# Examining the effect of interventions in emergency care for older people using a system dynamics decision support tool

## Abstract

Background: Rising demand for Emergency and Urgent Care is a major international issue and outcomes for older people remain sub-optimal. Embarking upon large scale service development is costly in terms of time, energy, and resources with no guarantee of improved outcomes; computer simulation modelling offers an alternative, low risk and lower cost approach to explore possible interventions.

Method: A system dynamics computer simulation model was developed as a decision support tool for service planners. The model represents patient flow through the emergency care process from the point of calling for help through to ED attendance, possible admission, and discharge or death. The model was validated against five different evidence-based interventions (geriatric emergency medicine, front door frailty, hospital at home, proactive care, and acute frailty units) on patient outcomes such as mortality, readmission, and length of stay.

Results: The model output estimations are consistent with empirical evidence. Each intervention has different levels of effect on patient outcomes. Most of the interventions show potential reductions in hospital admissions, readmissions, and hospital related deaths.

Conclusions: System dynamics modelling can be used to support decisions on which emergency care interventions to implement to improve outcomes for older people.

Keywords: Frailty; Emergency and Urgent Care; Interventions; system dynamics

# Background

Rising demand for Emergency and Urgent Care (EUC) is a major international issue and demand is rising annually, especially in older people. The management of older people in the EUC system remains sub-optimal [1], despite guidance from organisations such as the National Institute of Health and Care Excellence, the British Geriatrics Society, and the Royal College of Emergency Medicine [2-5].

It may be that by adopting frailty attuned care pathways, outcomes for older people can be improved. For example, geriatrician led services focusing on older people in the ED have been shown to reduce admissions [6]. However, context is important, and outcomes for patients will vary depending on the nature of the intervention, where and how it is implemented. For example, a seven-day, geriatrician led emergency department service might be possible in larger hospitals which are *relatively* well staffed but will be less feasible in smaller hospitals with different staffing levels.

Computer simulation is widely used in business and industry to test process or service redesign ideas on a computerised version (a model) of the real-world system before incurring the risks and costs of implementation. System Dynamics (SD) is a particular simulation approach that takes an aggregated, strategic view and captures the interactions between the different parts of a complex system [7]. In healthcare, SD is typically used to model patient flow around a care system with the number of patients at different parts of the system monitored over time. SD has been used to support healthcare policy decisions [8] and to show how small changes in one part of a healthcare system can have knock-on effects in another part [9,10].

The aim of this study was to develop and validate a whole-system, evidence-based SD model for people aged 75 or older attending Emergency Departments. The model was then applied in a hypothetical scenario to assess the potential impact of five evidence-based interventions on mortality, readmission, and length of stay.

# Methods

The development of the SD decision support tool was part of a wider study on Emergency Care for Older People (ECOP) [NIHR (17/05/96)]. First, the selection of interventions was informed by a systematic review of reviews, which considered *what* care models had been reported in the literature [11]**.** Second, a qualitative study captured *how* these emergency care models are delivered (to be reported separately). Third, the SD model was developed using parameters which were based on the EUC pathways and service outcomes experienced by 368,754 people aged 75+ who attended an ED in the Yorkshire and Humber region between April 2012 and March 2017. The SD decision support tool was sense-checked (by a wide range of professional healthcare experts) and the outputs validated against hospital metric data collected as part of the study and Office for National Statistics (ONS) data. Following validation, the decision support tool was used to examine the effect of each of the five interventions on a hypothetical hospital setting.

## Selection of interventions

The review described multiple potential interventions [11], five of which were selected based on the quality of the evidence on the effect sizes and following discussion with stakeholders: proactive care, hospital at home, geriatric emergency medicine, front door frailty, and acute frailty units. These were divided into three categories (pre-ED, ED, post-ED) depending on where the intervention was implemented. The interventions and the effect sizes are summarised in Table 1 (see also Appendix 1).

## How are opening times captured in the model

The decision support tool also allows the user to select the time that the chosen intervention is operational. For example, during a typical 9am-5pm schedule each weekday, 24 hours a day, 7 days a week, weekends, or other user-specified times. This enables the user to see the effect of an intervention on hospital outcomes depending upon which proportion of the patients are targeted. For example, if the intervention is operational all the time, then you would expect up to 100% of the patients to receive the intervention. However, if the service only runs during the week and not at weekends then the proportion of patients affected by the intervention will be far smaller (less than 50%). In effect, the decision support tool has been developed so that the user can see a more realistic effect size of a selected intervention. In relation to the geriatric emergency medicine intervention the user can also select the effect size for hospital admissions from the reported range [6].

Table 1 Interventions: studies and documented effect sizes

|  |  |  |  |
| --- | --- | --- | --- |
| Intervention | Description | Effect Size | References |
| PRE-ED |  |  |  |
| *Proactive Care* | Primary care led population risk stratification and nurse‐led care program consisting of CGA, care planning and care coordination for high-risk individuals. | * Negligible effects on mortality, admissions to hospitals or care homes.
 | [12],[13],[14] |
| *Hospital at home* | Providing holistic care to people with urgent care crises in their own homes. | * Hospital at Home with CGA led to similar mortality compared to hospital delivered CGA.
* Mortality (Risk ratio = 0.98, CI = [0.65, 1.47]).
* Older people living at home at six months (affecting readmissions) (Risk ratio = 1.05, CI = [0.95,1.15]).
* Reduction in admissions to long term residential care at six months (Risk ratio = 0.58, CI = [0.45, 0.76]).
 | [15] |
| In-ED |  |  |  |
| *Geriatric Emergency Medicine* | Consultant geriatrician led CGA | * Reduced admissions (absolute risk reduction 2.6%-19.7%)
* Reduced readmissions (Risk ratio = 0.74, CI = [0.55,1.00]).
 | [16], [17], [18], [19], [20] |
| *Front door frailty* | Nurse or allied health professional led CGA, often involving community in-reach. | * Reduced mortality (risk ratio = 0.92, CI = [0.55, 1.52]),
* Reduced admissions (risk ratio = 0.9, CI = [0.7, 1.16]),
* Reduced readmissions (risk ratio = 0.95, CI = [0.83, 1.08]),
* Reduced institutionalisation (risk ratio = 0.75, CI = [0.44, 1.29]).
 | [17], [19], [20], [21], [22], [23] |
| POST-ED |  |  |  |
| *Acute Frailty Unit* | Geriatrician led CGA delivered in short stay areas for admitted patients. | * Reduced mortality (risk ratio = 0.86, CI = [0.68, 1.1]),
* Reduced readmissions (risk ratio = 0.78, CI = [0.67, 0.92])
 | [24] |

CGA = Comprehensive Geriatric Assessment

## Data extraction

We carried out a linked data analysis of routine healthcare data for the entire Yorkshire and Humber (Y&H) region of the United Kingdom (population 5.5 million) using data from the CUREd research database [25, 26] (a large, linked database comprising of healthcare information for approximately one-tenth of England’s population). The database links NHS 111 calls, ambulance incidents, Accident & Emergency, Admitted Patient Care episodes and provider spell datasets, combining over 23 million linked patient episodes of care from April 2011 until March 2017. Emergency care in the region over the period was provided by one ambulance service (Yorkshire Ambulance Service) with a single emergency phone number (999), an NHS telephone triage service (NHS 111), 18 Type 1 Emergency Departments (24-hour consultant-led services with resuscitation facilities) and 13 acute hospital trusts. It is possible to track each patient from their initial emergency call, any conveyance to the ED, their ED attendance, through to ED discharge or hospital admission, and ED re-attendance.

The data analysis informed the following parameters (Appendix Table A1) for each age 5-year band (75-79, 80-84, 85-89, 90-94 and 95+):

* Number of patients in ED and in hospital
* Average daily number of ED attendances
* Average daily number of emergency admissions via ED
* Average daily number of emergency admissions **not** via ED, e.g. direct admissions to specialty services
* Average length of stay
* Average daily number of in-patient deaths
* Average proportion of patients who re-attend ED within 30 days of discharge

As the model follows a cohort of older people for one year, the metrics above are updated daily as patients move through the system. The model does not take account of time of day, day of week, or month, but uses the averages for these parameters over the full six years of data in the CUREd dataset, thereby smoothing out any daily or seasonal variation. This is because system dynamics modelling takes an aggregated, high-level perspective of the whole system that ‘focuses on the wood rather than the trees’: the aim of the tool is to understand and compare the broad impact of different interventions, not to produce detailed forecasts of future patient numbers or waiting times in ED. The model shows how an intervention in ED, which may potentially affect not only the length of stay for admitted patients but also reattendance or readmission rates after discharge, has complex knock-on effects over time at the hospital level.

The SD model drew upon several other data sources for the model parameters and initial patient population levels:

* ONS mortality statistics (2019) [27] and population estimates for the Yorkshire and Humber region (mid-2019) [28].
* Care homes: the number of care home residents in the Yorkshire and Humber region has been estimated from the care homes market study [29]. Recent estimates of the number of care homes in the Yorkshire and Humber region suggest 1,453 homes [30] which would lead to approximately 52,719 residents in the area. The number of care home deaths has been estimated from ONS data which looks at the number of deaths within the care sector [31].

In the SD decision support tool, users can either enter their own values of each parameter or use the default values included in the underlying model. The decision support tool includes a user interface which also allows the user the option to select a hospital setting nearest their own (based on three hospital archetypes – large, medium, small) and use the relevant model parameters in the baseline and intervention scenario runs.

## Development of the system dynamics model and user interface

The SD model within the decision support tool represents patient flow from the emergency call for help to discharge from the ED or hospital (Figure 1). A patient may attend ED after a call to the ambulance service (999) or NHS 111 or be directly admitted to hospital as an emergency. Some patients will die in the ED, hospital or at home. Following discharge, some patients will reattend within 30 days.

Figure 1 Schematic representation of patient flow



The technical development of the SD model will be reported separately. In brief, the SD model and its user interface were developed in AnyLogic (version 8.7.3). The SD decision support tool is designed to be used by clinicians, commissioners, and planners via a user-friendly interface which allows users (with no experience of simulation models) to select their data and run the baseline and intervention models. In the user interface, users can either enter their own or default parameters contained within the tool. Table 2 describes the constituent elements of the SD decision support tool where the user interface captures the model’s parameters and displays the results from the baseline and intervention scenarios. The user interface is laid on top of the SD model which estimates the patient flow in the hospital over a simulated year of running a chosen intervention. The inner workings of the SD model can also be viewed if required. The user progresses through each panel listed in Table 2, adding in their parameters before running the model and viewing their results.

Table 2 Elements of the SD decision support tool

|  |  |
| --- | --- |
| Element / Screen | Description / Purpose |
| Title screen | Introduces the user to the tool and its purpose |
| Summary screen | The user can enter the model’s parameters through the panels in this screen or via individual screens. |
| Data entry screen | The user can select to use the model’s built-in data or use their own hospital data |
| Location | In the Yorkshire and Humber version of the tool, the user can select a specific town / city / region from the area.In the generic version of the tool, the user can select from 42 English Integrated Care Systems.  |
| Population | A summary screen which displays population demographics for the selected location. |
| Hospital setting | The user can select the type of hospital that most closely represents their own hospital in terms of ED attendance and the number of emergency admissions. |
| Hospital parameters | The user can use / change the model’s parameters: daily ED attendance, emergency admissions, readmissions. |
| Intervention | The user can select from five interventions: proactive care, hospital at home, geriatric emergency medicine, front door frailty, acute frailty unit. |
| Hours of operation | The user can select the opening hours for the service: 24/7, weekdays (9am-5pm), weekends, other. |
| Target population | This allows the user to change the percentage of patients affected by the chosen intervention |
| Summary screen (completed) | This captures all the user’s responses and model parameters prior to running the SD model |
| SD model | The underlying system dynamics model which represents the flow of patients through the hospital system  |
| Results Menu | Allows the user to choose the results they are interested in:Emergency department, hospital, care home, readmissions, deaths, summary statistics |
| Individual results screen | Graphical output of the baseline (as is under the current system of operation) and intervention (when applying the chosen intervention to the hospital setting) results for a year. |

Figure 2 shows the initial summary screen where the user selects the parameters which best describe their hospital ED setting and the intervention they are interested in testing. Once the user has entered the hospital and intervention parameters, they can run the simulation and then view the results. As they complete each panel / screen, the information is displayed on this screen.

Figure 2 ECOP SD model - user Interface

**

Information on the chosen intervention and its outcomes are displayed, together with references to relevant studies and a ‘traffic light’ indicator of the quality of supporting evidence. By pressing the “Run Simulation” button, the SD tool reads in the model parameters from the user interface and uses them in the mathematical equations that describe the patient flow through the hospital. The model is simulated to run for one year with the following results captured each day:

* ED: the average number of patients attending and discharged each day
* Deaths: the cumulative number of hospital related deaths
* Hospital: average number of patients admitted from ED, admitted by other routes, and daily number of people in hospital and discharges
* Care homes: average number of patients discharged from hospital into a care home and the total number of residents
* Readmissions: number of patients readmitted to hospital from their home or a care home within 30-days of discharge

These results are displayed on the tool’s results screens and the user can choose which set(s) of hospital metrics to view. Each results screen shows the chosen hospital metric over a year under the current hospital setting (in red), compared with how it would look under the selected intervention (in blue). If the cited literature has suggested a reduction in a hospital metric such as the number of admissions, the graphical output will show the intervention line at a lower value than the baseline. A benefit of SD modelling is that the effect of the intervention on other parts of the system can also be examined. For example, seeing what effect the reduction in admissions has on the discharge of patients to care homes.

 Whilst the SD decision support tool only allows the user to examine the effects of one intervention at a time, there are back buttons included on each screen so that the user can return to a previous screen and alter a parameter or choose a different intervention before re-running the model and examining the results.

## Validating the System Dynamics model

There was stakeholder engagement throughout the tool’s development to ‘sense-check’ the emerging findings:

* The research team (methodologists as well as clinicians from primary care, emergency, and geriatric medicine) reviewed model development monthly for three years.
* An independent study steering committee (also including clinical and methodological experts) provided high level oversight on three occasions, and in particular gave a strong steer on which intervention scenarios to include in the model, considering the level of supporting evidence.
* A series of four external stakeholder events (three aimed at clinicians and commissioners and one at patients and carers, totalling around 40 individuals) considered the structure and usability of the user interface and results screens.
* The tool was also presented at two national NHS measurement classes attended by 60 attendees from 20 NHS organisations. The attendees included service managers, improvement and transformation leads, clinical directors, consultants and specialty doctors from frailty and emergency care departments within NHS Trusts, commissioning groups and local councils. The organisers of the events saw the tool as an adjunct to Statistical Process Control (SPC) and Pareto charts to support quality improvement projects.

### Internal and external validation

As well as sense-checking the model, validation is required to see if the model accurately represents the system’s behaviour. The model’s validity should be evaluated operationally by determining if the model output agrees with observed data. Internal and external validation were performed, and the results are captured in Table 3. Internal validation compares the results from the simulation model with summary statistics derived from the dataset that was used to estimate the model’s input parameters, in this case the CUREd database [25, 26]. External validation compares the model results with data from other sources that were not used in the model’s development.

As a means of internally validating the SD model, the estimated daily hospital metrics for the Yorkshire and Humber region were compared against the summary statistics from CUREd (the Internal Validation column in Table 3). The estimated average of daily ED attendances from the model is slightly lower than expected, however, the difference was less than 5% when compared with the average estimated directly from the data held within the CUREd database for 2012-2017. The daily average number of emergency admissions and patients in hospital are very close to their observed values. The daily average for readmissions estimated from the model is slightly larger than the value estimated from the CUREd database. The annual number of hospital related deaths estimated from the model is slightly less than the observed figure (approximately 1% difference).

As a means of externally validating the SD model, the estimated hospital metrics were also compared against other datasets such as Hospital Episode Statistics (HES) [32] and ONS data (Table 3). In terms of the daily number of ED attendances, the model’s output is very close to the value recorded in HES for the region during 2011-2014. The estimated number of emergency admissions is also very close to that estimated from the NHS’ published figures for March 2017 [33]**.**

Table 3 Validation of the emergency care SD model – at the Yorkshire and umber system level

|  |  |  |  |
| --- | --- | --- | --- |
| Model Output | SD model | Internal Validation (Y&H average) | External Validation |
| Daily A&E attendances | 562 ± 3 | 584 | 571 (HES 2011-2014 [32]) |
| Emergency Admissions (daily) | 104 ± 1.3 | 105 | 40,466 Emergency Admissions (all ages) in March 2017 which equates to a daily average of 1305 [33]. As 8.2% of the population are 75 and over, there should be 107 emergency admissions per day. |
| Patients in hospital (daily) | 442±0.4 | 440 |  |
| Readmissions (daily) from a patient’s own home / care home | 113±0.38 | 107 | During 2016/17 there were 529,318 readmissions which equates to approximately 1,450 per day. Y&H accounts for 8.3% of the UK which would lead to approximately 120 readmissions per day. |
| Hospital related deaths (annual) | 12,150 | 12,287 [10,157 – 13,504 deaths recorded in the CUREd database] | 12,242 (range: 11,191 – 26,102) estimated from the weekly deaths registered by the ONS and adjusted for patient age (68.5% of deaths in 2017 were amongst people aged 75 and over) and place of death (45.6% of deaths in 2017 were in hospital). |

As a final validation step, the results from the scenario analyses were compared against the expected outcomes for each intervention described in the cited literature. For example, with Front Door Frailty, the evidence suggests a slightly reduced number of hospital related deaths (risk ratio=0.92, CI=0.55-1.52), fewer admissions (risk ratio=0.9, CI=0.7-1.16), fewer readmissions (risk ratio = 0.95, CI=0.83-1.08) and fewer nursing home admissions (risk ratio=0.75, CI=0.44-1.29). Applied to the Yorkshire and Humber population, seven days a week, 8am – 8pm should see an estimated 4% reduction in the annual number of deaths, 5% reduction in hospital admissions, 2.5% reduction in readmissions and approximately 13% reduction in nursing home admissions (at four months). The results from the decision support tool when the Front Door Frailty scenario is applied to the Yorkshire and Humber region are shown in Table 4 and show a close agreement to the expected outcomes. The nursing home admissions metric may be worth further investigation as the six percent reduction is less than the expected amount. This may be because the risk ratio was applied at the 1-month mark rather than four months as stated in the cited literature and could explain how the effect size from the intervention was smaller than expected. The other four scenarios also showed similar results to the expected effect sizes cited in the literature.

In summary, internal, and external validation checks, and stakeholder sense-checking suggest that the SD model provides an accurate representation of the emergency care pathway for older people.

Table 4 Validation of the emergency care SD model – front door frailty scenario

|  |  |  |
| --- | --- | --- |
| Hospital Metric | SD model | Internal Validation (Y&H dataset) |
| Hospital admissions | 4.9% reduction | 5% reduction |
| Readmissions | * 2.3% reduction in readmissions from patient’s homes
* 2.5% reduction in readmissions from care home
 | 2.5% reduction |
| Nursing home admissions | * 6% reduction in nursing home admissions
 | 13% reduction |
| Hospital related mortality | * 7% reduction in the annual number of hospital related deaths which sits between the expected 4% reduction and the 8% value suggested by previous studies
 | 4% reduction |

## Scenario analysis

The main aim of the SD decision support tool was to allow users to see the effect of the selected interventions on key outcomes such as mortality, readmissions, ED revisits and nursing home admissions. The tool allows the user to compare the effect of the five interventions described in Table 1 with a baseline ‘as-is’ model. In the scenario analysis, the baseline model considers a large hospital in the Yorkshire and Humber region where the daily number of ED attendances is in the region of 650 (for all ages) and there are approximately 150 emergency admissions. The model parameters (for the 75 and older patient population) used in the baseline model are given in Table A1 (see Appendix). In the five scenarios that examine the effect of the interventions, the hospital parameters (given in Table A1) have been adjusted according to the risk ratios cited in the literature (see Table 1). The SD model has been run with the updated set of model parameters and the hospital metrics (admissions, older people in hospital, nursing home admissions, readmissions, hospital related deaths) have been compared with the baseline results. The comparisons are shown in Table 5.

# Results

 The baseline SD model suggest approximately 73 ED attendances each day, leading to 48 hospital admissions amongst the older people population. The model suggests 16 emergency admissions. The baseline model suggests that there will be approximately 62 people, aged 75 and over in hospital each day. The number of readmissions for our chosen age group under the baseline scenario is estimated at 14 with 11 coming from patients who have previously been discharged to their own home. The baseline model suggests that the annual number of hospital related deaths for older patients in a hospital of this size will be approximately 750.

The results of the SD model simulations for a hypothetical hospital setting in the Yorkshire and Humber region are summarised in Table 5. These results are for a service running over one year, and take account of reductions in admissions, readmissions, deaths, and institutionalisation amongst a cohort of patients aged 75 and above. It is worth emphasising that the model adopts a whole systems perspective, with some interventions creating knock-on effects further downstream or in the future.

By considering the whole system, the model can provide the missing links in the evidence. For example, in the hospital at home intervention, the cited literature does not provide evidence on the effect size in relation to the number of hospital admissions or the number of older patients in hospital beds. However, the model estimates the effect on both metrics. In the geriatric emergency medicine scenario, the evidence about the effect size on hospital numbers, nursing home admissions and hospital related deaths is limited. The tool, however, can show the potential reduction, as a result of, the intervention effects that were documented in the evidence. Similarly, with front door frailty and acute frailty units, although the evidence cited in the literature is not complete, the tool can be used to demonstrate what the effect sizes *might* look like in those categories.

Table 5 scenario analysis – the five interventions applied to a hypothetic large hospital in the Yorkshire and Humber region

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Intervention | Opening Times | Admissions | Older people in hospital | Nursing Home admissions | Readmissions | Hospital deaths |
|  |  | **Empirical evidence estimates** | **SD model estimate** | **Empirical evidence estimates** | **SD model estimate** | **Empirical evidence estimates** | **SD model estimate** | **Empirical evidence estimates** | **SD model estimate** | **Empirical evidence estimates** | **SD model estimate** |
| Proactive Care | 24 hours a day | Negligible | Negligible: may lead to one less admission over the year. | Not reported | Negligible | Negligible | Negligible | Not reported | < 0.5% reduction possible due to daily variation | Negligible | Negligible |
| Hospital At Home | 9am-5pm, weekdays | Not reported | (<1% reduction) which over the year could equate to approximately 50 fewer admissions | Not reported | Negligible: reductions in admissions and readmissions masked by daily variation | Reduction (RR=0.58) applied at 6 months | 2.4% fewer admissions which could equate to approximately 60 fewer during the year[[1]](#footnote-1).  | Larger proportion of people living at home at 6 months (RR=1.05, CI= [0.95,1.15]) | 1.5% reduction which could lead to 70 fewer readmissions | Slight reduction (RR=0.98) | < 1% fewer deaths which over the year could equate to approximately five fewer deaths. |
| Geriatric Emergency Medicine | 9am-5pm, weekdays | (2.6% - 19.7%) reduction | 2.6% reduction which over the year could equate to approximately 450 fewer admissions | Conflicting reports about LoS | Reduction of 1.5% (after considering the conversion rate of ED attendances to hospital admission.) This could equate to approximately 330 fewer patients in hospital over a year. | Limited evidence | Negligible | Reduced (RR=0.74) | 9.3% reduction. The evidence suggests a 26% reduction when applied to all older patients but as the service is not operational all the time, 37% of patients will be targeted leading to a target population of 9.6%) Over the year this could equate to approximately 450 fewer readmissions. | Data not included in reviews | 1.5% reduction (due to the 1.5% difference in hospital numbers) which over the year could equate to 11 fewer deaths. |
| Front Door Frailty | 8am-8pm, everyday | Fewer admissions (risk ratio = 0.9) | 4.9% reduction which over the year could equate to approximately 850 fewer admissions. | No clear evidence | 3.2% reduction (difference after considering the conversion rate of ED attendances to hospital admission). This could equate to approximately 730 fewer patients in hospital over a year. | Fewer admissions to nursing homes (RR=0.75) | 6% fewer which could equate to approximately 150 fewer during the year | Reduced readmissions (RR=0.95) | 2% reduction (the evidence suggests a 5% reduction when applied to all older patients but as the service is not operational all the time, 50% of patients will be targeted leading to a target population of 2.5%). Over the year this could equate to approximately 100 fewer readmissions. | Reduced mortality (RR=0.92) | 7% reduction (due to the reduced mortality suggested by the intervention and the reduced hospital numbers) which over the year could equate to approximately 50 fewer deaths |
| Acute Frailty Unit | 24 hours a day | Not included | 3.5% reduction which over the year could equate to approximately 610 fewer admissions. | Length of stay could be increased by ½ day | 1.6% reduction (after considering the conversion rate of ED attendances to hospital admission) which could lead to approximately 360 fewer inpatients over the year. | Not included | 7% fewer admissions which could lead to a reduction of 175 patients discharged to long term care over a year. | Fewer readmissions (RR = 0.78) | 22% reduction which over the year could equate to approximately 1,000 fewer readmissions. | Reduced mortality (RR=0.86) | 15% reduction which could result in approximately 110 fewer deaths over the year |

Having compared the interventions for this hypothetical scenario, there is potential to reduce hospital admissions and readmissions, leading to fewer older patients in hospital and hospital-related deaths. In terms of hospital admissions, front door frailty and acute frailty units offer the greatest potential in reducing numbers. The acute frailty unit offers the most noticeable reduction in hospital readmissions (22% fewer which could lead to a reduction of 1,000 readmissions over a year) whilst front door frailty sees a marked reduction in hospital inpatient numbers (3.2% reduction which could lead to 730 fewer patients in hospital over a year). Acute frailty units and front door frailty interventions also potentially offer larger reductions in the number of hospital related deaths and admissions to long term care facilities. For example, an acute frailty unit intervention could result in 15% fewer deaths (approximately 110 over a year).

 It is also worth noting that several of the services do not run all the time and are operational either between 9am and 5pm during the week or 8am and 8pm each day. This suggests further potential improvement, as services that extend their opening hours would see larger effect sizes on their admissions, readmissions etc. An added benefit of using a SD decision support tool is that the user can extend the opening hours in their virtual scenario and see what affect that has on their hospital metrics. This may prove useful for clinicians, commissioners and planners undergoing improvement projects or developing business cases to improve their hospital care for older patients.

# Discussion

To our knowledge, this is the first reported development and validation of a decision support tool focusing upon service for older people with Emergency and Urgent Care needs. The resultant SD decision support tool can help clinicians, service managers and commissioners to identify what EUC model might best suit their specific setting and gauge the impact of the service on not just immediate short-term outcomes (admission vs. discharge from ED), but the impact on the wider health and social care system, over one year.

## Relationship to wider literature

The bulk of the literature on emergency care models reports the impact of a single (albeit perhaps complex) intervention on a single cohort of individuals, and their associated outcomes in a linear manner [12-24]. In this study, the SD decision support tool permits an understanding of such interventions by taking a whole systems perspective that also incorporates temporal impacts on patients and therefore services. For example, seeing how a reduction in hospital readmissions may affect the number of patients discharged into care homes at a later date. Such an approach perhaps better mirrors the real-world impact of interventions in complex systems, such as the NHS.

Few studies describe the ‘dosing strategy’ of the intervention (i.e., the proportion of people who might *receive* the intervention, when the service’s opening hours and patient eligibility criteria are considered). By including a consideration of the services’ opening times, we can provide perhaps more grounded estimates of the impact of interventions.

In each of the studies [12-24],the effect sizes for the chosen hospital metrics (admissions, readmissions, length of stay, mortality), are typically given in terms of a risk ratio showing a summary estimate for the level of reduction observed. However, using a whole-system approach gives results that at first sight may feel somewhat counter-intuitive, to clinicians who are used to seeing summary estimates, but it does provide a more realistic estimation of what might be achieved with one scenario compared to another.

## Implications for practice

 The main aim of this SD decision support tool has been to enable any hospital to examine the benefit of a chosen ED intervention on their older population presenting at ED, without necessarily going through multiple different service development cycles. Clinicians and hospital planners can see the effect of the five interventions on their hospital setting and associated metrics. The user interface allows the user to easily enter their own data or use that contained within the tool and to view the graphical results produced. This whole system modelling might be especially relevant to the emerging Integrated Care Systems as they consider their Population Health Management approaches for older people. As more evidence-based interventions become available the tool can be adapted to include their effect sizes.

## Implications for research

Future iterations of the SD model might be further developed to incorporate frailty measures as these become more widely represented in underpinning datasets [1, 34], Patient Reported Outcome Measures adapted for emergency care settings, which are in development, and an increased range of service options. Future research is needed to develop and test this tool for use in other acute hospital settings.

## Strengths of the approach

Key strengths of the SD decision support tool are that it uses robust published evidence to create the scenarios, an integrated dataset reflecting the whole of the EUC pathway, and extensive stakeholder engagement to ensure that it is both user-friendly and a realistic representation of the system.

Another added strength of the SD decision support tool is in the ability of being able to visualise the impact of the intervention through the comprehensive set of graphs which compare the baseline and intervention results for several key hospital metrics (daily ED attendances, number of patients in hospital, readmissions, hospital related deaths) over a simulated year of operation. The user has the option to view the model as it updates or run the model and view the output results at the end of the simulated year. The model results can also be easily exported into Excel if needed.

One final strength of the tool is that the underlying SD model includes feedback loops which enable the user to see how different parts of the system connect and mirrors the patient behaviour in the real-world. For example, in the acute frailty unit intervention scenario, the evidence suggests that with the intervention increasing a patient’s length of stay by 0.5 days, there should be more patients in hospital. However, the reduction in patients readmitted leads to an overall reduction in hospital numbers.

## Limitations

First, we were not able to include frailty measures into the model, as these were not routinely embedded into the CUREd dataset. Whilst it would have been possible to capture Hospital Frailty Risk Scores for the admitted cohorts [35], this would not be available to include in the whole system model, which also captures outcomes on people attending but discharged from E.Ds. A second weakness is that we have only used interventions that have been reported in peer reviewed papers. Emerging care models, such as pre-hospital frailty services, offer promise, but the effect sizes for these interventions are uncertain. Future iterations of the SD model could allow for these novel interventions to be incorporated. A third drawback is that we were unable to model jointly delivered interventions, such as front door frailty in combination with acute frailty units, as only separate effects have been reported, so we do not know the combined effect sizes. Fourth, the model considers service outcomes, but we were unable to report upon person centred metrics as these were not included in the CUREd data. A final limitation is that the model does not include an estimate of the staffing resources needed to provide a service and would need to be considered separately by those seeking to implement a new or different service for older people accessing emergency care in their region. For example, one of the reasons that front door frailty and geriatric emergency medicine may not run all the time may be due to staffing levels and this would need to be considered alongside the outputs from the decision support tool.

## Conclusions

System dynamics modelling coupled with emergency care data can be used to support decisions on implementing emergency care interventions to improve outcomes for older patients. The decision support tool can support clinicians, service managers and commissioners to identify what EUC model might best suit their specific setting and gauge the impact of the service over one year. The tool provides a useful visual way of seeing the effect of documented intervention studies on a user’s own hospital setting filling in the missing gaps from the cited literature.

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## Appendix 1: Technical Summary

The technical summary provides information on the model parameters and the intervention effect sizes used in the model. The data analysis which informed the model will be reported separately [36]. Briefly, patients attended the ED on multiple occasions, generating 1,171,402 separate observations[[2]](#footnote-2). 494,181 (42.2%) of those who attended were managed and discharged from the ED; 677,221 were admitted.

Table A1 shows the built-in parameters used in the model and govern the daily number of patients attending ED, being admitted into hospital, being discharged, and dying in hospital. A detailed model specification is available on request from the corresponding author.

### Model Parameters

The model relies on the following rate parameters to govern the flow through the system:

* The hospital mortality rate
* The ED attendance rate
* The re-admission rate for patients from care homes
* The rate of emergency admissions
* The re-admission rate for patients from their own homes
* The death rate (patients in their own home)
* The death rate (patients in care homes)

Table A1: Model Parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | “75 – 79” | “80 – 84” | “85 – 89” | “90 – 94” | “95+” |
| Hospital mortality[[3]](#footnote-3)  | 2.4% | 2.6% | 3.5% | 4.3% | 5.6% |
| ED attendance[[4]](#footnote-4) | 23 | 22 | 18 | 10 | 3 |
| Emergency admission[[5]](#footnote-5) | 5 | 4 | 4 | 2 | 1 |
| Percentage of patients admitted from ED | 48.9% | 54.3% | 58.79% | 61.67% | 59.1% |
| Proportion of Re-admissions (care home) | 0.0000184 | 0.0000408 | 0.0000859 | 0.0001526 | 0.0001872 |
| Proportion of Re-admission (home) | 0.00002 | 0.00002 | 0.00004 | 0.00005 | 0.00004 |
| Death rate (home) | 0.0000242584 | 0.000027 | 0.0000969444 | 0.00028 | 0.0002824 |
| Death rate (care home) | 0.00031 | 0.00064 | 0.00095 | 0.0018 | 0.0025 |

### Intervention Effects

In several of the intervention strategies considered, the effect on the patient outcome is described in the literature in terms of a risk ratio (RR) (ratio of the probability of an outcome in an exposed group to the probability of an outcome in an unexposed group).

In some of the remaining interventions, odds ratios (OR) are given instead of risk ratios. The OR represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure.

where and

Risk ratios and odds ratios have been incorporated into the decision support tool in the intervention runs of the system dynamics model to determine the effect size associated with a particular intervention on a specific hospital metric.

1. Whilst the cited evidence suggests a 42% reduction this is at the 6-month mark. The simulation considers a target population of 37% due to the service’s opening hours which would lead to a suggested reduction of approximately 16%. The decision support tool uses a more conservative estimate of the risk ratio (0.93) applied at the 1-month mark. [↑](#footnote-ref-1)
2. 90,107 first phoned NHS111 and were either advised to go directly to the ED (9,882) or were taken by ambulance (80,225). There were 472,715 other patients who called 999 and were then taken to the ED by ambulance. The remaining 608,580 patient attendances were people that attended the ED without previously calling NHS111 or 999. [↑](#footnote-ref-2)
3. Proportion of hospital population that die each day [↑](#footnote-ref-3)
4. ED attendances per day, dependent on the hospital setting. Values given are for the Yorkshire & Humber region. [↑](#footnote-ref-4)
5. Number of patients admitted directly on to a ward. Values given are for the Yorkshire & Humber region. [↑](#footnote-ref-5)