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System Dynamics of Specialist Outpatient Clinic patient flow

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Stock-and-flow model

Systems Thinking is a way of understanding reality that emphasizes the relationships among a system's parts, rather than the parts themselves, and looking at cause-and-effect holistically rather than in silo. System Dynamics (SD) is a method to quantify these effects. SD uses "feedback loops" and "stock and flow" to understand complex systems. Stock represents accumulation, like water in a tank or patients in a healthcare system that flows from one tank or changes from one state to another. See Figure 1.

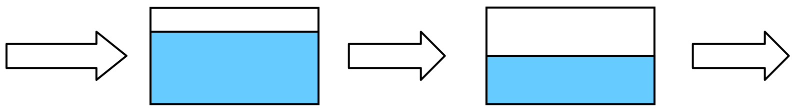

Fig. 1: Stock-and-flow representation

We applied the SD method to understand the patient flow in a hospital by simulating the process to identify the bottlenecks. The aim of the study is to look at patient flows between inpatient, outpatient, operating theatre and emergency care to identify resource bottlenecks.

Here we describe one of the sub-models that focused on the dynamics of the patient flow in the Specialist Outpatients Clinics (SOC). We also examine the widely-used Repeat Visit to First Visit ratio. See Figure 2.

SOC model using SD representation

SOC visits can be categorized as: the patient's First Visit (FV), and returning for follow-up as Repeat Visits (RV).

Patients come to the SOC from referral sources like Polyclinics, Emergency Department, General Practice, or self-referral. Each referral is a request for an appointment, where the date of the appointment maybe days or months later from the point of request. This waiting time is referred to as FV lead time. It is a performance indicator that hospitals track.

From a SD perspective, we treat the number of FV requests or bookings per day as "inflow" to the SOC system. The number of patients who are waiting to be seen, i.e., waiting list, will then be the "stock". The "outflow" rate is determined by the capacity of the clinics quantified by the number of FV slots that they can provide.

Of those FV attendances, a fraction will be given a follow-up appointment (see FV TCU percent in the Fig 2) and be seen repeatedly until they are discharged out of the SOC system.

"RV-FV ratio" is a widely tracked figure and reported in the MOH Statistics Bulletin. From a clinical protocol's perspective, it gives the average number of repeat visits that each FV visit (i.e. patient) will need, hence a longitudinal view. But in practice, it is computed based on the ratio of RV attendances to FV attendances for a given time period and is thus a cross-sectional measurement.

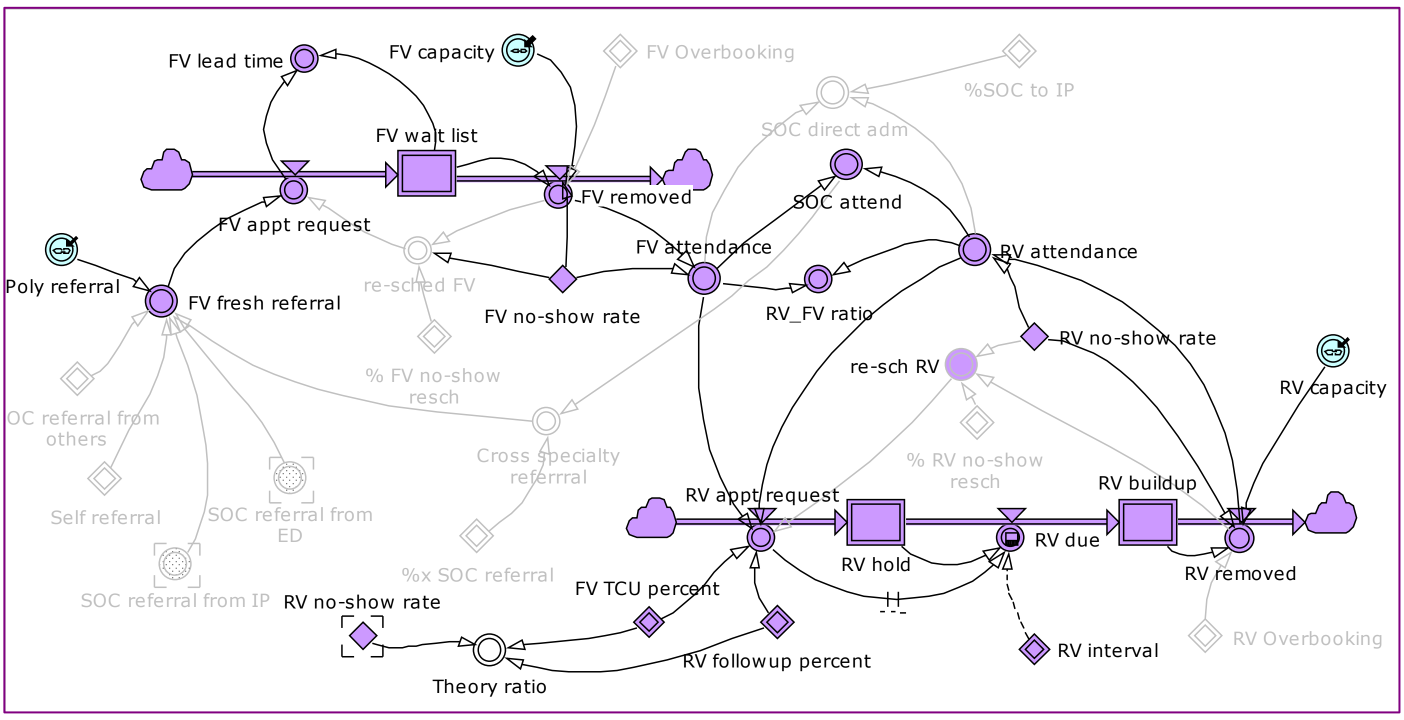

Fig. 2: Macro flow of SOC using stock-and-flow

Insights from the analysis – what can we learn from the visual mapping and quantitative results?

- ***Impact of creating FV slots on RV demand and vice-versa.*** When the appointment lead time for FV appointment is long, clinics may create extra FV sessions to clear the backlog as a short term measure. But as each FV attendance typically needs to be followed up with one or more RV in the future, clinics need to be prepared to create more RV slots in tandem. Using the model, we can estimate this delayed effect. In a similar manner, when the RV-FV ratio is reduced, e.g., from "right-siting" initiatives, we can work out the number of additional FV sessions created from fewer RV. This number is often lower than what is intuitively expected!

- ***RV-FV ratio.*** While it gives an indication of "RV to FV requirements", some caveats in interpretation:
  i. *Formula to relate RV-FV ratio and likelihood of revisit.* In a scenario where all patients turn up for appointments and there is sufficient capacity, the theoretical RV-FV ratio can be derived as f/(1-r) [where f = percentage of FV attendances that will be given RV, r = percentage of a RV attendance that will be given another follow-up visit]. At steady-state, the longitudinal and cross-sectional measurements will give the same figure.
  ii. *A constant RV-FV ratio does not necessarily mean that demand remains constant.* Most often we derive RV-FV ratio based on cross-sectional actualized (show-up) attendances. In a scenario of insufficient FV capacity, the FV lead time will increase. However, as each FV attendance still generates the same number of RV attendances, the RV-FV ratio will remain constant based so it is not a good indicator of change in demand.
  iii. *If FV demand is increasing, the current RV-FV ratio can underestimate the actual RV requirements.* Intuitively speaking, one is comparing the current FV attendances with the past RV attendances.

- ***RV TCU interval and workload.*** If the RV-FV ratio remains constant, changing RV TCU interval does not change the workload required in the long term. For instance, increasing the TCU will merely postpone the demand to a later date. In the short term, more new appointments could be planned, but the existing appointments are just being scheduled to a later date.

Limitation. The model has not considered the feedback of waiting time on demand and capacity. For instance, when the FV lead time is high, patients may opt for another hospital instead. Similarly, ad hoc sessions may be created to reduce the lead time and result in periodic increase in capacity, rather than fixed ones.

In summary, stock-and-flow modelling allows a visual mapping of the patient flow in the SOC. It provides better understanding of the dynamics and allows one to model "what-ifs". We also highlight some precautions when using the commonly used RV-FV ratio.

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