

Project Overview

Company Background

SingHealth is Singapore's largest public healthcare cluster, providing comprehensive, multi-disciplinary and integrated care through a network of acute hospitals, national specialty centres, community hospitals and polyclinics, offering over 40 clinical specialties.

Problem Description

SingHealth plans to build new hospitals in the coming decades to meet Singapore's future healthcare demands. Delays in Specialist Outpatient Clinic (SOC) appointments can propagate downstream, creating prolonged waiting times. A dynamic systems modelling approach that captures the interactions between patient demand, service capacity, and hospital resource utilisation is needed.

Objective

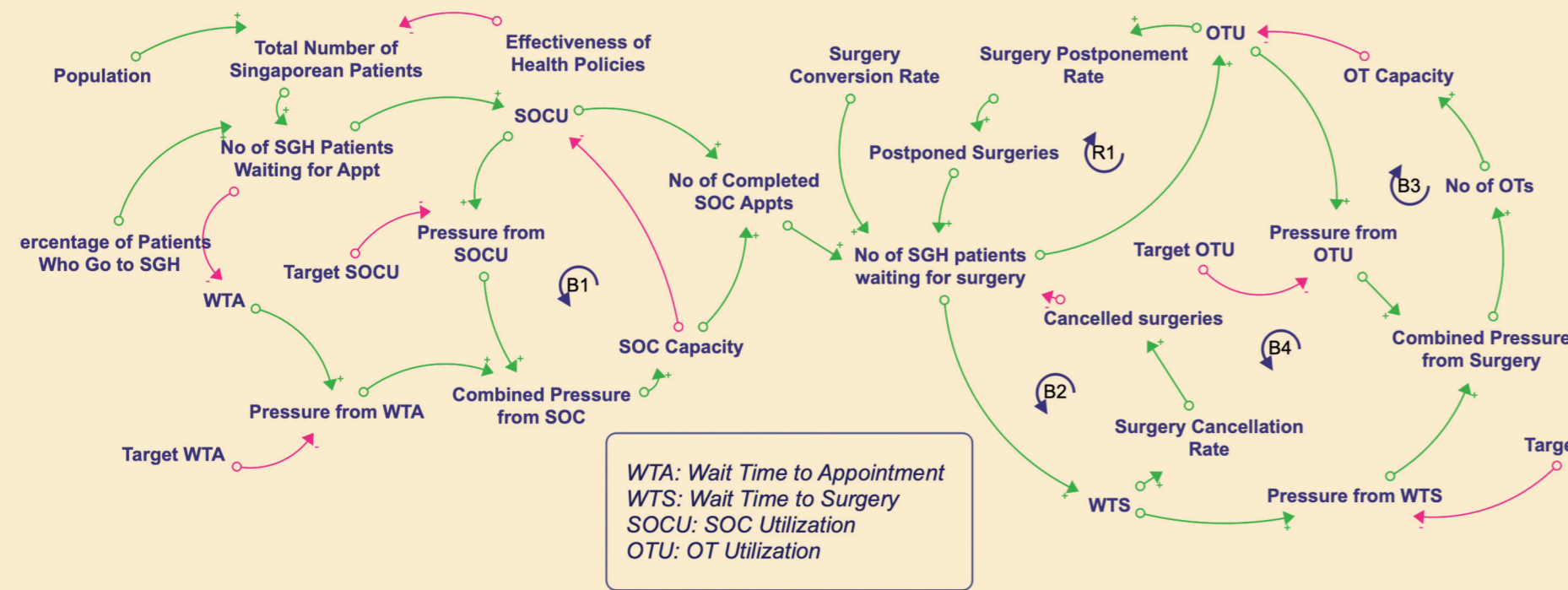
Develop a system dynamics model to assist decision-makers in planning for future hospital capacity in the next 5 years, enabling stakeholders to make more informed decisions regarding the capacity of future healthcare systems.

Key Skillsets Acquired

-  Stella Architect
-  Excel
-  Data Analytics & Visualisation
-  System Dynamics Modelling

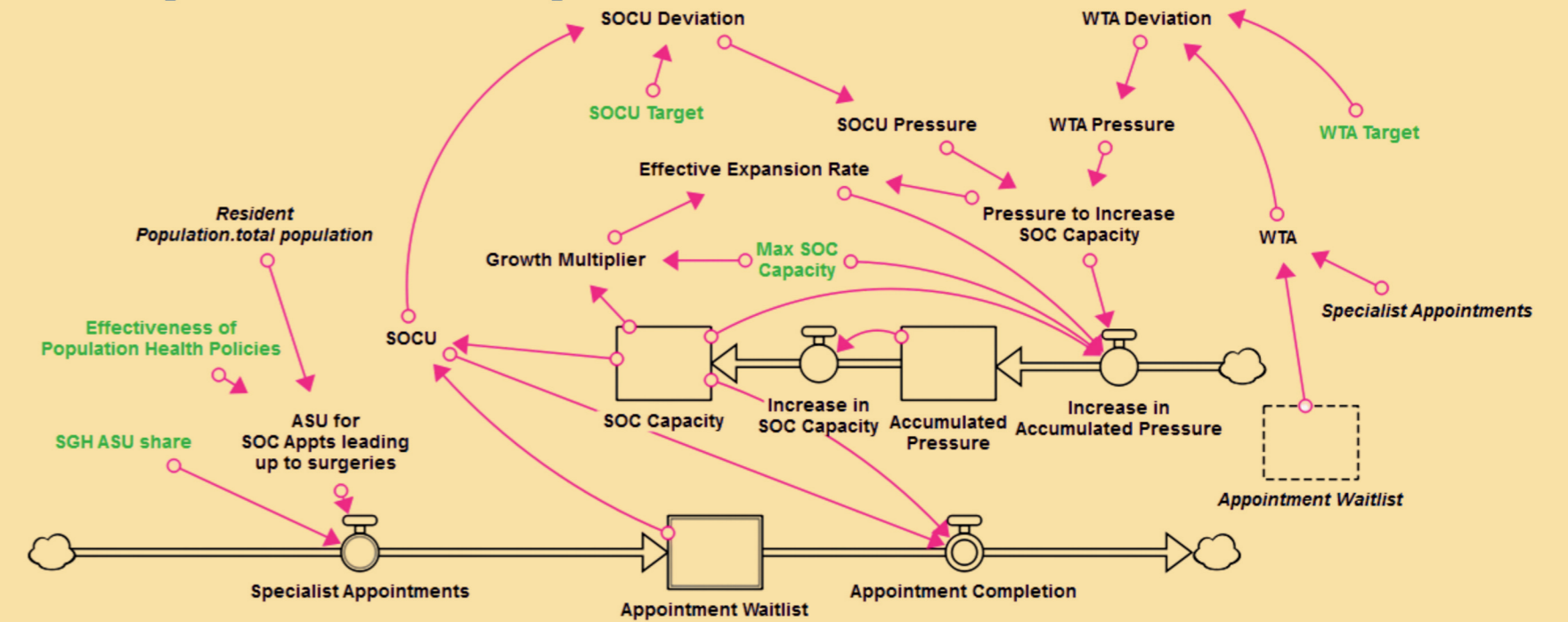
Methodology

Causal Loop Diagram (CLD)



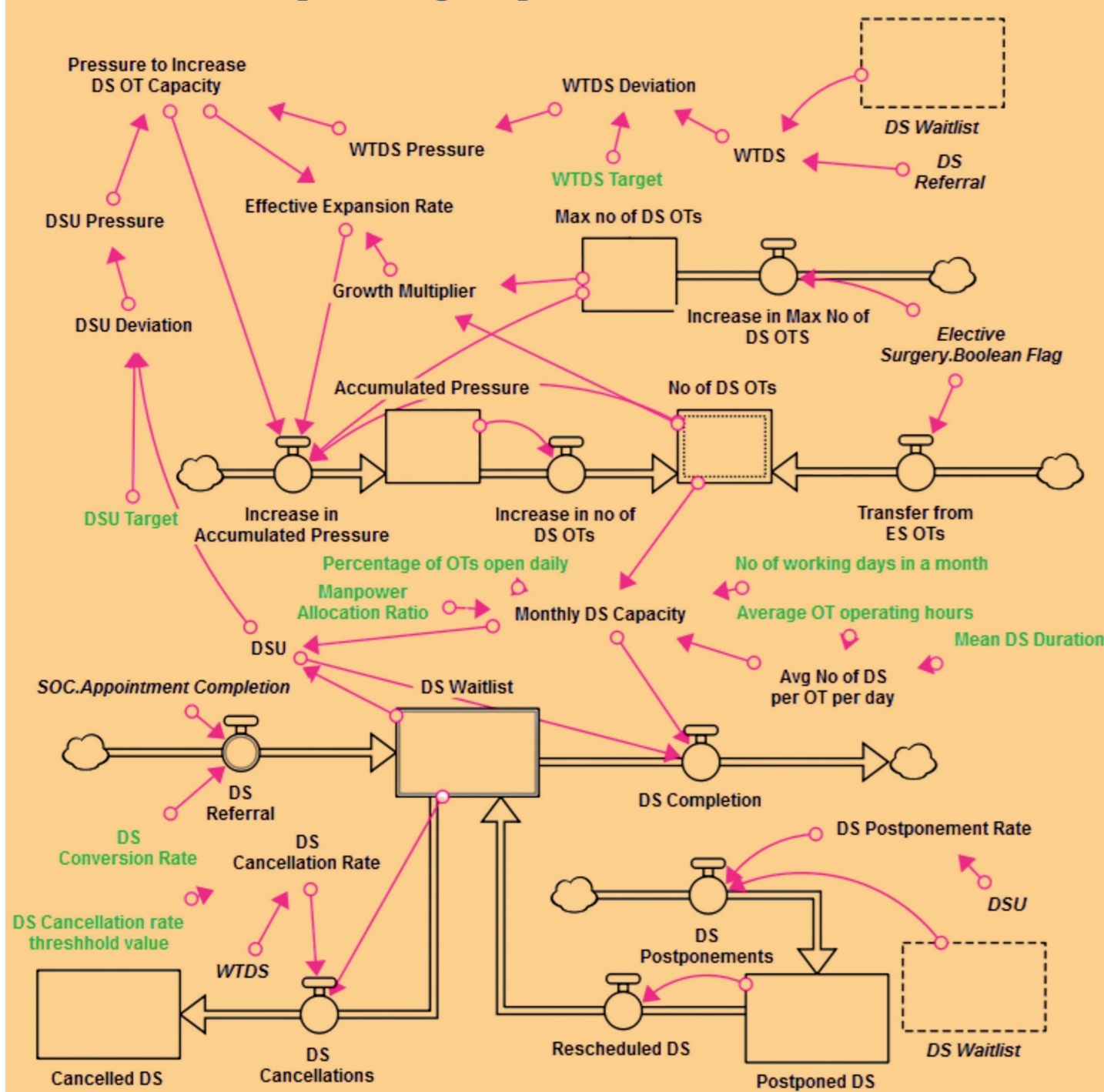
- CLD illustrates reinforcing and balancing feedback loops influencing hospital congestion.
- Conceptualised through collaboration with SingHealth stakeholders to identify key factors driving operating theatre inefficiencies and the underlying feedback mechanisms within the system.

Specialist Outpatient Clinic (SOC) Module



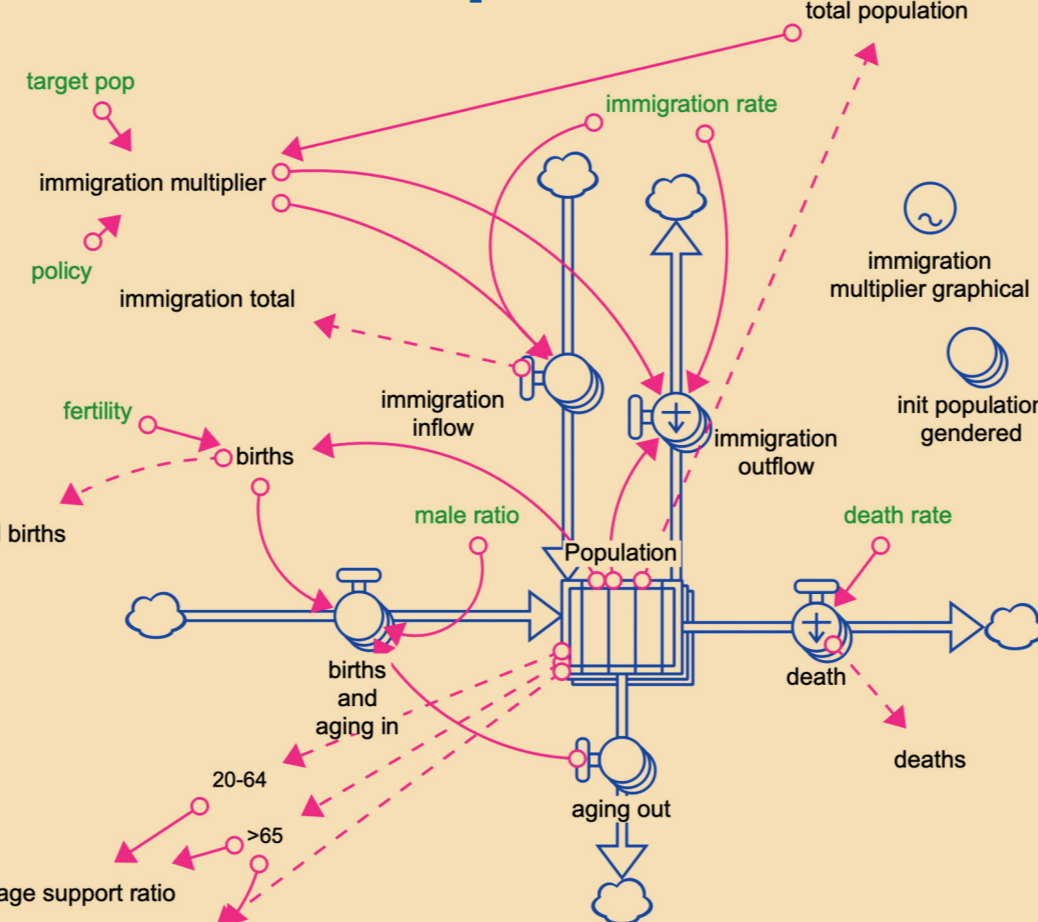
- Models appointment waitlist where demand accumulates over time and is reduced through appointment completion.
- Capacity is adjusted based on utilisation levels and wait time targets, which allows the system to respond dynamically to changes in demand pressure.

Day Surgery (DS) Module



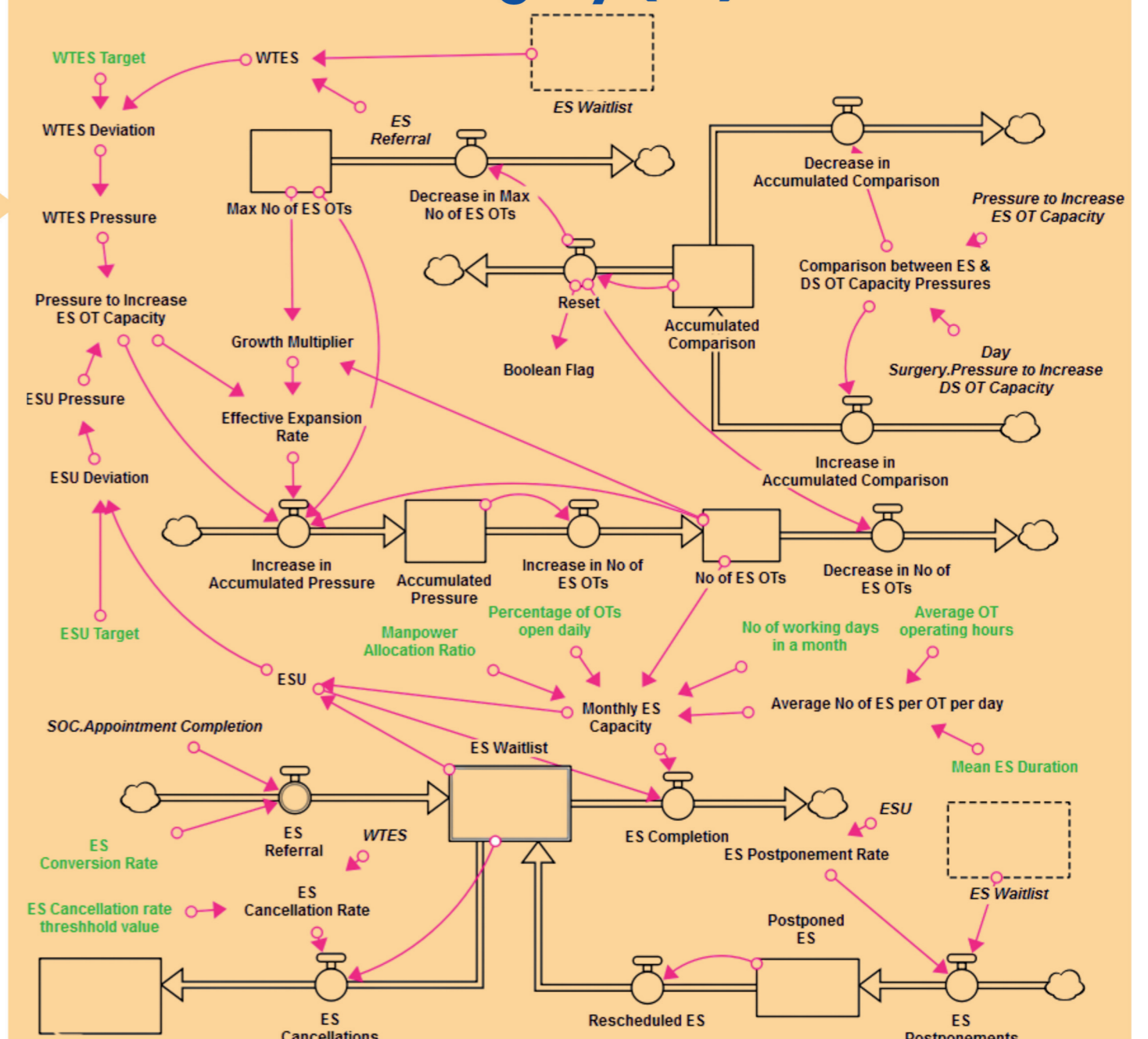
- Models DS demand from the SOC module, tracking performance via DS Utilisation (DSU) and Wait Time to DS (WTDS), and measuring system pressure from deviations against targets.
- Applies Gompertz function (Guo et al., 2025) and Prospect Theory (Schwartz et al., 2008) concepts to translate pressure into increased OT capacity, reducing ES waitlists and guiding DSU and WTDS toward target levels asymptotically.
- Incorporates real-world dynamics such as postponements, cancellations, and technological advancements by converting ES OTs into DS OTs.

Resident Population Module



- Directly adopted from previous group's SDP model, with a literature review conducted to ensure its correctness.
- Models resident population trends and immigration effects by means of the immigration formula, stratified by gender and age.
- Incorporates fertility rates, death rates, and initial population, using data from the Singapore Department of Statistics.

Elective Surgery (ES) Module



- Models ES demand from the SOC module, tracking performance via ES Utilisation (ESU) and Wait Time to ES (WTES), and measuring system pressure from deviations against targets.
- Applies Gompertz function (Guo et al., 2025) and Prospect Theory (Schwartz et al., 2008) concepts to translate pressure into increased OT capacity, reducing ES waitlists and guiding ESU and WTES toward target levels asymptotically.
- Incorporates real-world dynamics such as postponements, cancellations, and technological advancements by converting ES OTs into DS OTs.

Validation & Verification Methods

Unit & Dimensionality Checks

Strict unit checking was performed in Stella to ensure dimensional consistency throughout the model. Stocks, flows, converter were assigned consistent units, and all equations were verified to be dimensionally balanced. This confirms the internal mathematical consistency of the model.

Extreme Value Test

Extreme value testing was applied by assigning boundary values to critical parameters to assess structural validity. The model exhibited expected limiting behavior and all variables remained within feasible ranges.

Behaviour Over Time Checks

Simulation outputs were evaluated over time to ensure realistic system behavior. Key variables such as surgery waitlist, completion, and utilisation followed logical trends driven by system structure, with no unrealistic oscillations observed.

Future Work

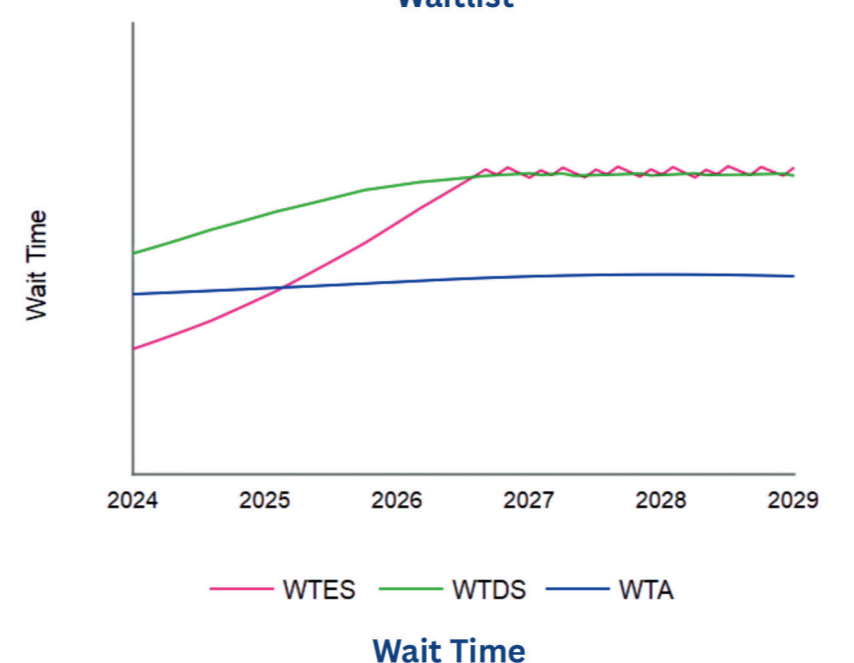
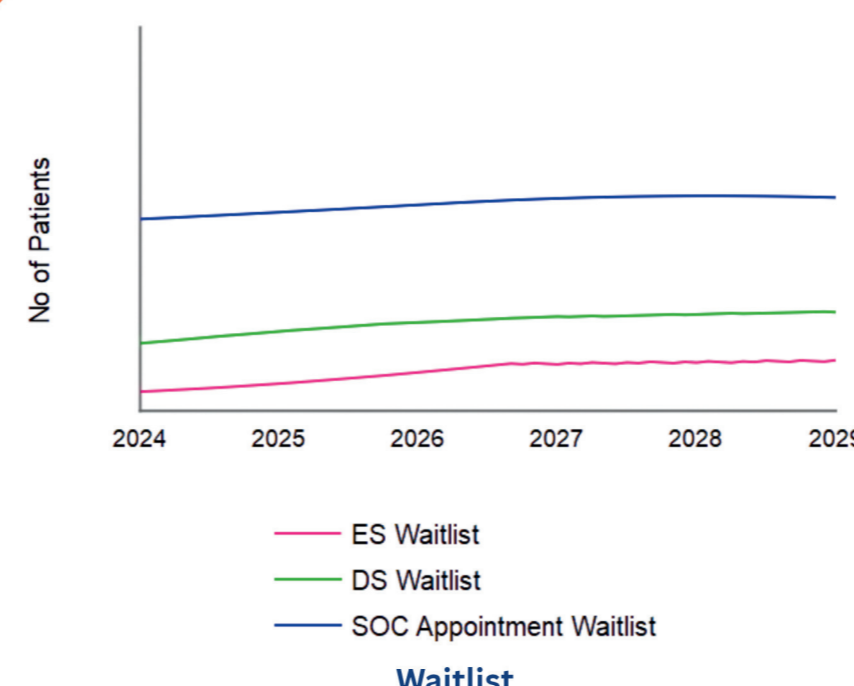
Inpatient Bed Management

Future work will focus on improving the allocation and utilisation of the inpatient bed include refining bed assignment strategies and incorporating more dynamic patient flow data. These improvements aim to reduce the waiting time and increase the overall system efficiency.

Dashboard Development

The dashboard will be created to provide clearer and more comprehensive data visualization. Additional features such as real-time updates and user-friendly interfaces will be explored. This will support better monitoring and more informed decision-making.

Results



Waitlist: All three waitlists grow continuously and display asymptotic behaviour toward the end of the simulation, with growth rates gradually slowing as capacity expansion begins to take effect.

Number of OTs: DS OTs expand in discrete steps, bounded by the Gompertz carrying capacity. ES OTs decline slightly, suggesting resource reallocation toward DS as its demand pressure dominates.

Wait Time: Wait times rise sharply at initialisation due to the delay between pressure buildup and capacity response, before gradually plateauing as balancing loops take effect. WTDS and WTES converge by 2026, reflecting competition for the same constrained OT capacity.

Utilisation: All three units remain at 100% utilisation throughout, signalling sustained overload. Continuously growing waitlists ensure demand perpetually exceeds capacity, leaving no operational slack in the system.

