?*, Journal of Economic Surveys 28(5):889–916 — public capital productivity elasticity of 0.083 (short run) to 0.122 (long run).

**[14]** Bass, F.M. (1969), *A New Product Growth for Model Consumer Durables*, Management Science 15(5):215–227 — the diffusion model used for ridership projection and time-phased social impact.

## D. Market and operating data

**[15]** World Bank — infrastructure financing frameworks and management of sub-national debt limits.

**[16]** Da Nang Metro Line 1 project file — contractor estimate of USD 10.11 billion and feasibility study of about USD 7 billion.

**[17]** Vietnam Electricity (EVN) — commercial electricity tariff schedule (about VND 2,200/kWh at the date of this proposal).

**[18]** Vietnam grid emission factor (as published by the regulator) and voluntary-market carbon credit prices (about USD 8/$tCO_2$ ) — used for the emissions estimate; see the limitations in Appendix C.

## E. International risk controls (Section 7.2)

**[19]** Monetary Authority of Singapore (MAS) — *FinTech Regulatory Sandbox Guidelines* (2016, updated 2022): boundary conditions limiting the scope of the test, exit plans for both failure and success, periodic reporting; the guidance on protecting payment-token service users requires segregation of client assets.

**[20]** Japan Financial Services Agency (JFSA) and the Japan Security Token Offering Association (JSTOA, founded 2019) — security tokens regulated under the Financial Instruments and Exchange Act (FIEA); requirements for segregation and secure custody of client assets and periodic audit; a self-regulatory body run by the major securities houses (SBI, Nomura, Rakuten).

**[21]** Financial Services Regulatory Authority (FSRA), Abu Dhabi Global Market (ADGM) — *Guidance on Regulation of Virtual Asset / Digital Securities Activities*: classification of tokens by substance (tokens carrying voting rights, dividends or redemption are treated as digital securities), full disclosure, independent auditor verification of underlying assets, custody segregation, trade surveillance and sanctions.

## F. Project separation, tourism land and BOT tolls (Sections 4.6–4.7)

**[22]** International Transport Forum / OECD (2018), *Funding Transport: Land Value Capture*; together with the hedonic literature on the coastal amenity premium in hotel and tourism accommodation valuation — commercial and tourism land typically carries a higher uplift multiple than residential, and captured value accrues non-linearly over time. This is the basis for the 3.0 multiple on coastal tourism land and for the 50-year value maturation curve.

**[23]** Compiled toll schedules from standard-compliant Vietnamese BOT road projects (the Hanoi–Hai Phong and Long Thanh expressways and newer routes): tolls of about VND 1,500–2,000/km for a standard vehicle, 30-year concessions, periodic toll adjustment; cross-referenced against international practice (Jasa Marga in Indonesia, NHAI in India).

# Appendix C — Caveats and limitations

This is an early-stage feasibility study. So that the appraisal council and investors can read it correctly, the following points qualify how certain its content is.

Most of the financial and social figures are simulation output based on estimated parameters, with no observed Da Nang data behind them. Specifically: the roughly 6% feasibility probability, the roughly 14% probability of clearing the five legal conditions, the roughly 6,353 households resettled, the roughly 202,000 jobs and all housing-affordability measures belong to the third confidence tier (Section 7.2). They are useful for showing dynamics and setting priorities, not as absolute numbers on which to decide an investment.

Pre- and post-infrastructure land values are estimates and require independent valuation. The developable land share along the corridor — the single largest driver of feasibility — requires the actual master plan to establish. The probabilities attached to the legal conditions are the analysis team's subjective estimates, not the view of a competent authority; legal instrument numbers follow the preparer's file, and originals should be checked before the material is relied on for legal purposes. The ratios and multiples used to separate the projects and price tourism land — the 45% tourism land share and the 3.0 multiple; the 50% industrial use-mix; the base Arterial flow of 30,000 vehicles a day — are base assumptions with sensitivity ranges in Appendix D, and require the master plan and a field survey to confirm.

The two Metro capex figures (USD 7 billion and USD 10.11 billion) have not been reconciled through negotiation. The shareholding structure and the sharing mechanism with the construction partner are proposals for negotiation, not commitments. The investor returns in Section 6 are conditional returns, achievable only if the preconditions are met; on an unconditional basis, expected returns are negative. Nothing in this proposal constitutes legal, financial or investment advice, and it is not an offer of securities.

On the option comparison (Section 5.2): the PPP and ODA options were assessed on a reduced-form cash-flow net position and scored against ten criteria, not modelled through a full PPP cash-flow model (BOT/BTL with detailed risk allocation). Their net position figures are comparative estimates and do not substitute for a separate feasibility study of each option.

On power and carbon: Metro traction power cost rests on an assumed energy intensity and tariff, and requires actual operating data to establish. Emissions avoided depend on the modal shift rate and the grid factor, both estimated; carbon credit value is small relative to total capital and should not be counted as a repayment source.

# Appendix D — Data sources and calculations

This appendix traces the origin of every number used in the proposal. Each number carries a code (D1, D2 …) and is classified into one of four origin groups; the final column gives the source document or the calculation itself. The purpose is to let the reader separate figures taken from documents from figures produced by calculation or simulation, and to see which method produced each simulated figure.

| Src | Meaning |
|---|---|
| V | Verbatim from a legal instrument or project file — the bracketed reference points to Appendix B |
| T | Transformed: a direct calculation — the formula is given on the same row |
| M | Modelled: Monte Carlo or agent-based simulation output (dfl24sim package, fixed seed 20260626) |
| G | Ground-truth required: a base assumption needing field data or an official document to confirm it (see Appendix C) |

*Table D.0 — The four origin groups*

Amounts are in VND billion unless stated otherwise. A single exchange rate of VND 26,300 per USD is used throughout (D6).

## D.1. Project scale and total capital

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D1 | Metro capex (two reference points) | USD 7 and 10.11 bn | V | Da Nang Metro Line 1 file: contractor estimate USD 10.11 bn; feasibility study ≈USD 7 bn [16] |
| D2 | Total Metro capital at USD 7 bn | 184,100 | T | = 7 × 26,300 (D6) |
| D3 | Total Metro capital at USD 10.11 bn | 265,893 | T | = 10.11 × 26,300 |
| D4 | Metro length / stations | 103 km · 24 ga | V | Da Nang urban rail master plan (airport – Hoi An – Tam Ky – Chu Lai) |
| D5 | Total Urban Arterial capital | 30,898 | G | Project file / preliminary estimate; an official cost estimate is required |
| D5b | Urban Arterial length | 87.6 km | V | Urban Arterial project file |
| D6 | Exchange rate | VND 26,300 per USD | V | Reference rate at the date of this proposal |
| D7 | Land acquisition and resettlement (Metro) | 19,109 | G | Estimate; an actual valuation and compensation plan are required |

*Table D.1 — Scale and total capital*

## D.2. The two-tranche capital stack

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D8 | Senior tranche share (senior debt) | 18% | G | Design: set small enough for farebox revenue to service (Section 6.1) |
| D9 | Value-Conversion Pool share (land-uplift participation) | 57% | G | Structural design; the remainder is covered by land value |
| D10 | Public seed capital | 46,025 | T | = 184,100 × 25% |
| D11 | Senior tranche coupon | ≈8% p.a. | T | Covered interest parity (CIP): USD rate + hedging cost |

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D12 | Senior tranche financing cost | 39,766 | T | = 0.18 × 184,100 × (0.06 + 0.02) × 30 × 0.5 (interest plus token premium, 30-year life) |

*Table D.2 — The two-tranche capital stack*

## D.3. Currency mix (Section 3.4)

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D13 | Lowest-risk mix | USD 45 / VND 30 / KRW 20 / JPY 5 | M | Minimises FX CVaR across the mix grid (FX simulation) |
| D14 | CVaR, lowest-risk mix / 100% USD | 713 / 1,177 | M | 95% CVaR on the foreign-currency obligation portfolio; FX simulation package |

*Table D.3 — Currency mix*

## D.4. Land value capture — three models (Section 3.3)

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D15 | Pre-infrastructure land value (whole corridor) | 106,568 | G | Estimated pre-infrastructure value; independent valuation required |
| D16 | Post-infrastructure land value (whole corridor) | 215,321 | G | Combined Metro and Arterial value at base multiples; separated in D.5 |
| D17 | Land uplift | 108,753 | T | = 215,321 − 106,568 |
| D18 | M1 — Development rights + shares (72%) | 154,660 | T | = the city's share under the Hong Kong Rail+Property model [6] |
| D19 | M2 — Consolidation and land readjustment (53%) | 113,754 | T | Retention rate under Japanese/Korean land readjustment [9] |
| D20 | M3 — Revenue sharing on land use rights (12%) | 25,526 | T | Business co-operation on land use rights |

*Table D.4 — Three land value capture models (whole corridor)*

## D.5. Project separation and coastal tourism land (Section 4.6)

This is the newest group of figures and the one that most needs to be transparent. All of it derives from base land values by land type (D21, D22), uplift multiples by type (D25–D27), planning ratios (D23, D24, D28) and one resonance factor (D29). Every planning ratio is an assumption requiring the actual master plan.

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D21 | Base value, industrial/logistics land | 42,000 | G | Estimate for industrial land along the Arterial; independent valuation required |
| D22 | Base value, TOD land around Metro stations | 79,792 | G | Estimate for land around Metro stations; independent valuation required |
| D23 | Developable land share, both zones | 25% | G | Estimate; requires confirmation from the master plan |
| D24 | Industrial use-mix of developable land | 50% | G | Base estimate; sensitivity range 30–70% (Section 4.6) |
| D25 | Uplift multiple, industrial land | 1.6 | G | Range [1.3–2.0]; commercial/industrial land [22] |

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D26 | Uplift multiple, residential land | 2.2 | G | Range [1.5–3.0]; residential land [22] |
| D27 | Uplift multiple, tourism/commercial land | 3.0 | G | Range [2.5–3.5]. Coastal hotel and commercial land appreciates more than residential; basis: commercial > residential, plus the coastal amenity premium [22] |
| D28 | Tourism/commercial share of Metro TOD land | 45% | G | Base estimate; sensitivity range 30–60%. The line runs airport → My Khe beach → Hoi An, a coastal tourism corridor |
| D29 | Resonance factor in the overlap zone | +15% | G | Both works raise prices in the overlap area |
| D30 | Base land value, Metro only | 59,844 | T | = 79,792 × (1 − 25%) |
| D31 | Base land value, overlap zone | 15,224 | T | = 25% × 0.5 × (42,000 + 79,792) |
| D32 | Metro TOURISM land value | 80,789 | T | = 59,844 × 45% × 3.0 (D30 × D28 × D27) |
| D33 | Metro RESIDENTIAL land value | 91,670 | T | = 59,844 × 55% × 2.2 + 15,224 × 0.5 × 2.2 × 1.15 (= 72,411 + 19,258) |
| D34 | Metro capture value (total) | 172,459 | T | = 80,789 + 91,670 (D32 + D33) |
| D35 | Arterial capture value | 64,406 | T | = 42,000 × 0.75 × 1.6 + 15,224 × 0.5 × 1.6 × 1.15 (= 50,400 + 14,006) |
| D36 | Metro-attributable land retained by the city | 124,170 | T | = 0.72 × 172,459 (D34) |
| D37 | Metro break-even price excluding tourism value | ≈USD 8.9 bn | T | Solves net(price) = 0 with retained land of 0.72 × 150,915 (Metro without the tourism component) |

*Table D.5 — Project separation and coastal tourism land*

## D.6. Urban Arterial: BOT tolls and capex ceiling (Section 4.7)

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D38 | BOT toll | VND 1,500–2,000/km | V | The level charged on standard-compliant Vietnamese BOT roads (Hanoi–Hai Phong, Long Thanh) [23] |
| D39 | Traffic | base 30,000 vehicles/day | G | Base estimate; range 20,000–40,000 (urban); DSCR 1.59–3.17 across the range |
| D40 | Operating cost ratio (O&M) | 30% | G | As a share of toll revenue |
| D41 | Concession term | 30 years | V | BOT market practice [23] |
| D42 | Net toll revenue p.a. (low/mid/high) | 672 / 1,175 / 1,790 | T | = toll × 87.6 × traffic × 365 × (1 − 30%) ÷ $10^9$ |
| D43 | Arterial senior tranche | 5,562 | T | = 0.18 × 30,898 |
| D44 | 30-year debt service annuity at 8% | 494 p.a. | T | = 5,562 × 0.08 × $1.08^{30}$ ÷ ($1.08^{30}$ − 1) |
| D45 | DSCR at capex of 30,898 (low/mid/high) | 1.36 / 2.38 / 3.62 | T | = net revenue (D42) ÷ annuity (D44) |
| D46 | Arterial-attributable land retained | 46,372 | T | = 0.72 × 64,406 (D35) |

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D47 | Arterial net position at capex of 30,898 | +31,974 | T | = 46,372 − 30,898 × 0.466 (D46 − capex × factor D58) |
| D48 | Capex ceiling (low/mid/high) | 40,000 / 72,500 / >90,000 | M | Capex sweep, taking the highest level still holding DSCR ≥ 1 and net position ≥ 0 |

*Table D.6 — BOT tolls and the Arterial capex ceiling*

## D.7. Land value maturation curve, 50-year horizon (Section 4.7)

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D49 | Time horizon | 50 years | V | Standard Hong Kong lease term [6]; maximum Vietnamese land use term [2] |
| D50 | Maturation function (logistic) | F(t) = 1/(1+e^(−k(t−t_mid))) | T | Value maturing each year: Δ(t) = realized(t) − realized(t−1) |
| D51 | Industrial land: t_mid 7, k 0.35 | 90% by year 14 | G | Matures fast once the road is open [22] |
| D52 | Tourism/commercial land: t_mid 12, k 0.22 | 90% by year 23 | G | Moderate; hotels are built once the line runs [22] |
| D53 | Residential land: t_mid 18, k 0.18 | 90% by year 31 | G | Slowest; requires population to arrive [22] |
| D54 | Discount rate | 8% p.a. | T | = senior tranche coupon (D11) |
| D55 | Present value factor | PV = Σ Δ(t)/(1.08)^t | T | Discounts the capture value maturing in year t |
| D56 | Present value / nominal | ≈39% | T | Across all three land types; an additional layer of conservatism, not a replacement for the nominal figure |

*Table D.7 — Maturation curve and present value*

## D.8. Metro capex grid and net position (Section 4.5)

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D57 | Anchor steady-state DSCR | 2.406 (at USD 7 bn) · 1.384 (at USD 10.11 bn) | M | Simulated steady-state farebox cash flow |
| D58 | Capital-to-cost conversion factor | 0.466 | T | = 0.25 (seed capital) + 0.18 × 1.2 (senior tranche financing cost) |
| D59 | DSCR by price (USD 7 → 10 bn) | 2.41 → 1.42 | T | Linear interpolation between the two anchors (D57) |
| D60 | P(feasible) by price | ≈17–20% | M | Monte Carlo; near-flat across price (capex is not the binding constraint) |
| D61 | Metro net position (USD 7 → 10 bn) | +38,379 → +1,612 | T | = 124,170 − total capital × 0.466 (D36 − capital × D58) |

*Table D.8 — Metro capex grid*

## D.9. Net position under five options (Section 5.1)

For each option, net position = land retained − city capital − financing cost, computed on the Metro project at USD 7 billion. Metro capture value (172,459) is below total capital (184,100), so only an option that transfers most of the capital requirement to investors produces a clearly positive net position.

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D62 | A. Token | +38,379 | T | = 124,170 − 46,025 − 39,766 (retains 72% of land, contributes 25% of capital, senior tranche 18%) |
| D63 | B. ODA | −48,461 | T | = 172,459 − 184,100 − 36,820 (retains 100% of land, carries 100% of capital) |
| D64 | C. PPP | +4,266 | T | = 117,672 − 73,640 − 39,766 (retains 68%, contributes 40% of capital) |
| D65 | D. Phased | +31,000 | T | = 106,925 − 46,025 − 29,900 (retains 62%, contributes 25%, lower financing cost) |
| D66 | E. No metro (BRT) | +34,186 | T | = 64,596 − 15,000 − 15,410 (small capital, low capture) |

*Table D.9 — Net position under five options*

## D.10. Financial and legal probabilities (Sections 4.2–4.4)

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D67 | Financial feasibility probability | 6.2% | M | Monte Carlo, 2,387,600 paths, 507 agents; product of the capital conditions |
| D68 | Probability of clearing all five legal conditions | ≈14% | G | Product of five conditional probabilities; the team's subjective estimate, not the view of a competent authority |
| D69 | Combined financial × legal probability | ≈0.86% | T | = 6.2% × 14% |
| D70 | Expected sunk loss if land is acquired first | ≈16,434 | T | = 19,109 × 86% (probability of not clearing the legal gateway; conservative assumption that nothing spent is recovered) |
| D71 | Value of the legal-first option | = D70 | T | The difference in expected loss between the two sequences (Section 4.4) |

*Table D.10 — Financial and legal probabilities*

## D.11. Economic and social impact (Sections 5.3–5.4)

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D72 | Public capital productivity elasticity | 0.08–0.12 | V | Aschauer [12]; Bom & Ligthart meta-analysis [13] |
| D73 | GRDP contribution (demand peak / supply base) | annual path | M | Lagged multipliers (demand) + elasticity-based productivity (supply) |
| D74 | Steady-state operating employment | ≈202,000 (year 20) | M | Four-dimension social simulation |
| D75 | Shift away from motorcycles | annual S-curve | M | Bass diffusion [14] |
| D76 | Households resettled | ≈6,353 | G | Estimate; field survey required |
| D77 | Housing affordability (years of income) | annual path | M | Simulated; deteriorates as value capture intensifies (the trade-off in Section 5.4) |

*Table D.11 — Economic and social impact*

## D.12. Traction power and carbon (Sections 5.5, 6.1)

| ID | Item | Value | Src | Basis / formula |
|---|---|---|---|---|
| D78 | Electricity consumption | by passenger-km | **T** | = steady-state passenger-km × 0.10 kWh/passenger-km + 20% station load |
| D79 | Commercial electricity tariff | VND 2,200/kWh | **V** | EVN tariff schedule [17] |
| D80 | Power cost p.a. | = D78 × D79 | **T** | Second-largest O&M line after labour; sensitive to the tariff |
| D81 | Emissions avoided | $tCO_2$ per year | **M** | Modal shift net of metro traction emissions (grid factor declining 2.3% p.a.) |
| D82 | Carbon credit price | USD 8 per tonne | **V** | Voluntary market [18] |
| D83 | Carbon value relative to total capital | small share | **T** | = emissions avoided × price; a supplementary benefit, not a primary repayment source |

*Table D.12 — Power and carbon*

Every figure coded G is an assumption that must be replaced by field data or an official document before it is used for an investment decision. The ones that matter most — the developable land share, the tourism land ratio and multiple (D24, D27, D28), base land values (D15, D21, D22) and the legal gateway probabilities (D68) — are restated in Appendix C.

# Appendix E — Formulas and quantitative methods

This appendix gives the mathematics and method behind each simulation block, so that a technical reviewer can verify how the results in the main text were produced. Appendix A describes the model and its assumptions; Appendix D traces the origin of each number; this appendix gives the formulas. Each section names the source module and, where applicable, the corresponding code in Appendix D.

> **Notation**
> Rates, discount factors and weights are written as decimals (0.08 = 8%). Amounts are in VND billion unless stated otherwise; the conversion rate is VND 26,300 per USD. $t$ is the time index in years (or months where stated), $H$ the horizon, $r$ the interest or discount rate, $\sigma$ volatility, $w_i$ the weights, Σ a sum, Π a product, $E[\cdot]$ expectation, $Var(\cdot)$ variance. The caret ^ denotes exponentiation where the exponent has more than one term.

## E.1. Core finance formulas

The formulas reused across every valuation and debt-capacity block. Source: *core/finance/primitives.py*.

$$NPV = \Sigma\, CF_t / (1+r)^t - C_0 \quad (t = 1 \ldots T) \quad \text{(E.1)}$$

$$a(r,n) = (1 - (1+r)^{-n}) / r \quad \text{(E.2)}$$

$$IRR:\ \text{the root } r \text{ of } \Sigma\, CF_t / (1+r)^t = 0 \quad \text{(Newton–Raphson iteration)} \quad \text{(E.3)}$$

$$IRR = MOIC^{(1/n)} - 1 \quad \text{(zero-coupon token, single repayment)} \quad \text{(E.4)}$$

$$DSCR = NOI / (\text{principal} + \text{interest due in the year}) \quad \text{(E.5)}$$

$$LLCR = PV(\text{remaining cash flow}) / \text{outstanding debt} \quad \text{(E.6)}$$

$CF_t$ cash flow in year t; $C_0$ initial capital outlay; *NOI* net operating income; *MOIC* multiple on invested capital. Financing thresholds applied: DSCR ≥ 1.4 and LLCR ≥ 1.6 (Table 6.x). Corresponding Appendix D codes: the DSCR series (cash-flow group).

## E.2. Two-tranche capital stack and cost of capital

The senior tranche is coupon-bearing debt; the Value-Conversion Pool is repaid out of land uplift and carries no interest charge against project cash flow (which is why it is excluded from DSCR). Source: *capital_structure.py*, *fx_optimizer.py*.

$$\text{Effective coupon (CIP, hedged component):}\ \ c = r_{base} + (r_{VND} - r_{base}) + spread \quad \text{(E.7)}$$

$$\text{Weighted senior tranche coupon:}\ \ \bar{c} = \Sigma\, w_i\, c_i \quad \text{(E.8)}$$

$$\text{Value-Conversion Pool return:}\ \ R = uplift / (1 - issue\_discount) - 1;\ \ annualised: (1+R)^{(1/H)} - 1 \quad \text{(E.9)}$$

$$\text{FX loss:}\ \ L_{FX} = principal \times \Sigma\, w_i\, (1 - hedge) \cdot \max(0, \Delta S_i) \quad \text{(E.10)}$$

$$\text{Objective function for the currency mix:}\ \ \min [\ \bar{c} + \lambda \cdot CVaR / principal\ ] \ \ \text{subject to}\ \ w_{USD} \geq 0.40 \text{ and } w_{USD} = \max w_i \quad \text{(E.11)}$$

Effective coupon under covered interest parity (CIP): forward points ≈ the domestic minus foreign rate differential. *hedge* is the hedge ratio (base 0.7); $\lambda$ the risk-aversion coefficient; CVaR per formula E.21. Appendix D codes: the FX mix (USD 45% / VND 30% / KRW 20% / JPY 5%), coupon ~8%.

## E.3. FX and yield-curve simulation (no-arbitrage)

Multi-currency exchange rates are simulated on CIP rather than as independent processes, so the no-arbitrage condition holds. Source: *macro.py*, *abm/model.py*.

$$\text{CIP (stochastic differential equation):}\quad dS/S = (r_{dom} - r_{for})\,dt + \sigma\,dW \qquad \text{(E.12)}$$

$$\text{Nelson–Siegel yield curve:}\quad y(\tau) = \beta_0 + \beta_1 \cdot (1-e^{-x})/x + \beta_2 \cdot [(1-e^{-x})/x - e^{-x}],\quad x = \tau/\lambda \qquad \text{(E.13)}$$

$$\text{Discount factor:}\quad DF(\tau) = 1 / (1 + y(\tau))^{\tau} \qquad \text{(E.14)}$$

$$\text{Multi-currency correlation:}\quad Z' = L \cdot Z,\quad \text{where}\quad C = L\,L^{T}\ \text{(Cholesky decomposition)} \qquad \text{(E.15)}$$

$$\text{Land price (GBM):}\quad S_{t+1} = S_t \cdot \exp[(\mu - \tfrac{1}{2}\sigma^2)\Delta t + \sigma\sqrt{\Delta t} \cdot Z] \qquad \text{(E.16)}$$

$$\text{Mean-reverting rate/FX (Vasicek):}\quad r_{t+1} = r_t + \kappa(\theta - r_t)\Delta t + \sigma\sqrt{\Delta t} \cdot Z \qquad \text{(E.17)}$$

$S$ the VND/foreign-currency rate; $W$ Brownian motion; $Z$ a standard normal variate; $\kappa$ the speed of reversion, $\theta$ the long-run equilibrium level; $\beta_0, \beta_1, \beta_2$ and $\lambda$ the yield-curve parameters; $C$ the FX correlation matrix (USD–VND 0.45; USD–KRW 0.50).

## E.4. Land value capture and separation over time

TOD land value matures along a logistic curve over 50 years, is discounted to present value, and is then split between the two projects by land use. Source: *corridor_v6.py*, *land_models.py*, *land_overlap.py*.

$$\text{Maturation curve (logistic CDF):}\quad F(t) = 1 / (1 + e^{-k(t - t_{mid})}) \qquad \text{(E.18)}$$

$$\text{Normalised maturation:}\quad realized(t) = (F(t) - F(0)) / (F(H) - F(0)) \qquad \text{(E.19)}$$

$$\text{Present value factor:}\quad \varphi = \Sigma\,[realized(t) - realized(t-1)] / (1+r)^{t}\quad (t = 1\ldots H) \qquad \text{(E.20)}$$

$$\text{Tourism/commercial value:}\quad V_{tour} = V_{base} \cdot f_{tour} \cdot u_{tour} \qquad \text{(E.21)}$$

$$\text{Overlap split by use-mix:}\quad V_{ind} = V_{overlap} \cdot u;\quad V_{res} = V_{overlap} \cdot (1 - u) \qquad \text{(E.22)}$$

$$\text{BOT revenue p.a.:}\quad Rev = toll_{km} \times L \times Q \times 365 \times (1 - O\&M) \qquad \text{(E.23)}$$

$$\text{City net position:}\quad NP = land_{retained} - 0.25 \cdot V - (0.18 \times 1.2) \cdot V \qquad \text{(E.24)}$$

The 0.466 factor in the net position = 0.25 (public seed capital and land acquisition) + 0.18 × 1.2 (senior tranche financing, including a 20% arrangement fee). $k$ is the slope of the value maturation curve, $t_{mid}$ the year at which 50% is reached (industrial ≈ 7, commercial ≈ 12); $f_{tour}$ the tourism land ratio (0.45), $u$ the industrial use-mix ratio. Appendix D codes: 184,100 (capex), 172,459 (nominal capture value), 124,170 (Metro-attributable land retained).

## E.5. The legal gateway and the value of sequencing

The five legal conditions are modelled as independent events (a conservative assumption); the value of establishing the legal position first is quantified as an option. Source: *legal_gateway.py*, *factors.py*.

$$\text{Probability of clearing all five conditions:}\quad P = \Pi\,p_i\quad (i = 1\ldots5) \qquad \text{(E.25)}$$

$$\text{Expected loss:}\quad E[L] = \Sigma\,(1 - p_i) \cdot damage_i \qquad \text{(E.26)}$$

$$\text{Land option (Black–Scholes):}\quad d_1 = [\ln(S/K) + (r + \tfrac{1}{2}\sigma^2)T] / (\sigma\sqrt{T});\quad d_2 = d_1 - \sigma\sqrt{T} \qquad \text{(E.27)}$$

$$Call = S \cdot \Phi(d_1) - K \cdot e^{-rT} \cdot \Phi(d_2) \qquad \text{(E.28)}$$

$p_i$ the probability of clearing condition i; $\Phi$ the standard normal cumulative distribution; $S$ the expected land value, $K$ the execution cost, $T$ the term. The option value quantifies the risk cost avoided by settling the legal position before any drawdown. Appendix D codes: probability of clearing the five conditions ≈ 14%, land acquisition at risk VND 19,109 bn.

## E.6. Feasibility simulation and uncertainty decomposition

Feasibility is computed by simulation over roughly 2.4 million paths, separating two kinds of uncertainty: epistemic (unknown, reducible by research) and aleatory (inherently random). Source: *samplers.py*, *epistemic.py*, *engine_v5.py*, *validation.py*.

*Sampling: Monte Carlo (random) · Latin Hypercube (stratified) · Sobol (quasi-random sequence)* (E.29)

*Parameter correlation: $z' = \sqrt{\rho} \cdot z_{common} + \sqrt{(1-\rho)} \cdot z_{idiosyncratic}$* (E.30)

*Epistemic branch weights (BMA): $w_b = \Pi$ prior; aggregation: $P = \Sigma\, w_b \cdot P_b$* (E.31)

*Feasibility criterion: (senior tranche closes) ∧ (Value-Conversion Pool closes) ∧ (DSCR ≥ threshold) ∧ (land coverage ≥ threshold)* (E.32)

*Convergence (confidence interval half-width): $z \cdot s / \sqrt{N}$* (E.33)

For each epistemic branch b, an aleatory simulation gives P(feasible | b); $P_b$ is the branch feasibility probability and $w_b$ its Bayesian (BMA) weight. $s$ is the sample standard deviation and $N$ the number of paths. Criterion E.32 is a joint condition: every term must hold. Appendix D codes: P(feasible) ≈ 6%, ~2.4 million paths, more than 500 agents.

## E.7. Sensitivity, robust optimization and value of information

Variables are ranked by their effect on feasibility; the configuration is chosen by robust optimization rather than by maximising probability on an uncalibrated model; and the research most worth paying for is quantified. Source: *gsa.py*, *robust.py*, *voi.py*.

*First-order Sobol index: $S_1{}^i = Var(E[Y \mid X_i]) / Var(Y)$* (E.34)

*Spearman rank correlation: $\rho$□ (main effect, monotonic)* (E.35)

*Regret: $reg(c,b) = P^*_b - P(c,b)$, $P^*_b = max_X\, P(c,b)$* (E.36)

*Robust decision (min–max regret): choose $argmin_\chi\, max_\beta\, reg(c,b)$* (E.37)

*Value of information: $payoff(proceed) = p \cdot B - (1-p) \cdot L$* (E.38)

*$EVPI = E_b[\, max(payoff_b, 0)\, ] - max(\, \Sigma\, w_b \cdot payoff_b\, , 0\, )$* (E.39)

$Y$ the output (IRR or feasibility), $X_i$ parameter i; $c$ the decision configuration, $b$ the epistemic branch; $B$ the benefit if successful (100,000), $L$ the loss if not (40,000). EVPI is the upper bound on the value of perfect information; EVPPI (by variable) ranks survey priorities. Appendix D code: Sobol index for the legal gateway ≈ 68%.

## E.8. Tail risk

Extreme shocks are fitted with Extreme Value Theory on the actual input data — not on the model's own output, which would be circular — and tail loss is then measured with CVaR. Source: *tail.py*.

*Generalised Pareto distribution (exceedances over threshold u): $P(X - u \le y \mid X > u) = 1 - (1 + \xi y/\beta)^{(-1/\xi)}$* (E.40)

*Value at Risk: VaRα = the α-quantile of loss* (E.41)

*Expected tail loss: $CVaR\alpha = E[\, L \mid L \ge VaR\alpha\, ]$* (E.42)

$\xi$ the shape (tail) parameter, $\beta$ the scale parameter, $u$ the threshold; α = 0.95 and 0.99. CVaR measures the average loss in the tail beyond VaR, and is used for both FX risk (E.10) and fiscal risk (E.49).

## E.9. Heterogeneous agents and regional coupling (econophysics)

The financial system is modelled as a population of heterogeneous agents deciding on utility and loss aversion; inter-regional capital flows are modelled as a coupled dynamical system, integrated with energy conservation as a numerical stability check. Source: *abm/agents.py*, *abm/hamiltonian.py*, *factors.py*.

*CRRA utility: $u(w) = (w^{(1-\gamma)} - 1) / (1 - \gamma)$* (E.43)

*Prospect value (loss aversion): $v(x) = x^{\alpha}$ if $x \ge 0$; $-\lambda(-x)^{\alpha}$ if $x < 0$* (E.44)

$$\text{Regional coupling (Hamiltonian):}\quad dq_k/dt = \partial H/\partial p_k = p_k/m_k \tag{E.45}$$

$$dp_k/dt = -\partial H/\partial q_k = -V'_k(q_k) - \Sigma_j C_{jk} q_j \quad \text{(symplectic integration, conserving } H\text{)} \tag{E.46}$$

$$\text{Reference-class forecasting (optimism correction):}\quad \text{realized} = (1 - \text{bias}) \cdot e^{N(0,\sigma)} \tag{E.47}$$

$\gamma$ risk aversion (base 3.0); $\lambda$ = 2.25 and $\alpha$ = 0.88 (Kahneman–Tversky); $q_k$, $p_k$ the capital position and momentum of region k, $C_{jk}$ the coupling matrix (shock propagation). Energy error is checked to confirm the integration is stable. *bias* is the optimism bias in the demand forecast.

## E.10. Growth contribution and social diffusion

The growth contribution separates into a construction-phase demand effect and a long-run productivity effect via the public capital elasticity; social impact is spread over time with Bass diffusion. Source: *growth.py*, *economic_timephased.py*, *social_diffusion.py*.

$$\text{Long-run productivity (Aschauer):}\quad \Delta\text{productivity} = \varepsilon \cdot (\Delta K_{infra} / K),\quad \varepsilon \sim \text{Triangular}[0.05;\ 0.40] \tag{E.48}$$

$$\text{Bass diffusion (CDF):}\quad F(t) = (1 - e^{-(p+q)t}) / (1 + (q/p)\, e^{-(p+q)t}) \tag{E.49}$$

$$\text{Agglomeration uplift:}\quad \text{level} = \varepsilon_{agg} \cdot (\text{density\_increase}) \cdot \text{Bass\_ramp}(t - t_{build}) \tag{E.50}$$

$\varepsilon$ the output elasticity of public capital (Aschauer 1989; Bom & Ligthart 2014 ≈ 0.08–0.17); $p$ the coefficient of innovation ≈ 0.03, $q$ the coefficient of imitation ≈ 0.38 (Bass 1969); $\varepsilon_{agg}$ the agglomeration elasticity (Combes/Duranton 0.04–0.08). Four social channels: employment, ridership, resettlement, housing. Appendix D code: GRDP contribution 1.39–2.53 points.

## E.11. Public finance framework and option comparison

Assessed on the standard appraisal framework: value for money against a public sector comparator, contingent fiscal liabilities, and multi-criteria scoring across the five options. Source: *city.py*, *alternatives.py*.

$$\text{Value for money (PSC):}\quad PSC = \text{capex} \cdot (1 + 0.20) + \text{capex} \cdot r_{public} \cdot H \cdot 0.5 \tag{E.51}$$

$$VfM = PSC - \text{total cost of the token option} \tag{E.52}$$

$$\text{Contingent fiscal liability (PFRAM):}\quad CL = \text{public\_first\_loss} \times \text{trigger\_factor} \quad \text{(tail from E.40)} \tag{E.53}$$

$$\text{Option scoring:}\quad \text{score} = M \cdot w \quad \text{(}M\text{ the 1–5 score matrix, }w\text{ the normalised weights); ranked in descending order} \tag{E.54}$$

The PSC adds a 20% retained overrun risk provision (the Flyvbjerg benchmark) and the public financing cost. $CL$ is the contingent liability triggered by a shock, with tail parameters taken from the generalised Pareto fit (E.40). $M$ is the five-option × ten-criterion score matrix. Appendix D code: net position under the five options (Token +38,379 … BRT +34,186).

**— End —**