VIV–TAVR FORECASTING · VERSION 6

Demography-Anchored Forecasting of ViV-TAVR

Korea today, Singapore next: a refreshed Monte Carlo framework grounded in registry data and population demography, with adoption modelled on top rather than baked in.

Hyunjin Ahn · Charles Yap

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Progress update, methodological pivot & next steps

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Presentation Overview

1 Introduction & Plan

2 Initial Findings

3 The Pivot

4 New Approach

5 Results

1

Introduction & Plan

Where we are, what we set out to do, and the original blueprint.

Clinical & Modelling Objective

One-sentence goal: estimate future volumes of ViV-TAVR in Korea (and later Singapore), split into TAVR-in-SAVR and TAVR-in-TAVR, using registry data plus a patient-level Monte Carlo model anchored to demography.

What the model must deliver

Annual ViV-TAVR volumes over the next 10–25 years.

Two paths to ViV-TAVR (schematic)

TAVR-in-SAVR path

Where We Are in the Project

Written updates have already outlined our first Korea-only ViV-TAVR forecast. Today we focus on why we pivoted the modelling strategy, what the new demography-anchored results look like, and how we will extend this to Singapore.

1 Korea model v9

Monte Carlo engine implemented; demography-anchored index volumes; ViV candidates vs realised separated.

2 Current focus

Explain the pivot away from adoption-driven extrapolation, show the "3× not 8×" Korean forecast, and link this to editorial critiques.

3 Next steps

Apply the same framework to Singapore with UN projections, then build explicit adoption curves on top for cross-country comparison.

Prior Blueprint: Genereux US Model

Shared core methodology

1. Use historical index TAVR/SAVR volumes by age.

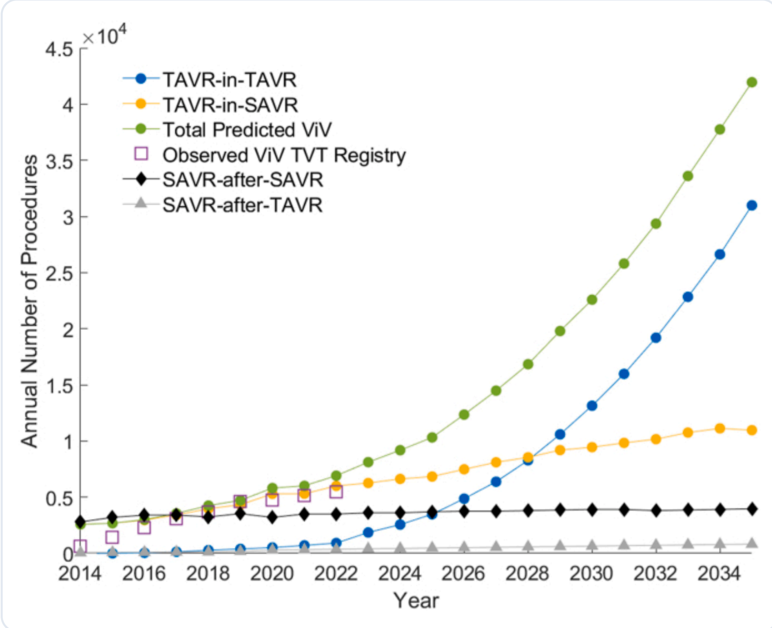
2. Extrapolate index volumes into the future.

3. Run Monte Carlo for durability, survival, and failure.

4. Apply assumed ViV penetration curves (e.g. 10%→60%).

We reused the patient-level Monte Carlo logic, but later changed how index volumes and penetration are handled for Korea.

Genereux et al. – US TVT ViV forecast



Prior Blueprint: Ohno Japan Model

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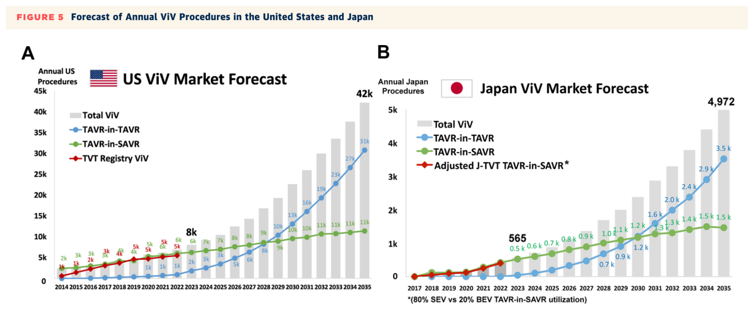
Ohno & Genereux – JACC Asia US vs Japan



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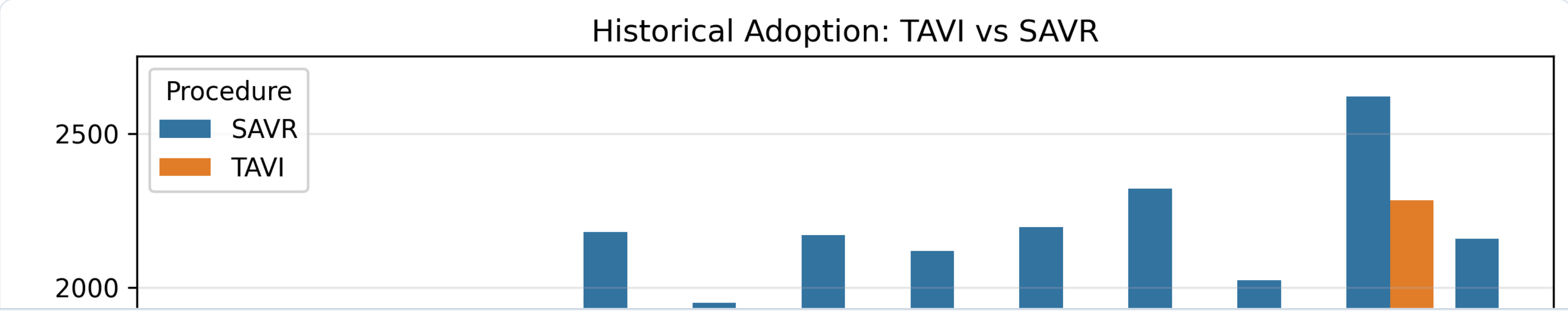
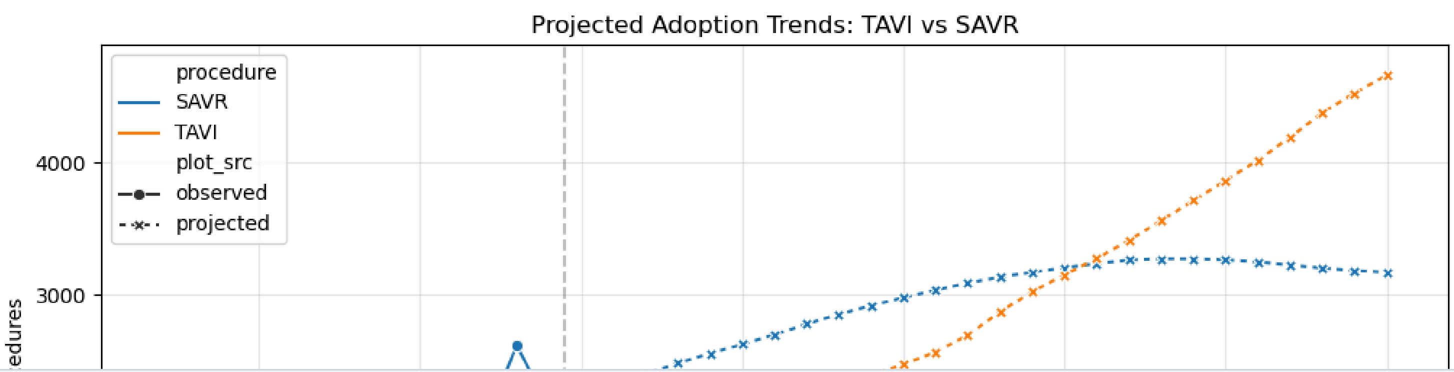
Initial Findings

First pass at Korean data and the "Old Forecast".

Korea Data: Index Volumes 2015–2024



First-pass ViV Forecast (Genereux/Ohno replication)



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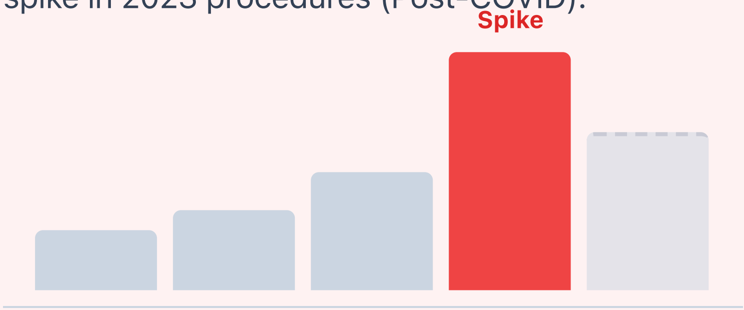
The Pivot

Why the old model failed and the new demography-anchored concept.

Why the Original Approach Failed

1. The 2023 "Backlog Spike"

Korean registry data showed a massive, anomalous spike in 2023 procedures (Post-COVID).



Linear extrapolation from here creates infinite growth.

2. The JACC Critique

> *"Extrapolations... potentially introducing bias... significant adjustments were made... clinical factors were not accounted for."*

Conclusion: We cannot blindly apply US/Japan growth rates (Ohno et al.) to Korea's unique aging demographic.

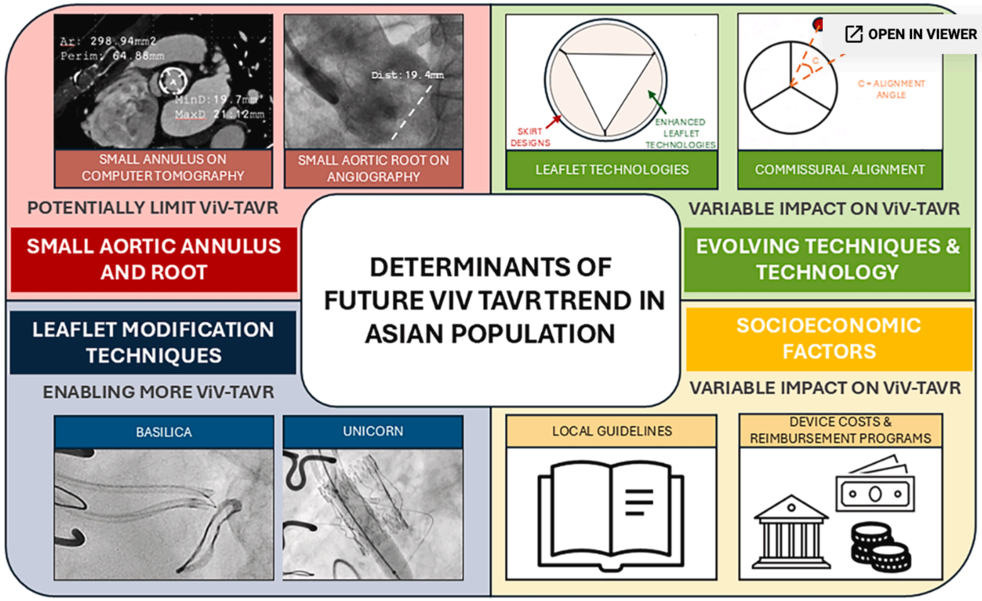
Editorial Critique & The Case for a Pivot

Predicting the Future of ViV-TAVR

More importantly, what about the future? In this issue of *JACC: Asia*, Ohno et al[9] presented findings, using a newly developed model, that predict future trends of ViV-TAVR with regards to procedural volume.[6] Their model forecasted that by 2035, ViV-TAVR will constitute approximately 8% of TAVRs in Japan and 15% in the USA.[9] It is also predicted that the volume of TAV-in-TAV will equal TAV-in-SAV by 2028 in the USA and by 2030 for Japan.[9] Whereas such projections highlight an anticipated surge of ViV-TAVR, alerting clinicians of the need to tackle this rising problem, interpretation of such predictions requires caution.

Although the model postulated a trend of 4-fold increase in ViV-TAVR in Japan in 10 years' time, assumptions at various levels and different magnitude were made.[9] Thus, the true picture of future ViV-TAVR may not be entirely reflected by the model. During the data input for the described model in the Ohno et al[9] study, it was noted that extrapolations were made to project potential procedural volumes (both TAVR and SAVR) in Asian populations, potentially introducing bias to the model calculation. Of particular attention, significant adjustments to data were made when extrapolating the projected numbers of TAV-in-SAV procedures with self-expanding valves.[9] Whereas the investigators have taken into consideration of possible element of market share when projecting self-expanding valves' TAV-in-SAV volume, many other crucial factors, including clinical factors and patient characteristics were not accounted for.[9] Also, SAVR volume was projected to be plateauing, instead of changes in other directions (eg, a decline).[9] Therefore, such adjustments and extrapolations may potentially misrepresent the true picture. Furthermore, some assumptions for certain data input, for example, bimodal distribution of bioprosthetic valve failure, were based on expert opinion, further introducing potential bias into the model calculation.[9] Despite this, the model did fit well into the Society of Thoracic Surgeons' volume trend and has a reasonably accurate prediction on the global trend.

To further enhance prediction of future ViV-TAVR trend, particularly in Asian populations, several important factors need to be taken into consideration. These include clinical and anatomical characteristics relating to Asian populations (eg, small aortic annulus), advent and maturation of advanced TAVR/ViV-TAVR techniques and technologies, as well as evolving socioeconomic factors (Figure 1).



Critique of Extrapolation (Ohno et al.)

- **Over-projection:** Predicted 4-fold increase in Japan by 2035, but relied heavily on assumptions.

Our Methodological Pivot

- **Adoption is Volatile:** Pure adoption curves are sensitive to shocks (e.g., reimbursement, pandemics) and hard to calibrate from early data.

The Pivot: A Demography-Anchored Approach

OLD MODEL

Linear Extrapolation

"Procedures will grow by X% every year based on history."

TRANSFORMED INTO

NEW MODEL (v9)

Risk × Demography

"Given the stable risk profile of a Korean patient, how many failures occur as the population ages?"

Pop Structure

4

New Approach

Methodology, Monte Carlo engine, and the demography anchor.

Design Goals for the Demography-Anchored Model

Goal 1 · Anchor to Demography

Make age and sex structure explicit. Drive index TAVR/SAVR volumes using:

per-capita risk × population

Avoid arbitrary regression lines; let population ageing dictate the trend.

Goal 2 · Minimise Speculative Inputs

Report ViV candidates first as the primary output.

Treat ViV penetration as an optional scenario layer on top (e.g. US-style ramp).

Make every assumption modular so it can be swapped or stress- tested.

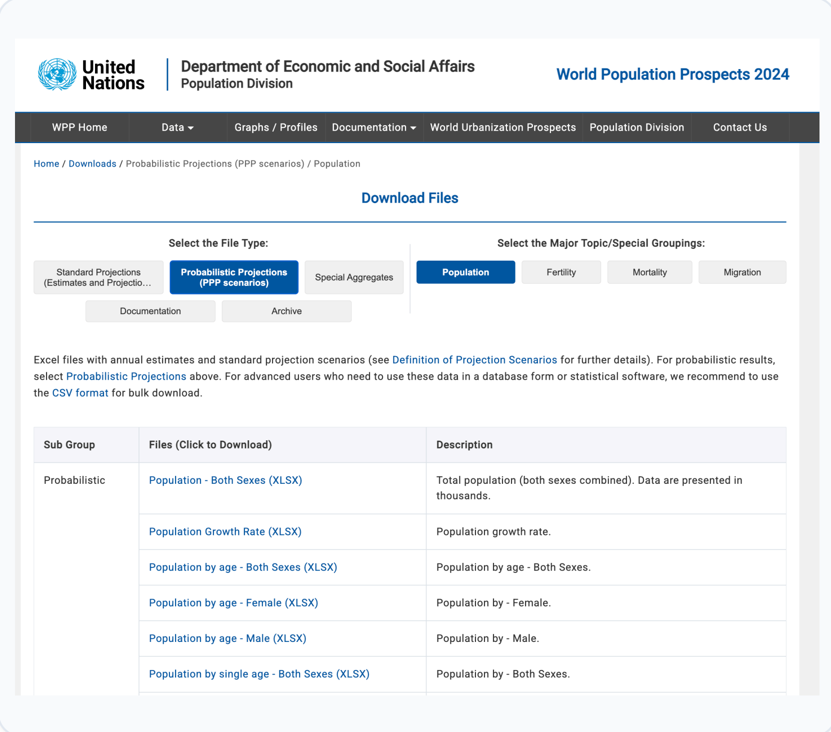
Goal 3 · Transparent Mechanics

Explicitly model the "Race":

`Death vs Valve Failure`

Patients are dropped if they die before failure. No "ghost patients" getting ViV.

Data Source: UN Population Projections



UN World Population Prospects

We utilize the **'Median' Probabilistic Projection** tables, providing a robust central forecast for the next 75+ years.

1. **Granular Resolution**
   Unlike KOSIS (Korean Gov) data which often groups by 5-year intervals, the UN dataset provides **year-by-year** projections, essential for our annual Monte Carlo simulation.

2. **Consistency**
   The projections align closely with national statistics but offer the extended horizon and detail needed for long-term ViV forecasting.

Demography as the Driver: The Formula

Core projection formula

For each year $y \geq 2025$, sex, and age band:

$$\mathrm{IndexVolume}_{y,sex,age} = \mathrm{risk}_{2023\text{–}24,sex,age} \times \mathrm{population}_{y,sex,age}$$

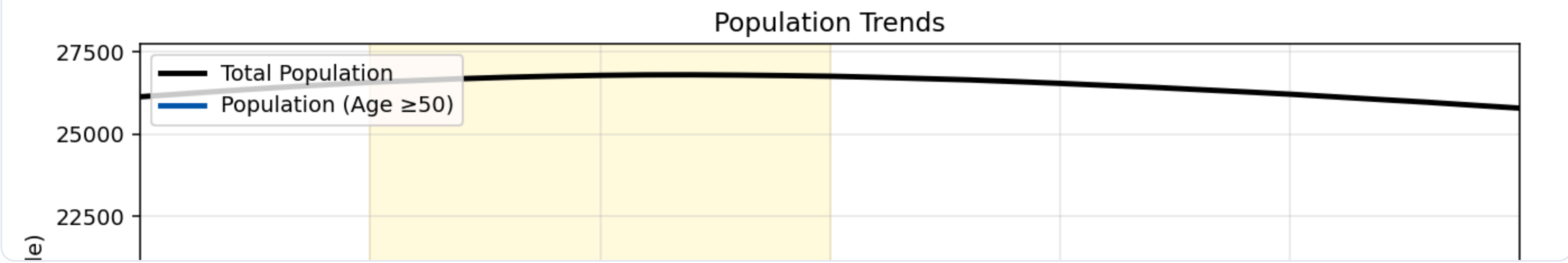
Risks are computed from 2023–2024 HIRA registry counts for TAVR, SAVR, and redo-SAVR.

Population projections are taken from national tables, later to be standardised to UN WPP for Korea vs Singapore.

Summing over age and sex gives total index TAVR/SAVR volumes per year.

Intuition: instead of saying "TAVR grows by X% per year", we ask: "If each age–sex group is treated at 2023–24 rates, what happens as the population ages?"

Korean Population Trends



Younger cohorts stable or shrinking.

Strong growth in 75–79, 80–84, and ≥85, especially women.

Simulation Architecture (model_v9)

1

Pre-Compute

Ingest Data Sources

- HIRA Registry (2015-2024)
- Ministry Pop Stats
- Age/Sex Bands

2

Risk Calculation

Establish Anchor

```
Risk = Obs / Pop
```

Generates stable risk profiles per age-band based on 2023-24 data.

3

Monte Carlo

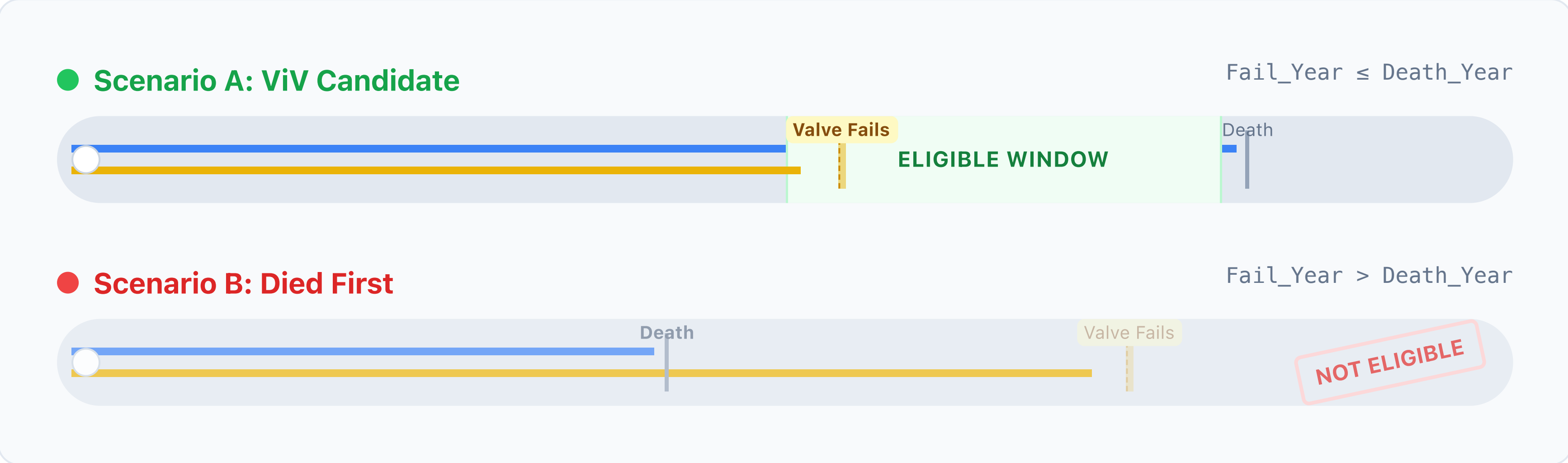
The Engine

- 100 Runs per Scenario
- Durability vs Survival
- Stochastic Jitter (5-10%)

Filters Applied: Redo-SAVR subtraction applied. Speculative penetration (60-80%) removed for conservative floor.

The Core Logic: "The Race"

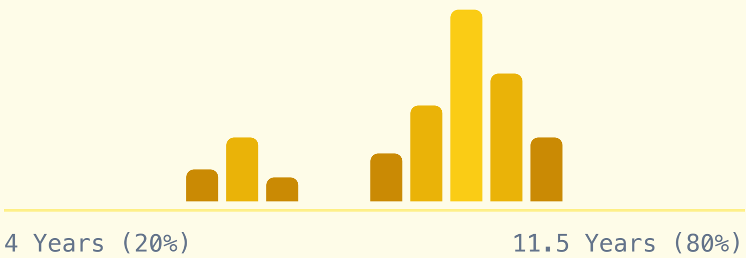
Inside the Monte Carlo Engine, every simulated patient runs a "Race" between two dates. A patient only becomes a candidate if their valve fails while they are still alive.



Sampling Distributions

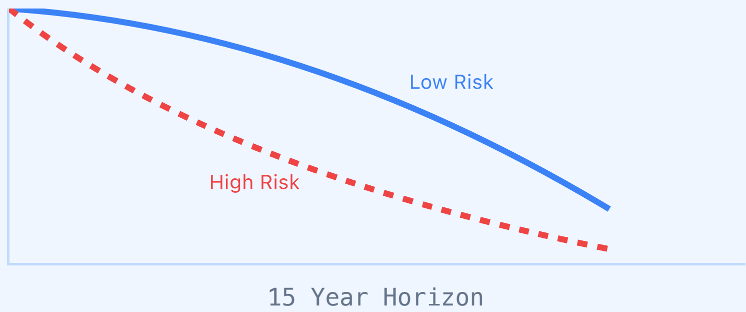
Durability

Bimodal Mixture Model: Valves fail in two clusters (Early Manufacturing vs Late Wear).



Survival

Actuarial curves adjusted for risk category (Low/Int/High).



Monte Carlo Engine & ViV Candidate Flow

Single-patient pipeline

1. Assign index procedure year, age, sex, and type (TAVR/SAVR).
2. Draw risk category (low / intermediate / high risk).
3. Sample survival time and valve durability (bimodal for TAVR, age- split for SAVR).
4. Determine failure year vs death year; candidate if failure occurs before death and within the horizon.

Durability and survival distributions are inherited from the Genereux/Ohno setup; we mainly change how many index procedures enter the engine each year.

From failures to realised ViV

All valve failures in a year.

→ Subset where patient is alive at failure.

→ ViV candidates (alive + within forecast horizon).

→ Subtract redo-SAVR targets (risk-based).

→ ViV-eligible pool.

→ Apply chosen penetration scenario → realised ViV.

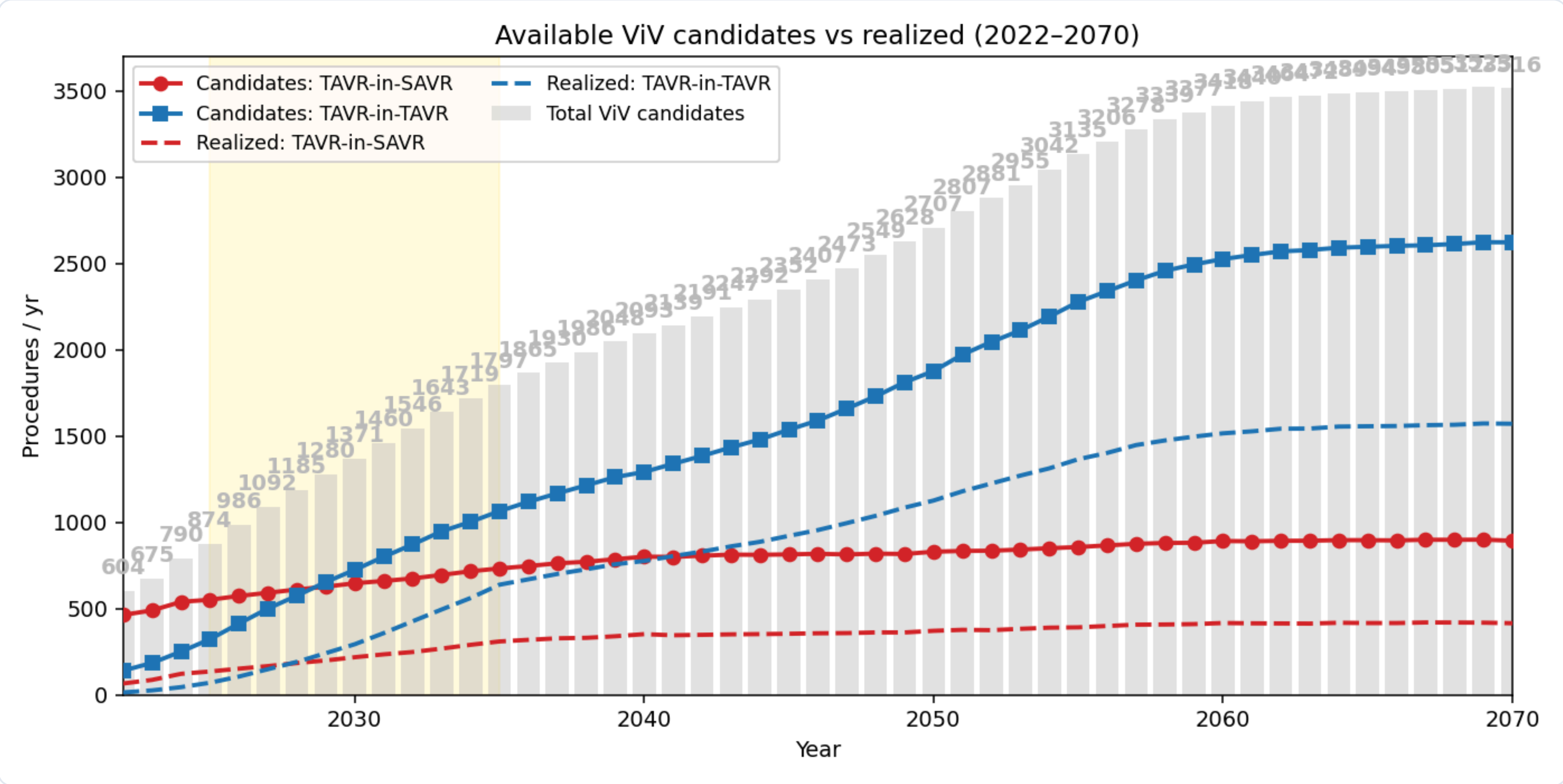
Key idea: candidates and eligible counts are data-driven; penetration is explicitly a scenario, not embedded in the core forecast.

5

Results

The new 3× forecast, comparisons, and next steps.

Korea: ViV Candidates vs Realised ViV



Grey bars: total candidates · Solid lines: TAVR-in-SAVR / TAVR-in-TAVR candidates · Dashed: realised ViV under US-style penetration.

2.5–3×, not 8×

Split by ViV type

Planning signal

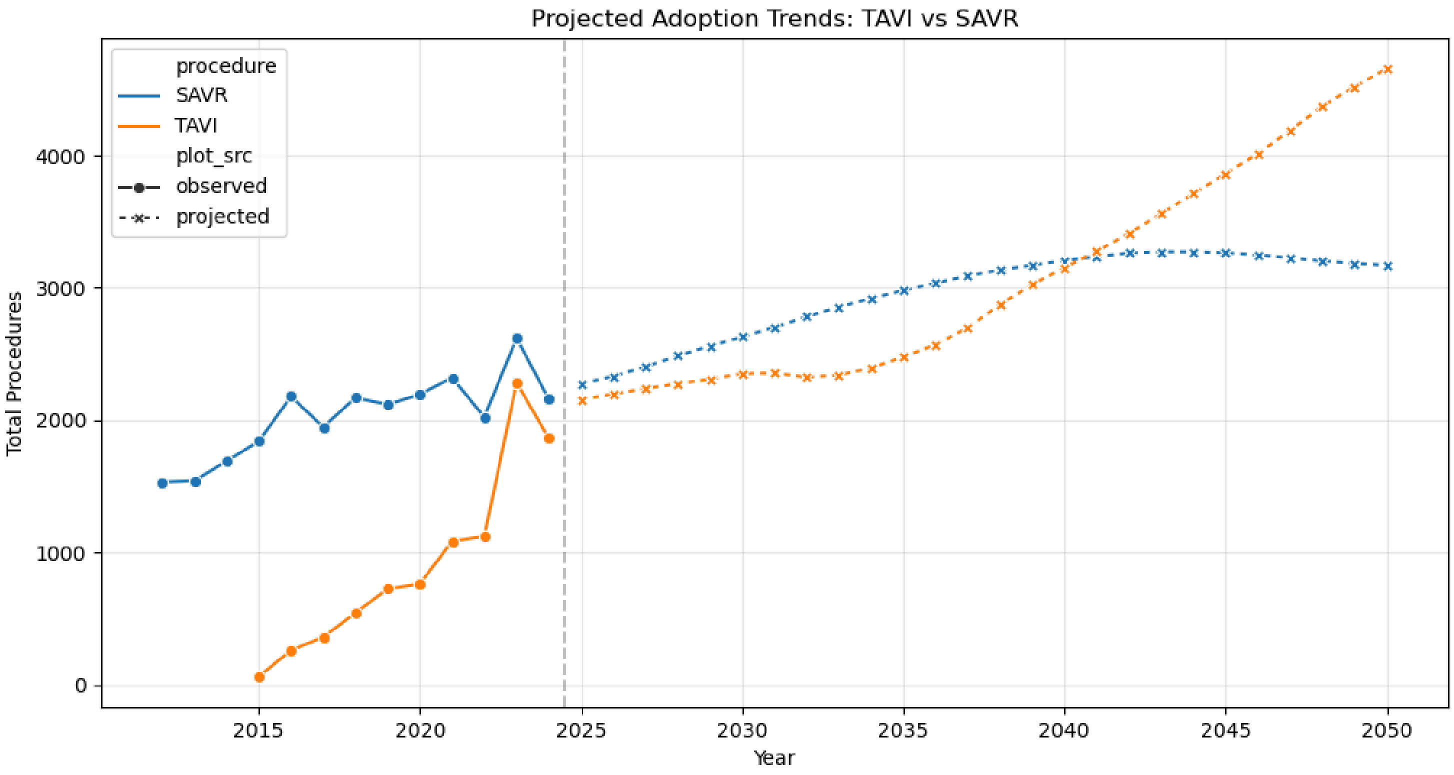
Total ViV candidates rise from ~790 in 2024 to just under 2,000 in 2035 — roughly a 2.5–3× increase driven by ageing, not explosive extrapolation.

Both TAVR-in-SAVR and TAVR-in-TAVR increase, with TAVR-in-TAVR gradually taking a larger share of candidates and realised procedures.

Within 2025–2035, the demography-driven increase is moderate but clinically significant — a more realistic planning baseline for Korean structural heart programmes.

Model Comparison (2035)

Supporting: Index Volumes (2015–2050)



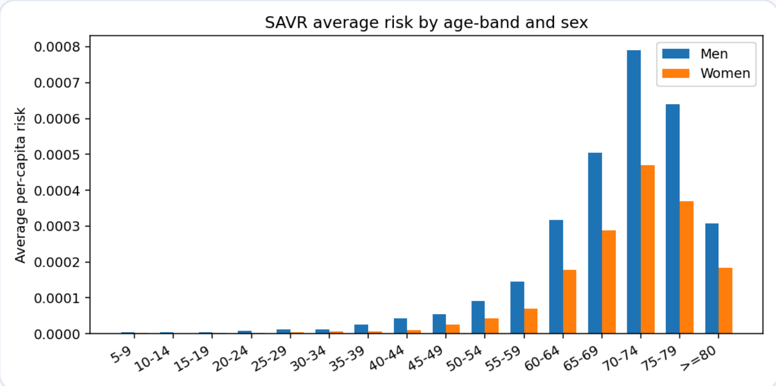
2023 spike is preserved but not used as a straight-line extrapolation.

Post-2025, volumes evolve with demography; SAVR can plateau or decline naturally.

Addresses editorial concerns about aggressive extrapolation on top of flat SAVR.

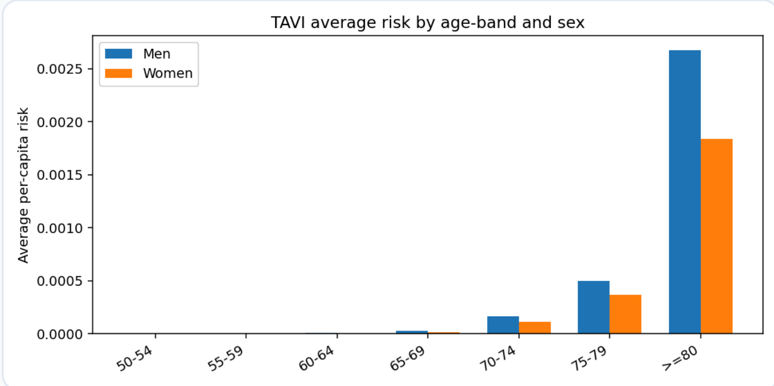
Why SAVR Baseline Decreases: 1. Distinct Risk Profiles

SAVR Risk Profile



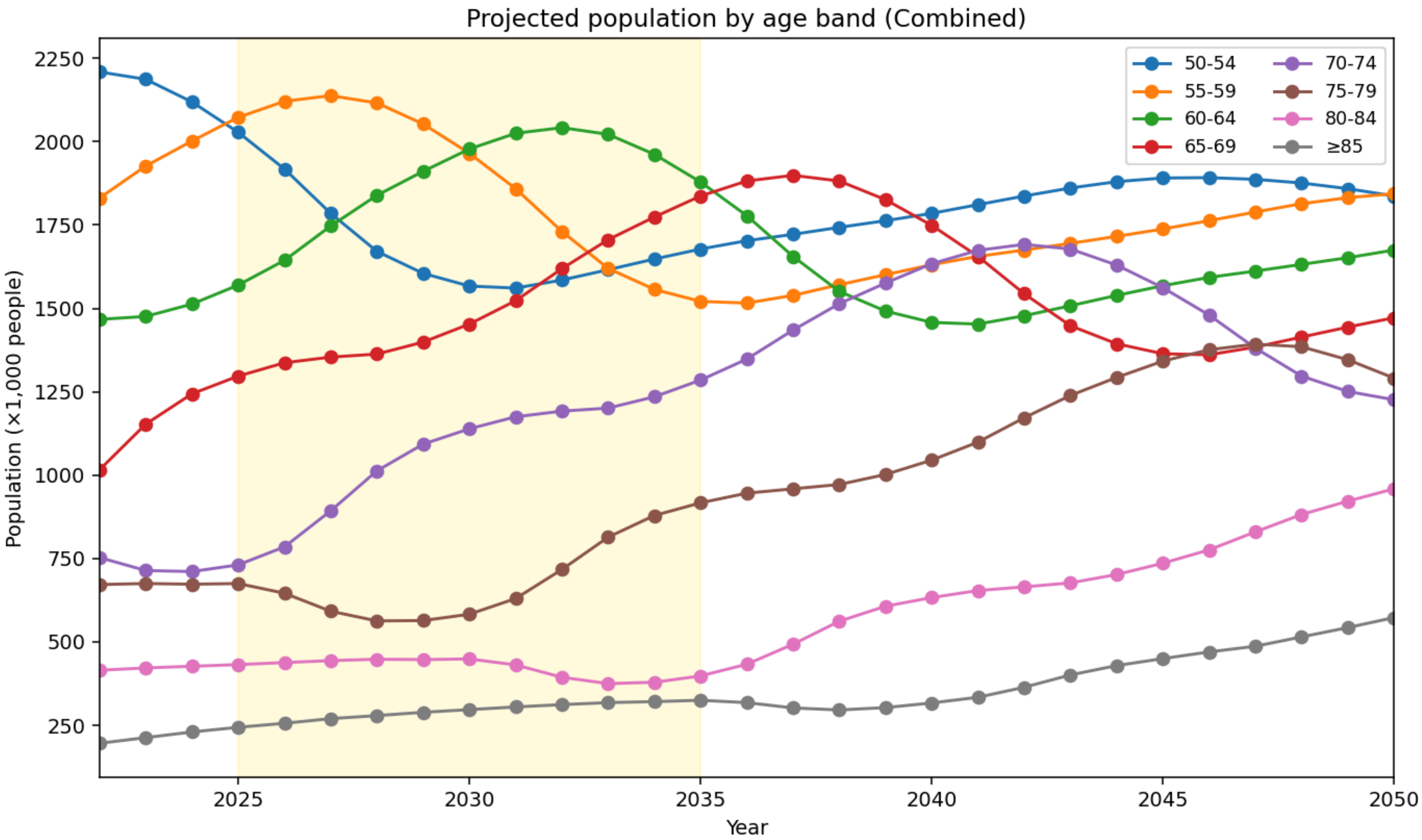
SAVR risk peaks in the **70-74** and **75-79** age bands. It drops significantly for patients 80+.

TAVI Risk Profile



TAVI risk is highest in the **80+** age bands (3-4x higher than SAVR). This age-dependence is critical.

Why SAVR Baseline Decreases: 2. Demographic Shift



The "SAVR Generation" Shrinks

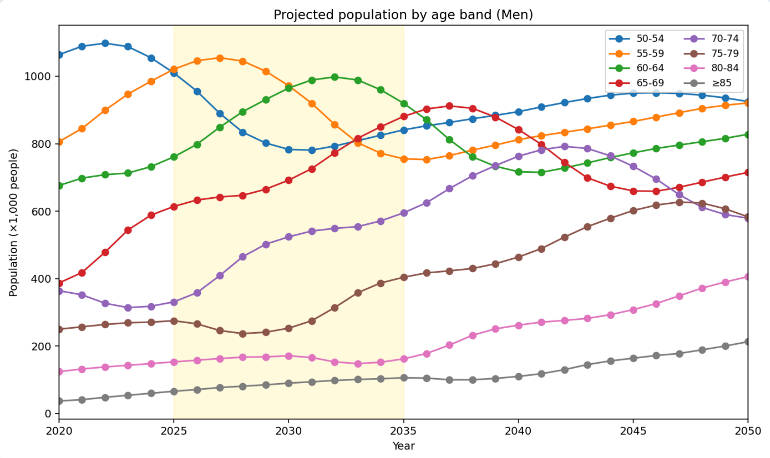
70-74 Age Cohort: This group drives SAVR volume. It peaks around **2042** and then **decreases** significantly by 2050.

80+ Age Cohort: This group drives TAVI volume. It continues to **grow rapidly** through 2050.

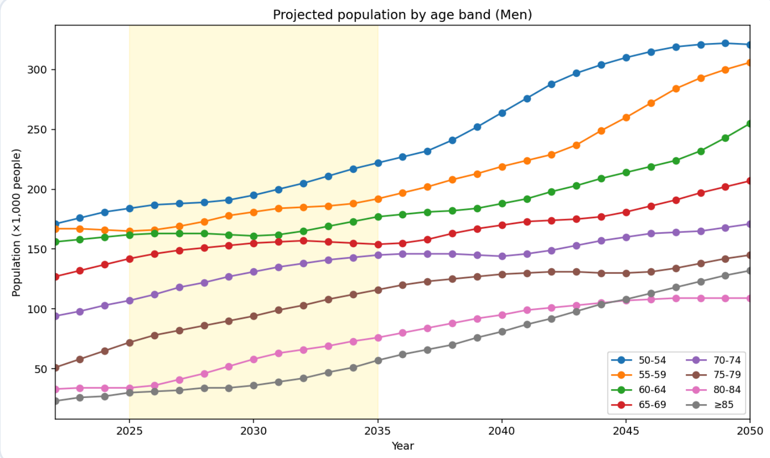
Result: Even though the *average* age increases, the specific bucket for SAVR shrinks, causing the baseline volume decline.

Extension to Singapore & UN Population Projections

Korea (2022–2050)



Singapore (2022–2050)



What This Model Offers · Publishing Value & Limitations

Contribution & publication angle

Clinical planning signal (Korea): demography-driven ~3× rise in ViV candidates over a decade, not 8×, with explicit TAVR-in-SAVR vs TAVR-in-TAVR splits.

Methodological advance: demography-anchored risk × population design; candidates vs penetration clearly separated; redo-SAVR handled consistently.

Comparative insight (with Singapore): same engine applied to two Asian countries with distinct demographies, as a constructive extension/critique of the US–Japan models.

Key limitations & uncertainty

Per-capita risks assumed stationary at 2023–24 levels.

Survival/durability curves taken from international literature, not re-estimated in a Korean cohort.

Device evolution, guideline shifts, and policy shocks not explicitly modelled.

ViV penetration scenarios remain speculative, even though now clearly labelled as such.

The goal is transparency: make the mapping from assumptions → output explicit so that assumptions can be updated and the model rerun.

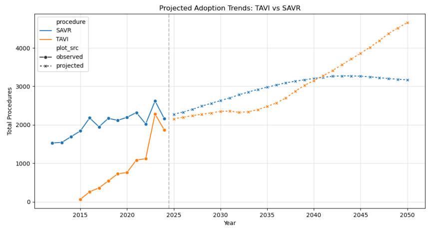
Future Direction: Explicit Adoption Curves & Wrap-Up

From baseline volumes to adoption dynamics

Once baseline TAVR/SAVR volumes are anchored to demography, we can model adoption as explicit logistic (sigmoid) curves.

Slow initial uptake → rapid growth → plateau, calibrated against historical Korean data and cross-country patterns.

Allows us to move beyond "frozen" per-capita risk while keeping core demography logic intact.



Summary & feedback we're seeking

Does the demography-anchored framing feel clinically intuitive and credible?

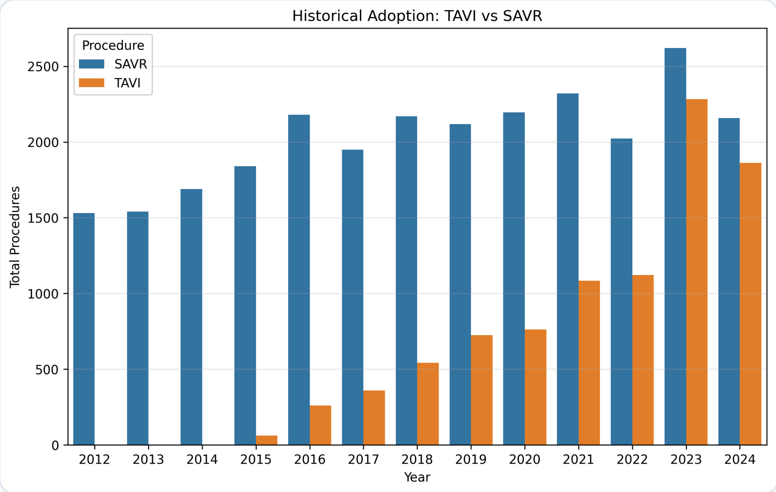
Which scenarios (policy, device, adoption) should we prioritise in sensitivity analyses?

Thoughts on target journals, conferences, and authorship structure for the Korea+Singapore paper.

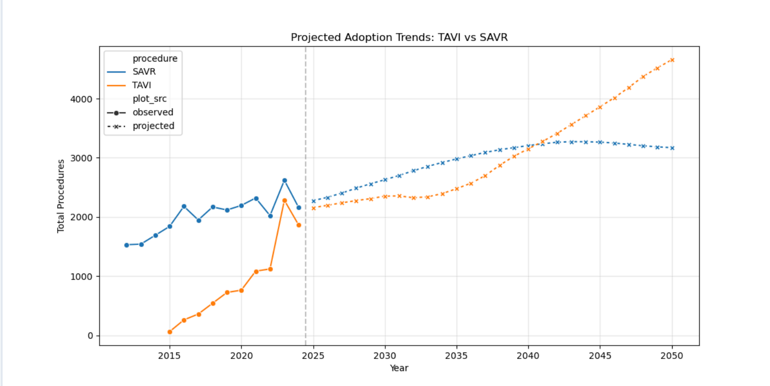
This closes the current progress update; the next milestone is to complete the Singapore run and assemble a comparative manuscript.

Baseline Adoption: Historical & Projected

Historical Adoption



Projected Adoption

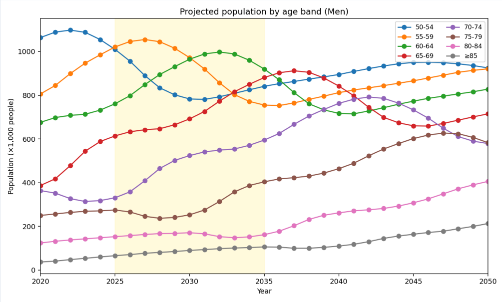


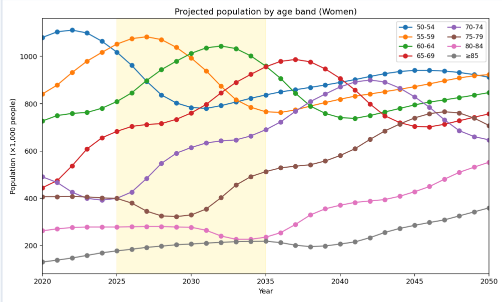
Population Projections (2022–2070)

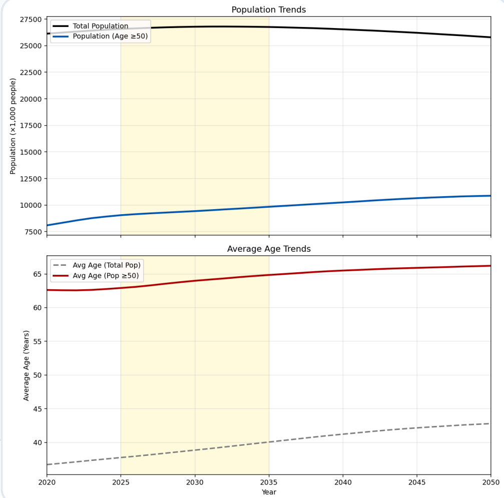
Men

Women

Summary Trends



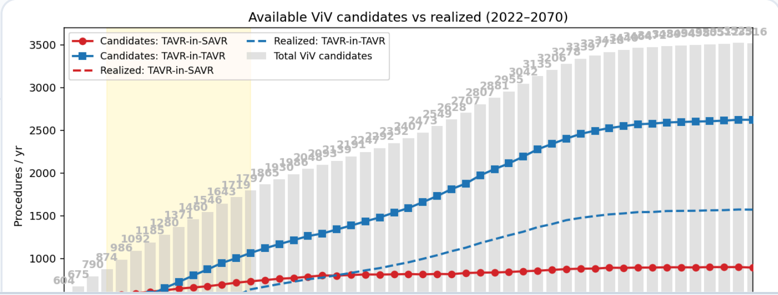


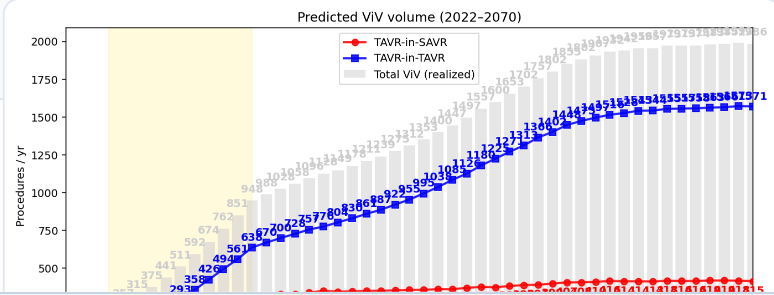


Realised ViV Scenarios

ViV Candidates vs Realised

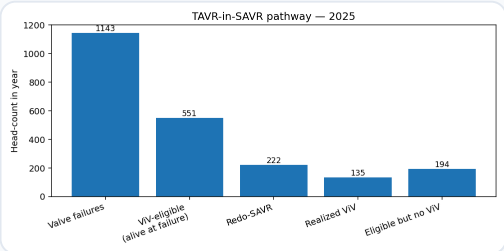
Realised ViV (Pretty)



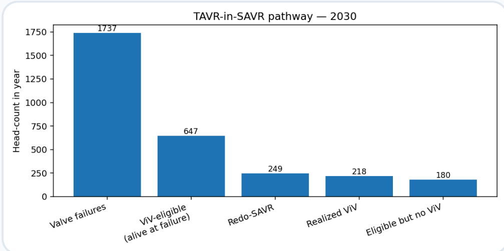


Waterfall Pathways (TAVR-in-SAVR)

2025



2030



2035