**Can a system dynamics model of the emergency department show which levers reduce bottlenecks and delays to improve access to care?. Sue McAvoy, Andrew Staib, and Gregory Treston.**

**Intro:**

The purpose of the paper is to evaluate how a system dynamics (SD) patient flow model of an emergency department (ED) can identify effective strategies for reducing backlogs and improving access to care. Dynamic simulation models that map interdependencies at the systems level can provide a more comprehensive understanding of the system and its implications for performance, including the drivers that improve outcomes of costs and patient experience. A pilot SD model was designed and developed for the ED, based on the Mater Public Hospital Emergency Department, to show how different strategies could have led to different outcomes compared to business as usual (BAU). The paper highlights the potential benefits of using SD models in healthcare institutions to optimize resource allocation, data use, wait times, access to care, and other factors that affect patient outcomes.

“Paul et al. (2010) presented a review of ED simulations literature from 1970 to 2006 with the goal of highlighting how simulation studies can enhance understanding of overcrowding in ED's and as a tool can potentially help inform solutions.”

“Mohiuddin et al. (2017) systematically reviewed the peer-reviewed literature to investigate the use of computer simulation for understanding the causes of overcrowding in the ED under the jurisdiction of the UK National Health Service. They found that 10% of simulations used SD modelling.”

“Salmon et al. (2018) reviewed simulation modelling applied to ED's focusing on all English language

papers from 2000 to September 2016. Of 254 relevant publications, 209 papers employed DES, only 18 (7.1%) used SD, and a further 13 (5.1%) used a combination of either DES/agent-based modelling or DES/SD.”

“SD is a method focusing on the “big picture” and can be used to understand the feedback mechanisms within the ED and its related departments and their influence on both system behaviour and system efficiency over time.”

“To develop the model and establish a base case, real historical time series data for five separate weeks were used. The logic behind the weeks sampled was to capture seasonality impacts from different times of the year and also enabling comparison by ensuring one of the weeks was consistent across all 3 years. Synchronized random variables are used to direct and distribute patients on pathways. The model was informed by anonymous patient-level flow data collected from EDIS for five full 7-day week periods covering Monday 00:00 through to Sunday 23:59 for the weeks of February 6, 2017 (summer), October 2, 2017 (spring), February 5, 2018 (summer), February 3, 2019 (summer), and June 9, 2019 (winter). Patient-level data for the reference mode/model construction and incorporated delays and volumes included (a) assigned triage category, (b) arrival mode, (c) arrival time, (d) triage date and start time, (e) triage end time, (f) time doctor seen, (g) total length of stay, (h) first location, (i) time to admission request, (j) time to ward ready, (k) time from admit request to ED discharge, (l) actual ED discharge time, and (m) disposition pathways. The model construction and parameterization was based on the assumptions and data sources in Table 1. Most assumptions are decisions which can be changed in the model.

Sensitivity analysis:

* Time seeing doctor and testing times increased by 50%
* and 75%.
* A Poisson distribution was used to randomly arrive all
* patients.
* No delay versus a calibrated delay for exiting acute.
* Increasing percentages designating acute by 10%.

“If the choice is increasing capacity by hiring more doctors or adding acute beds, the model suggests that the more effective intervention for improving timely access to emergency care as measured by improved patient flow is increasing the capacity of acute beds. Figures 16 and 17 show that greater acute bed capacity (Scenario 1) acted to alleviate pressure; however, it also adds to underutilization during the quiet times. The model shows that the addition of acute beds alone does not yield the best flow outcome nor does the sole addition of short-stay beds. ED dynamics are all about enabling flow. The addition of short-stay beds will impact flow if these beds are full when acute flow pressure exists and if the threshold number of doctors is deployed to ensure patients can clear the ED. For the BAU week, there were some periods when both acute and short-stay beds were full at the same time. The optimal outcome for improving ramping (flow) was modifying all three levers: acute beds, doctors, and short-stay beds (Figure 18). “The model shows that under certain dynamics, the addition of an extra doctor to remove blockages can be counterintuitive. The value of that doctor is a function of the resource interdependencies at the time the extra doctor is added. According to Figure 18, an additional doctor on day shift does not measurably relieve ramping.”

“An SD model is an aggregate model at the system level so it will not pick up nuanced patient-level dynamics. There is value in not incorporating all the detail complexity. Strategy should not respond to every operational nuance. The risk of doing so is more pronounced oscillation in resource deployment as the system overshoots and undershoots desired goals, which can be costly and frustrating. Resourcing and the feedbacks between resources is a critical determinant of performance. The model currently does not differentiate between experienced doctors (consultants, senior health officers, and registrars) who can expedite patient treatments more quickly than junior doctors whom protocol requires must consult senior doctors prior to making decisions or ordering tests. Worker burnout is outside scope. Break times and time to handover as shifts change have not been explicitly modelled. The role of nurses is not explicit in the model; however, the delays specified would reflect wider resourcing and ward availability. Doctor's breaks are not considered and neither is seasonality. Some of these dynamics, although beyond the scope of this pilot model, are scoped for the next stage of this work.”

**Conclusion:**

The study is a work in progress that explores the use of a system dynamics (SD) model to understand trade-offs and how various interventions can impact multiple outcomes in the emergency department (ED) healthcare system. The authors note that the pilot SD model shows promise but should be regarded as only the first step. The model provides a communication tool for healthcare professionals, managers, and data analysts to better understand the interdependencies in this complex system. The simulation model through scenario analysis appears to show which levers effectively reduce backlogs to improve access to care. However, assumptions should be continuously challenged, and system components currently treated as endogenous should be built out in stock and flow form. The study provides valuable insights into internal and external trends and behaviors, but regularly updating the model parameters with current data feeds would be ideal, especially considering seasonality's impact on system behavior. The authors suggest that SD has the potential to improve the quality and productivity of healthcare and can have strategic value and policy impact in an area of healthcare that is facing significant challenges. They determined that it is worth investigating further.

**System Dynamics (SD) in Healthcare Setting:**

**Pros:**

1. **Allows for comprehensive view of system**
2. **Can model different interventions to understand how outcomes change**
3. **A SD model helps optimize**

**Cons:**

1. **Not easy. Requires expertise**
2. **The model can easily become very complex**
3. **Time consuming to learn SD and learn about modeling in SD**
4. **Requires many assumptions**

**Important Exhibits:**

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