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IMPROVING HOSPITAL DISCHARGE FLOW THROUGH SCALABLE USE OF DISCRETE TIME SIMULATION AND SCENARIO ANALYSIS

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ABSTRACT

Inadequate patient flow from hospitals into community care is often blamed for bed blockages in the acute setting. This is bad for patient experience and outcomes and has an upstream knock-on effect for Accident and Emergency performance and, in turn, ambulance offload delays and response times. Despite the large numbers of acute bed-days lost to delayed discharges and the ambition to expand home-based community care, there has been a deficit of modelling studies investigating the dynamics of this pathway and providing the relevant insights to service planners. Working closely with healthcare managers, this paper reports on the development and deployment of versatile simulation tools for modelling both the home-based and bedded community step-down pathways, known as 'Discharge to Assess' or D2A in England's NHS. Developed in open source 'R', these tools offer scalable solutions for exploring different scenarios relating to demand, capacity and patient length of stay.

Keywords: Healthcare management, Resource allocation, Community services, Discharge planning.

1 INTRODUCTION

Intermediate care describes services typically provided in the community that support the integration and continuity of care between different health and care settings, such as bridging the transfer from hospital-based care to patients' normal residence. Key purposes are to facilitate timely discharge from the acute hospital setting for mainly older and frail patients (Levin and Crighton, 2019; McGilton et al, 2021) and to promote faster recovery, maximise independence, and prevent readmission (Sezgin et al, 2020). With rising life-expectancy globally, health and care systems must support a growing number of frail and elderly patients in a cost-effective and technically productive way. Yet, there remain various challenges to achieving this, not least a lack of fluidity in the movement of patients along the acute discharge pathway, leading to the propagation of discharge delays in the more costly upstream settings (Cadel et al, 2021).

Health and care systems have responded to the growing proportion of elderly people in their populations with strategies that attempt to distribute resources more optimally between acute and community healthcare, and between health and social care. In many countries, the provision of integrated care models has been a focus for decades, aiming to improve system efficiency and quality of care by working across multiple services, providers, and settings (WHO, 2016). In England, recent reforms have seen the establishment of statutory Integrated Care Systems (ICS) which mandate collaboration within and between National Health Service (NHS) organisations and Local Authority social care, with intermediate care and acute discharge planning a key focus (Department of Health and Social Care, 2021).

In the English NHS, the Discharge to Assess (D2A) service (NHS, 2021) encompasses three time-limited pathways which provide intermediate 'step-down' care for patients discharged from hospital for a period of up to six weeks (Figure 1). The underlying rationale is to reduce unnecessary use of acute hospital resources beyond the point a patient is deemed medically fit for discharge by transferring them to a setting in which their longer term health and social care needs can be properly assessed. Patients discharged on D2A pathway 1 (P1) return to their usual place of residence and receive domiciliary visits from community health services. If more intensive post-acute rehabilitation is required, then patients – who are expected to return to their usual place of residence eventually – may be discharged on D2A pathway 2 (P2), which involves transfer to a non-acute bedded facility for up to six weeks. D2A pathway 3 (P3) is also non-acute bed-based care, but is reserved for those requiring the most complex health and social care need assessments. Many of the patients in this pathway will subsequently go on to a long-term care home placement. In England, of those that enter a D2A pathway following an acute admission, it is expected that at least 90% will require P1, with a maximum of 8% and 2% requiring P2 and P3 respectively (NHS, 2021).

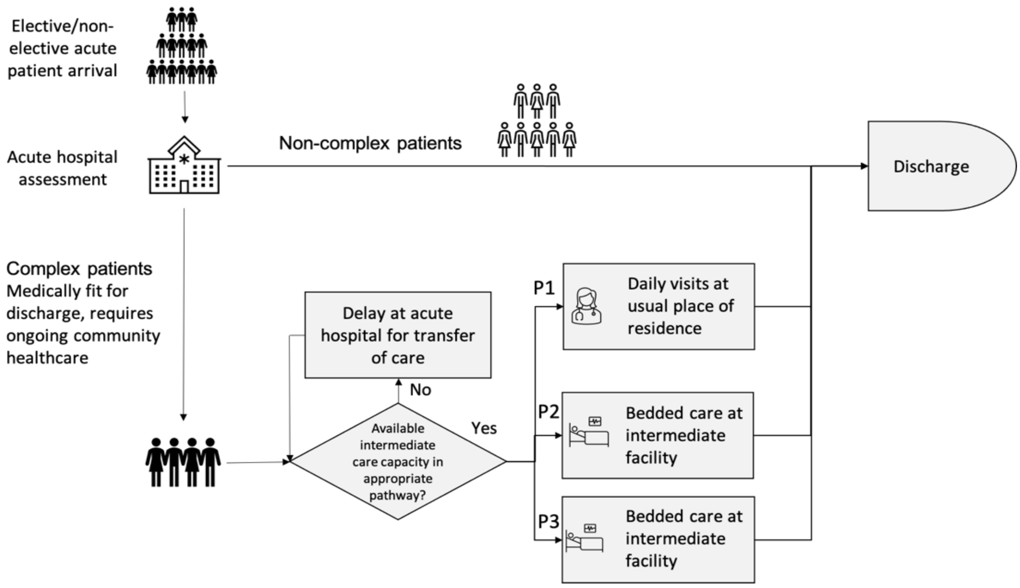

Figure 1 *Organisation of intermediate care services in the English National Health Service (NHS).*

For modelling community care, investigators have considered bedded facilities (Patrick et al, 2015) and home visits (Demirbilek et al, 2019). However, a review of modelling studies of community services (Palmer et al, 2017) found that multiple care settings are rarely considered and also that time-varying demand is not captured. In those studies that do consider the interaction between acute and community care, this is often limited to a specific type of disease, such as stroke care, childhood asthma, or other chronic diseases (Monks et al, 2016; Wood and Murch, 2020). Nonetheless, these accounts do demonstrate the value in modelling the wider context of the pathway. Without considering these interactions, it is difficult to meaningfully assess the full extent of various capacity considerations in the performance of upstream services, and to derive a more thorough understanding of the wider health and care system operation.

The objective of this study is to report on the development and practical use of a purpose-built computer simulation tool for modelling the D2A P1-3 complex discharge pathways, from the point a patient is deemed medically fit for discharge from acute hospital, to admission and discharge from the intermediate care provider. The simulation method employed for modelling bed-based intermediate care services (P2 and P3) is detailed in Section 2.1. This is extended in considering visits-based intermediate care services (P1) in Section 2.2. Examples of real-life use in a major health and care system in and around Bristol is presented in Section 3, through a selection of scenarios requested by service managers and modelled via the simulation tool. Finally, Section 4 contains a discussion regarding practical implementation, strengths and limitations, and further research opportunities.

2 METHODS

2.1 The Bed-based Care Pathway Model

After discharge from the acute hospital, patients assigned to the D2A P2 or P3 pathways are transferred to a step-down bed-based care facility for a given length of stay. Daily referrals and lengths of stay are sampled from appropriate statistical distributions using empirical data or other sources of information. The capacity in this setting is represented in terms of the number of intermediate care beds available with the patient occupying such a bed for the entirety of their length of stay. If a referred patient is unable to be transferred to a community care bed due to capacity being fully occupied, then he or she will continue to occupy the acute hospital bed until capacity in the community is available. The queue discipline is first-in first-out (FIFO). By setting the capacity to a sufficiently large number, the model allows any patient to enter the assigned pathway without any delay in the acute hospital. The resulting estimate of the number of beds occupied illustrates the maximum capacity needed to have zero delayed discharges from the acute hospital. The above events are simulated over discrete time-steps, with each bed-based care pathway (in this case P2 and P3) treated independently.

2.2 The Visits-based Care Pathway Model

Patients assigned to a visits-based D2A P1 pathway will reside in their usual place of residence after being discharged from the acute hospital and will be provided care by one or more care workers during regular visits. As in the bed-based model, patients referred but unable to be discharged into the pathway due to unavailable capacity, remain in an acute hospital bed and represent a delayed discharge. As with the bedded-care pathway model, daily referral rates and duration of service can be generated from statistical distributions estimated from the user-defined data. Likewise, the initial and final daily visit requirements are sampled from user defined distributions. Discussions with the intermediate care providers revealed that the number of visits tapers over the duration of the service, which is a particularly interesting dynamical property.

For this pathway model, the capacity is defined as the number of available visits in the system, i.e. the number of patients that can be admitted into the pathway (also defined as ‘slots’), multiplied by the average number of visits required per day. Hence, at full capacity a patient with a high number of required visits and/or long service time may prevent patients with lower service requirements from accessing the community care and this will create delays with respect to discharge from the acute hospital. Figure 2 shows an illustration of how patients waiting in the queue are admitted when capacity becomes available. On the left-hand side there are sampled daily visit demands of the queueing patients over their sampled lengths of stay, and on the right-hand side the remaining visit requirements of the patients currently admitted in the service. At each discrete time step, the queue is searched for the longest waiting patient(s) whose demand can be accommodated, based upon service capacity (dashed line). Then, the corresponding patient is admitted to the P1 pathway. There are many different rules that can be assumed while deciding on which patients in the queue should be admitted first (e.g., FIFO, highest load first etc.). Our decision rule is based on current practice in the healthcare system for which this model is applied. However, as these patients are especially characterized with complex needs, there is no "one rule fits all" and alternative admission rules can be interchangeably used in real practice. In the scope of this work, we have controlled that with the assumed admission rule, patients with higher initial visit requirements are not over-harmed. Comparison of different queuing admission rules can be conducted as part of future work.

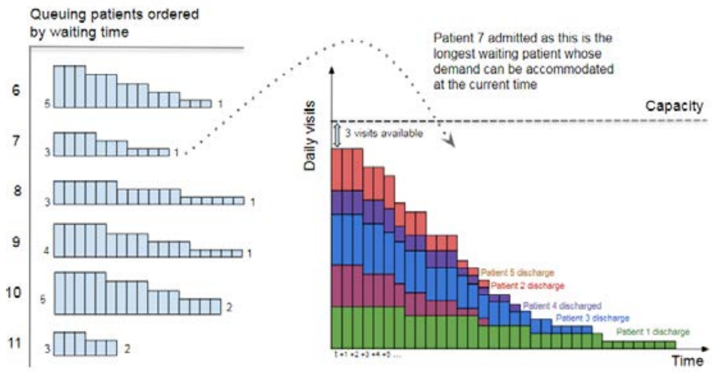

Figure 2 *Illustrative example of state of the system for P1 at a particular time in the simulation.*

2.3 Model Implementation

The simulation tool is designed to be scalable such that it enables flexibility in designing the modelled system in terms of numbers and types of pathways, localities, and parameters, as well as parameter combinations relating to various what-if scenarios. The tool uses a Microsoft Excel spreadsheet into which the user enters the required input information including:

- Daily arrival rates into each pathway.
- Initial conditions of each pathway and locality, including both the initial occupancy of each pathway (how many patients are currently in the service at the beginning of simulation period, by pathway and locality) and the initial queue in each pathway (how many patients are ready to be discharged into a pathway waiting in the acute at the beginning of simulation period).
- Capacity in each pathway, in terms of either visits/slots (P1) or beds (P2 and P3).
- Distribution of length of stay in each D2A pathway with related parameters (e.g. mean, standard deviation, median).
- For P1 pathway, the initial number of visits, final number of visits and corresponding distribution assumed for an average patient over their service time.
- Average costs of intermediate care service of each pathway and acute hospital bed.

The Excel spreadsheet can then be read in by the simulation model, which employs the routines described in Sections 2.1 and 2.2, and is coded in 'R'. On completion, csv files containing the full simulation output data are automatically generated and deposited in the user's working directory. Outputs are also provided in Microsoft Word reports, produced automatically through the 'R Markdown' package. These reports include the inputs used by the model for each scenario. Plots are used to illustrate each referral scenario, and tables for length of stay and capacity under each scenario. For each day in the pre-determined horizon period, the model estimates the mean number of patients in each pathway, the mean number of acute patients delayed, and the mean number of days patients are delayed under given capacity constraints. For each pathway, three plots show the mean daily number of patients in D2A service, mean daily numbers of acute patients delayed, mean number of acute delayed days and corresponding cumulative costs over the prediction horizon.

3 APPLICATION

3.1 Study Setting and Context within the BNSSG Healthcare System

The Bristol, North Somerset and South Gloucestershire (BNSSG) health and care system serves a resident population of a million across three local authorities and a mixture of large metropolitan, rural, and coastal locations. The city of Bristol contains a higher proportion of younger individuals and has a more culturally and ethnically diverse demographic than either North Somerset or South Gloucestershire. Rural and coastal areas contain a greater proportion of older individuals and pockets of severe deprivation. Overall, however, the age profile of BNSSG is similar to the England average.

Acute care is provided by two hospital trusts with intermediate care provided by a single community services provider. At the time of the study (October 2022), the D2A pathways had high occupancy rates with all 234 available caseload slots in service in the P1 pathway, 92% of the 199 beds and 98% of the 154 beds in use in P2 and P3 respectively. This contributed to significant delays to accessing the three pathways, with 81, 84 and 85 patients in acute care ready and awaiting discharge (henceforth, this is referred to as the number of 'blocked' acute beds). Mean D2A durations of service were 16, 38 and 45 days for the P1-3 pathways, with respective medians of 6, 32 and 39 days illustrating the significant variation.

A particular over-arching complexity of D2A pathways, which makes them difficult to model and plan for, is that responsibility, accountability and control for them are not the remit of any single organisation in the ICS. For example, the effects of mitigating circumstances for one aspect of the pathway or organisation. Reducing delays in discharging patients from acute beds may have significant adverse consequences elsewhere for the pathway or other organisations; in this case on pressures to increase downstream capacity or increase system productivity. This means, in turn, that there is a large number of influential stakeholders whose agendas, priorities and budgets do not always align with each other and need to be taken into account with due recognition afforded to potential trade-offs between them. The creation of the ICS is the latest attempt to support a joint approach to the D2A issue and the acute, community health, and social care interface more generally. However, this, in turn, depends critically on good data flows, access to them, and methodologies for their transformation into usable and effective information which can act as a central focus for exploring planning scenarios in a holistic, system-focused manner. The purpose of this modelling is to support that 'data to information' transformation both through quantification of planning scenarios and a greater overall local awareness of which data are relevant.

3.2 Scenarios

The starting point for the model is the current system state in each local authority: the number of patients occupying each pathway and the number of patients in acute beds who are currently delayed while waiting to be discharged into a D2A pathway. These data are directly pulled from existing, routinely collected datasets. Referrals into D2A settings are based on the actual trend over the previous six months by local authority using anonymised patient-level data. This provides the 'baseline scenario' and enables comparisons to be made between current and target proportions of patients entering each pathway.

Three length of stay (LOS) scenarios (current baseline, target and intermediate – the middle point between current baseline and target), and two arrival rate options (current baseline and target) are automatically generated, and all combinations of these scenarios are outputted in the routine report for each local authority area. This combination provides a total of six scenarios for nine pathways (i.e. for each D2A Pathway P1-3 in each of the three local authorities). Additionally, unrestricted capacity scenarios are considered for each LOS (current, intermediate and target) and pathway split (current and target) in order to assess maximum capacity required if none of simulated patients had to join the queue in the acute hospital. The target mean D2A LOS are 10 days, 21 days and 28 days and the target pathway split is 70%, 10% and 10% for P1-3 respectively. The remaining 10% of the acute referrals correspond to patients with complex mental health diseases and are out of scope of the modelling. Table 1 summarises all twelve scenarios designed based on the combination of different options.

Table 1. *Scenarios considered for the simulation modelling.*

Scenario	Capacity	LOS (mean days)	Arrivals (P1-3 pathway split in percentage)
1	Baseline	Baseline	Baseline
2	Baseline	Baseline	Target (70;10;10)
3	Baseline	Target (10;21;28)	Baseline
4	Baseline	Target (10;21;28)	Target (70;10;10)
5	Baseline	Interim	Baseline
6	Baseline	Interim	Target (70;10;10)
7	Unrestricted	Baseline	Baseline
8	Unrestricted	Baseline	Target (70;10;10)
9	Unrestricted	Target (10;21;28)	Baseline
10	Unrestricted	Target (10;21;28)	Target (70;10;10)
11	Unrestricted	Interim	Baseline
12	Unrestricted	Interim	Target (70;10;10)

3.3 Results

For each of the nine combinations of BNSSG locality (the three local authorities) and D2A P1-3 pathways, modelled parameters and scenario combinations are summarised and plotted (an example is provided in Figure 3). For each of the twelve scenarios, outputs include: the number in service (the number of patients estimated to be utilising the service given service capacity); the number awaiting service (the number of patients estimated to be delayed in the acute sector awaiting D2A); and the mean days delayed (the mean number of days delayed in the acute sector). In the plots, some of the scenarios have similar results as reflected by an overlap of the lines. This happens either because the mean number of patients in service hit capacity (illustrated by a flat horizontal line on fixed capacity input figure), or the mean number of patients in the queue and mean number of days delayed hit 0 when capacity is significantly higher than the demand (e.g., scenarios with unrestricted capacity assumption).

Looking at the baseline scenario, which represents the current status of parameters and assumes that input parameters will remain the same over the simulation horizon, one can see that the queues in the acute will build up extensively in all localities for the P2 and P3 pathways. The combination of scenarios allows the decision maker to see what the impact of different strategies may have on the outputs. For example, achieving the target pathway split of 70%, 10% and 10% for pathways P1-3 respectively has a much higher impact on reducing the number of patients delayed in the acute compared to improving the LOS to intermediate values. However, the target pathway split will increase the arrivals through P1 which will in turn cause delays in the acute. So, a strategy that combines LOS reductions and achieving target pathway split may be a better solution for controlling negative outcomes.

The unrestricted capacity scenarios (Scenarios 7-12) allow to see what capacity should be in order not to have patients delayed in the acute as any patient who is referred to a pathway is immediately admitted as there is always available capacity. Based on these scenarios, the outcomes show that given current LOS in the community and daily demand rates, the capacity needed can go up to three times more than current capacity for certain locality-pathway pairs. But, on the other hand, if target pathway split and target LOS are achieved than current capacity would be sufficient and could even be reduced.

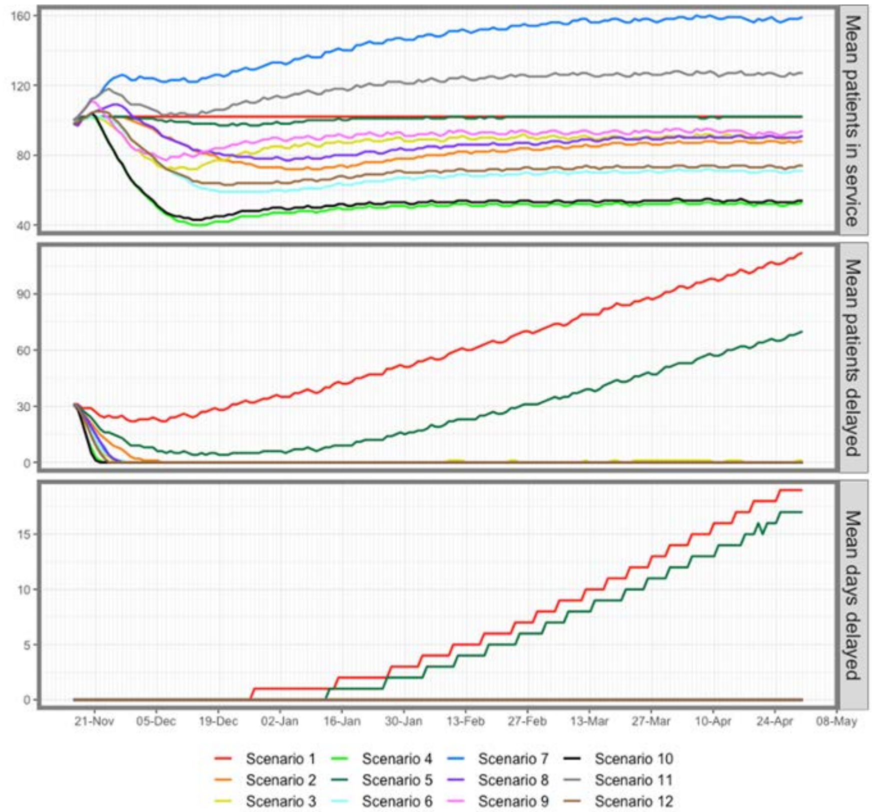

Figure 3 *Example output for Bristol Local Authority D2A P2 pathway for all considered scenarios.*

4 DISCUSSION

4.1 Reflections on Practical Implementation

As a project to develop a model that was both practical and straightforward to understand and implement by non-technical modellers, it was recognised that there was an imperative to engage and work closely with acute and D2A stakeholders from the outset. This was always seen as a two-way process: to understand from them what a 'useful model' looked like and how it might fit with local agendas and decision-making structures, and for the project team to explain and convey what the model was capable of doing for them in supporting a knowledge and skills transfer (not least so modelling could become independent of technical support by the project team). At the time of writing this remains an ongoing process with a good degree of trust between the research team and the stakeholders from all of the principal organisations involved.

The modelling development process has itself generated a greater awareness locally of what constitutes relevant data for D2A planning purposes and increased broader awareness of the whole-system nature of D2A. Also important in this is a recognition that the model has relevance from a care professional as well as strategic planning perspective.

The process of implementation has been iterative from the start. It began with outputs from an initial construct of the model – itself modified through early discussions with local stakeholders – being presented to stakeholders through existing meeting forums focused on D2A issues. Maintaining a standing presence at these forums, and demonstrating an understanding of the D2A system generally, also helped in keeping current an awareness of the model amongst stakeholders and gaining trust that the project team were properly engaged with pertinent D2A issues. A breakthrough in acceptance was the incorporation of modelling estimates into supporting a successful business case proposal of approximately £13 million to further develop and maintain the D2A system locally, and to support its subsequent implementation phase. Using the IPACS model and results from the scenario analysis, stakeholders have now the ability to not only quantify how different strategies (e.g., reduction in LoS, change in spread of the demand) and their combinations can impact key outcomes of their system but also compare different local authorities to characterize best practices. The model is now used as a decision supporting tool which allows better informed decision making for intermediate care service commissioning. There has also been recent interest in using the model to explore scenarios for activity planning for 2023-24.

4.2 Strengths and Limitations

It is crucially important to optimise the complex discharge flow as the efficient and effective movement of patients along the D2A pathway has direct and indirect consequences for the wider acute and community care system. An under-performing discharge pathway results in delayed patients in acute hospitals and reduced available bed capacity. This, in turn, imposes operational delays for Accident and Emergency departments and ambulances and reduced elective capacity (where theatre capacity may be left idle). A large number of patients as a result will not be in the best location for receiving optimal care for their conditions and at greater risk of decompensation and hospital-acquired infection.

Despite these major issues to be addressed, the field has seen a relatively low levels of interest from the academic community so, alongside the above-mentioned practical benefits to the Bristol healthcare system, a strength of this current study is in addressing that research deficit. This has been approached through a flexible modelling tool that can approximate the various pathways, parameters and scenarios currently under consideration. The designed flexibility of the tool will enable the model to be adapted and scaled up to address similar issues in other health and social care systems. While individual ICS areas have unique legacies and starting positions, the underlying issues of D2A are the same right across the UK.

Limitations of this modelling study are, as always, multifaceted. From a technical perspective the current scope of the model does not cover all aspects of the whole discharge pathway system (for example, specific social care inputs, specialised palliative care pathways or longer-term post-D2A pathways such as permanent placement capacity in care homes, or ongoing community health and social care services). These are identifiable gaps, but outside the scope of the current research project. Other limitations lie outside the model and reflect ongoing issues with data completeness and accuracy across organisations. This issue is not confined to Bristol and will be repeated to various degrees across the NHS.

4.3 Further Research Opportunities

With plans to enhance use of home-based care, there exist various opportunities for future simulation and other advanced analytics efforts. These may include developing the pathway model to include social care, which would enable similar analysis of the effect of capacity of this service on upstream services, including D2A as well as acute hospital care. Further work could also examine the effect of acute blockages on Accident and Emergency performance and, in turn, ambulance offload delays and ambulance response times. Investigators may also wish to consider the efficiency of the home-based service from a vehicle routing perspective, in ensuring an optimal schedule of home visits based on a given capacity. Finally, efforts could be directed toward analytical solutions or approximations, thus bypassing the need for relatively computationally-costly simulation models.

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