Looking in the Wrong Place for RTT Improvements: A System Dynamics Study of Outpatient Management

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BACKGROUND

Aneurin Bevan University Health Board (ABUHB) in South Wales is in the process of redesigning their outpatient services. The performance measure for outpatient management in Wales is to reduce the time from referral to commencing treatment (RTT).

Given the challenges with raising healthcare demand on the background of financial austerity healthcare organisations are increasingly struggling to meet national RTT targets.

Whilst RTT targets are helpful in understanding new patient backlog, they fail to take into account the fact that for a number of conditions, such as Diabetes or Rheumatoid arthritis, many patients require regular on-going follow-up.

There is currently a poor understanding of how the new and follow-up queues interact. Furthermore, the currently favoured strategies for managing the RTT target may have unintended consequences.

The System Dynamics (SD) model briefly sketched here provides valuable insight into the dynamic behaviour of outpatient queues. Furthermore, it suggests that some of the current practices of managing such queues may have unintended negative consequences as they delay the time between treatments for follow-up patients.

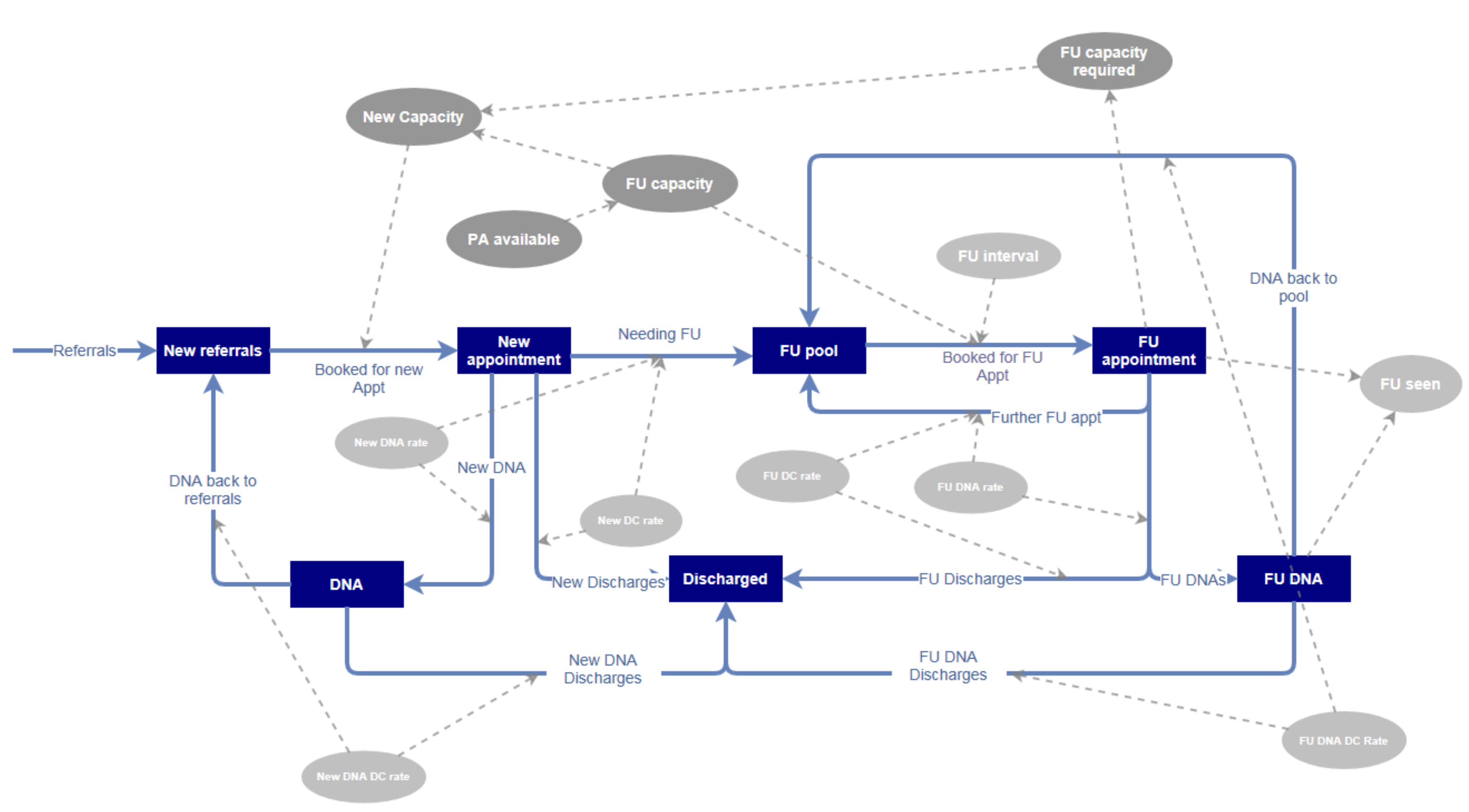
A SYSTEM DYNAMICS MODEL OF THE OUTPATIENT SYSTEM

Design Process

The present model was created because a Rheumatology Consultant was "drowning" in patients and sincerely wished to understand in more detail the impact of management strategies on the new and follow-up (FU) queue in his clinic.

A process map of the outpatient clinic was developed with the support of the Rheumatologist, a service manager and a mathematical modeller. This was then used as the basis for the development of a Stocks and Flows Model built using Insight Maker (www.insightmaker.com) and Mathematica 8.0 (Wolfram Research). Data to populate the model was collected from the hospital's Patient Administration System (PAS). Verification was undertaken with the Rheumatologist and the service manager; validation was undertaken using data from PAS. Among the outpatient management paradigms to be tested are

- the focus on new patients,
- the balance of system capacity and
- a telephone reminder service to reduce the number of patients who do not attend their appointments (DNAs).



The following system is a simplified version of the visualisation above as it neglects patients who do not attend their appointments (DNAs).

$$\begin{aligned}
\dot{x}(t) &= I(t) - \min\{x(t), \Omega_{new}\} \\
\dot{y}(t) &= (1-a_{new}) \cdot \min\{x(t), \Omega_{new}\} - \min\left\{\frac{y(t)}{b}, \Omega_{FU}\right\} + (1-a_{FU}) \cdot z(t) \\
\dot{z}(t) &= \min\left\{\frac{y(t)}{b}, \Omega_{FU}\right\} - z(t)
\end{aligned} \qquad (1)$$

$a_{new} \in (0,1)$ ... weekly discharge rate of new patients

$a_{FU} \in (0,1)$ ... weekly discharge rate for follow-up (FU) patients

$b \in \mathbb{N}$ ... number of weeks between two consecutive appointments

$\Omega_{new} > 0$ ... capacity constraint for first appointments

$\Omega_{FU} > 0$ ... capacity constraint for follow-up (FU) appointments

$I(t) := I > 0$ ... new patients referred to the service during week t

$x(t) \geq 0$ ... number of patients waiting for a first appointment at week t

$y(t) \geq bz(t)$ ... size of the "pool of follow-up (FU) patients"

$z(t) \geq 0$ ... number of follow-up (FU) patients seen during week t

WORK IN PROGRESS – FIRST RESULTS

What is the capacity needed to sustainably operate an outpatient clinic?

To answer the question we analyse the unconstrained system, i.e. $\Omega_{new}, \Omega_{FU} = \infty$, and find what total capacity would be required to match demand – corresponding to an outpatient system with no queues. In this case the system simplifies to two variables, i.e. the follow-up (FU) patient pool, $y(t)$, and the number of FU patients seen, $z(t) \leq y(t)/b$, while the number of patients waiting for a first appointment, $x(t)$, reduces to a weekly "inflow" $I(t) := I$. (Recall that DNAs are omitted in this approach!)

$$\begin{aligned}
\dot{\boldsymbol{y}}(\boldsymbol{t}) &= (\boldsymbol{1}-\boldsymbol{a_{new}}) \cdot \boldsymbol{I} - \frac{\boldsymbol{y}(\boldsymbol{t})}{\boldsymbol{b}} + (\boldsymbol{1}-\boldsymbol{a_{FU}}) \cdot \boldsymbol{z}(\boldsymbol{t}) \\
\dot{\boldsymbol{z}}(\boldsymbol{t}) &= \frac{\boldsymbol{y}(\boldsymbol{t})}{\boldsymbol{b}} - \boldsymbol{z}(\boldsymbol{t})
\end{aligned} \qquad (2)$$

The **steady state quantities** can be computed in a straightforward way from the simplified system equations above and resemble **Little's Law** known from Queueing Theory:

$$\hat{\boldsymbol{y}} = \boldsymbol{b} \cdot \hat{\boldsymbol{z}} \quad \text{and} \quad \hat{\boldsymbol{z}} = \hat{\boldsymbol{\rho}} \cdot \boldsymbol{I} \quad \text{with} \quad \hat{\boldsymbol{\rho}} := \frac{\boldsymbol{1}-\boldsymbol{a_{new}}}{\boldsymbol{a_{FU}}} \qquad (3)$$

In steady state, the "arrival rates" correspond to the weekly throughput, $\hat{z}$. The "waiting time" is equal to the planned interval between two consecutive appointments, b. The product of these two quantities accounts for the total number of patients in the outpatient system, $\hat{y}$. (Recall that this result does not hold along the transients!)

The steady state number of appointment slots (new patients need twice as long as follow-up patients) required to guarantee that on the long run patients do not have to wait is equal to $\hat{\Omega} := \hat{z} + 2I$.

First results derived include insights about how to (re-)shape outpatient clinic management strategies.

Result 1

In the long-run sustainably state altering the follow-up interval b (either shortening or lengthening it) does not change the number of patients that can be seen per week – however it drastically impacts the number of patients in the FU pool. ***Don't shift follow-up appointments backward to bring in more new patients (e.g. to meet RTT targets)!*** It destabilises the system and makes patients wait longer for their FU appointments.

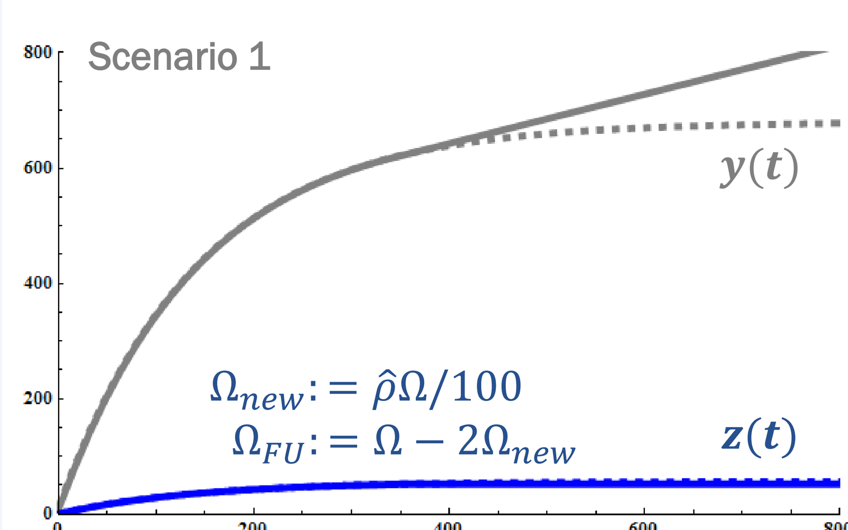
Result 2

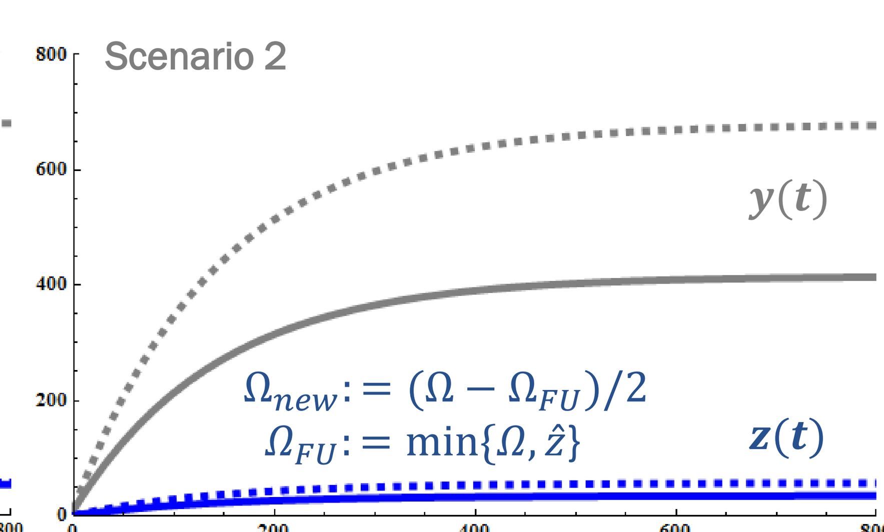
The number of follow-up patients that can be sustainably seen every week depends upon the number of patients who are not discharged after their first appointment, and the rate at which they are discharged later on. ***Don't bring in patients if you can not guarantee their follow-up treatment!*** This is particularly important if the success of treatment depends on the timeliness of the FU treatments and causes deterioration in case of delay.

How does the "FU to News" ratio affect outpatient clinics if capacity is below demand?

If actual capacity is below demand, i.e. $\Omega < \hat{\Omega} := \hat{z} + 2I$, the way of "sharing" appointments between the treatment of new and follow-up (FU) patients critically affects outpatient flow. In practice, the "FU to News" ratio is observed to be held constant for very long stretches of time. Though this is mostly counterproductive if away from the steady state, we tested several constant "FU to News" ratio scenarios (two depicted here) due to the persistence of this strategy in the daily practice of outpatient management.

In scenario 1 resources are shared based on the steady state "FU to News" ratio, $\hat{\rho}$, of the unconstrained model (2), in scenario 2 on the bases of the equilibrium quantity, $\hat{z}$, for FU patients (*solid lines in below charts refer to these scenarios; the unconstrained base case is depicted by dashed lines; the parameters derived for a Rheumatology clinic are:* $I = 6$, $a_{new} = 0.15$, $a_{FU} = 0.09$, $b = 12$, $\Omega = 64$; initial conditions are chosen to indicate that at time $t = 0$ some patients are already in the system, i.e. $x_0 = z_0 = 0, y_0 = 12$).





Operating the system on the basis of $\hat{\rho}$ (scenario 1) allows to stabilise $x(t)$ – but due to "missing" capacity FU demand eventually overshoots scarce supply and waiting times for FU patients increase. Operating the system based on the steady state number of FU appointments $\hat{z}$ (scenario 2) does not allow to stabilise the number of patients waiting for a first appointment, $x(t)$. Too many resources are then planned to be allocated to FU patients: the FU pool "dries out" while the RTT targets for new patients are permanently breeched and require initiative clinics.

Result 3

Divide available resources wisely when under capacity, i.e. flexibly adapt the "FU to News" ratio and be aware of its true level!

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