DEVELOPING SIMULATION MODELS OF POSSIBLE FUTURE SCENARIOS FOR THE DELIVERY OF ACUTE CARE IN NHS AYRSHIRE AND ARRAN TO INFORM THE DECISION MAKING PROCESS

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ABSTRACT

This paper describes the simulation study carried out in NHS Ayrshire and Arran as part of the Review of Services Project. The project explores the development of new proposals for a major reconfiguration of services.

The main objectives were to look at volumes of patients attending the A&E departments and flowing through the inpatient sites under the different proposed models of care, and then to assess bed capacity requirements for all specialties under different scenarios. Using the lessons learnt from previously presented proposals, computer simulation models were built in Simul8 for each of the proposed scenarios for the future delivery of care. The paper is about the creation of those models, the assumptions made and the interpretation of the outputs generated. The paper reflects the difficulties in giving a recommended number of beds and the approach accepted for this study.

Keywords: Healthcare Reorganisation, Simulation Modelling, Bed Planning

1. INTRODUCTION

NHS Ayrshire & Arran is currently reviewing the provision of emergency and unscheduled care, elective and rehabilitation services. As part of this review, simulation models have been developed to aid decision making on the delivery of a range of services. The reason for this was that the team tasked with developing these proposals wished to use simulation models with the aim of determining necessary bed capacity. Models have been constructed using interviews with key clinical staff, activity data and patient records to establish referrals, rates and lengths of stay. Despite questions about the relevance of the data to the proposed new system of service delivery, a series of recommendations have been made. Sensitivity analysis has been carried out and reported, as well as a series of verification and validation checks on the results.

A recent review of the legacies of simulation modelling in healthcare, Eldabi at al (2007), argues that applications for operational decision support have become increasingly significant and describes Simulation modelling as an ideal method of evaluating strategies that authorities may have in mind. Our paper aims to demonstrate the usefulness of applying simulation for re-organization of healthcare services and provides a case study on bed planning for a set of proposals.

The paper is divided into 10 sections. The first two sections introduce the background of the study. Section three describes patient flows in the development of the conceptual model followed by an overview of the computer model in section 4. Sections five and six explain simulation scenarios, the data used and assumptions made in this study. Section seven reports on the analysis of the outputs from the modelling and makes recommendations on the number of beds required under these proposals. Section eight describes how this modelling was validated and verified and finally sections nine and ten present some discussion points and give a brief conclusion.

2. BACKGROUND TO THE STUDY

Ayrshire is situated in south-west Scotland on the Firth of Clyde coastline. Consisting of the local authorities of North, East and South Ayrshire, the area stretches from Largs in the north to Ballantrae in the south and from the west coast to Muirkirk and Cumnock in the east, and includes the islands of Arran and Cumbrae.
NHS Ayrshire & Arran provides a comprehensive range of health services and healthcare to a population of around 367,000. There are two district general hospitals in the health board area, Ayr Hospital and Crosshouse Hospital.

2.1 REVIEW OF SERVICES (ROS)

This is the second time that proposals for the future delivery of care in Ayrshire & Arran have been developed, due to a ministerial decision, following the Scottish elections 2007, to overturn the health board's previous plans to reorganise services including the downgrading of Ayr Hospital A&E. Simulation modelling was carried out to inform the decision making for the first set of proposals, Dickson and Lara (2007). For this new set of proposals, the Cabinet Secretary set constraints to maintain A&E services at Ayr Hospital and retain as many of the original proposals as possible. The RoS team was tasked with developing new proposals that Simulation would inform in terms of volumes of patients going through the system and bed capacity requirements at specialty level.

3. CONCEPTUAL MODELLING

The first stage in a simulation study is to develop a conceptual model of the system to be analysed. As described in a recent study by Balci and Ormsby (2007): "A simulation conceptual model represents the highest layer of abstraction that is closer to the level of thinking of managers, analysts, and simulation model designers".

The main conceptual model was developed consulting the RoS team and other healthcare professionals. In addition, the experience and lessons learnt from the models built in the first set of proposals for the RoS project were incorporated. The objective was to formulate a generic conceptual model with two complete Emergency Care Facilities (ECF) and from which other scenarios with proposals would be developed in line with the emerging shortlist of options for the future delivery of acute care.

The patient pathways through the models start with arrival at the A&E departments from a specific source of referral such as emergency services, GP referrals or self presenting patients. As soon as they arrive in the system children are transferred to the Paediatrics facility, which is on the Crosshouse Hospital site. Regardless of their means of entering the system e.g. by ambulance, self presentation etc. all patients are assigned a triage category, determined by initial assessment from medical or nursing staff in the A&E department. The five triage categories and descriptions are shown in Table 1 below.

Number	Colour	Definition	Description
1	Red	Immediate resuscitation	Patients in need of immediate treatment for preservation of life
2	Orange	Very urgent	Seriously ill or injured patients whose lives are not in immediate danger
3	Yellow	Urgent	Patients with serious problems, but apparently stable condition
4	Green	Standard	Standard A&E cases without immediate danger or distress
5	Blue	Non-urgent	Patients whose conditions are not true accidents or emergencies

Table 1: Manchester Triage Scale:

Depending on the triage category, patients are routed into the appropriate area within the A&E department or to an Assessment Unit, (this would be a new facility that would alter the flow of patients through the department and reduce the number of patients with inappropriate admissions to an inpatient bed). If patients are in the lower spectrum of triage (categories blue or green) and there is a closer Community Casualty Facility (CCF) patients are routed to attend there instead of the A&E.

After emergency treatment patients are either discharged or become inpatients under the relevant speciality. The second stream of patients entering the system is the scheduled arrivals to the inpatient sites for elective care procedures. The third entry point to the system can be from direct GP admissions where patients enter the system directly to an inpatient bed. An overview of the entire conceptual model is shown in Figure 1.

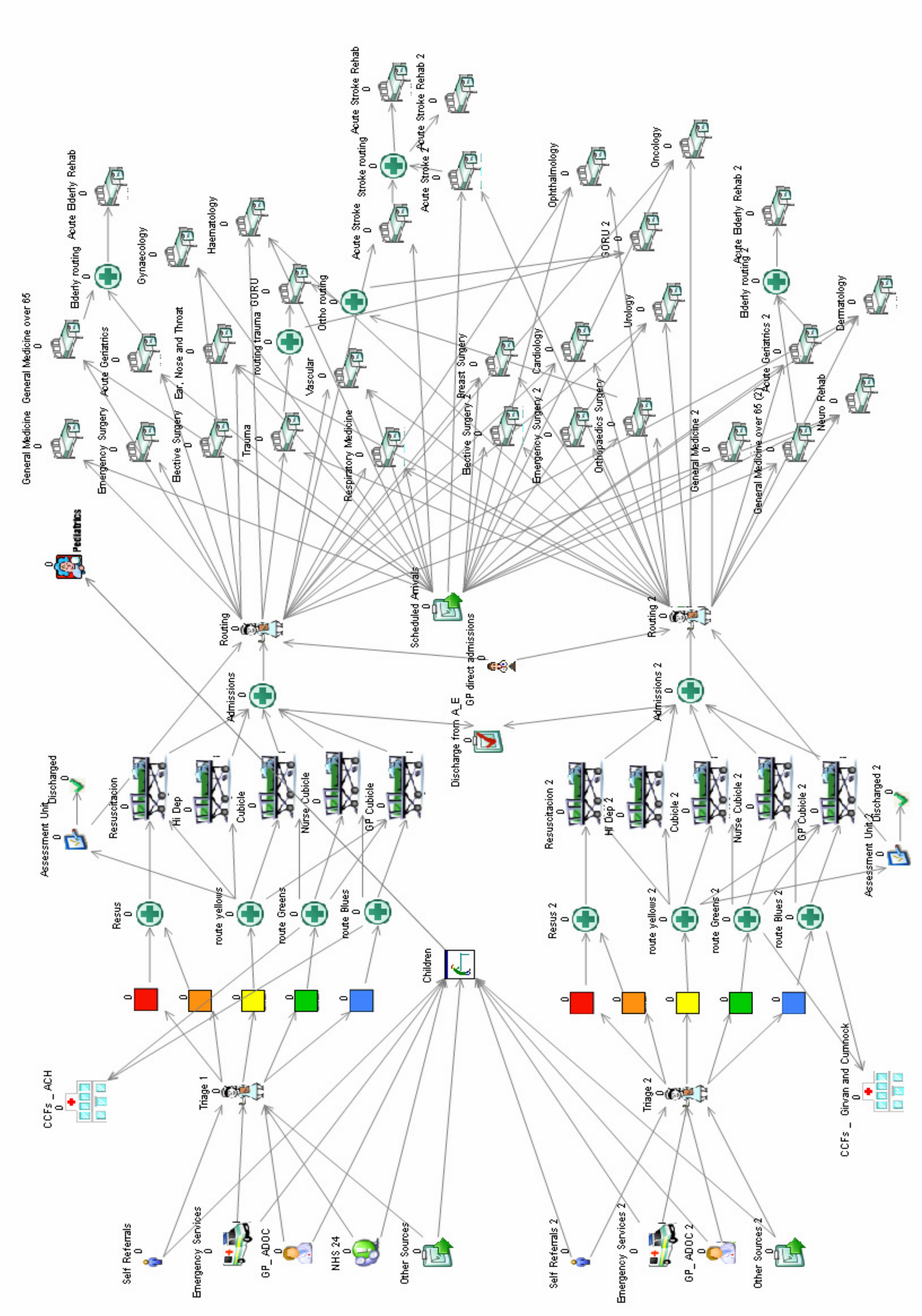

Figure 1: Conceptual simulation model

The conceptual model was built based on having two full ECFs (scenario 7) and from this, new scenarios were created as variations on the level of service provision at Ayr Hospital. The flow of patients was altered depending on the model.

Once patients are admitted to a bed in the appropriate facility they stay for a length of time based on historical data and the assumed impact of changes in service delivery.

4. THE COMPUTER MODEL

The computer model in Simul8 was built using the conceptual model developed to understand the system configuration and the knowledge of the processes happening in that system. Statistical analysis of historical data was used to inform the model.

The model development and configuration focused on delivering the outputs that would influence the decision making process. Determining the bed capacity requirements was considered to be the main objective. The models were therefore built, focusing on determining occupancy, by assessing issues and processes within the flow of patients.

The attributes of the patients are coded within the model in the form of labels including: age; type of care required (emergency or elective, surgical or medical), triage category, length of stay, speciality and whether the patient was admitted or not.

Depending on their attributes, patients flow through the model. These flows are configured using proportions of past presentations. This means that the model is incredibly data-driven. As is often the case with data, the historical data collected was not in the correct form to input in the model and it was very difficult and time consuming to identify patients and their categorization under specialties. The length of time patients' stay was configured according to distributions created using historical data and input into the model in the form of probability profiles. Literature and practice would suggest that using a distribution is a more accurate way to assess bed capacity as it better reflects the randomness of the real world.

The models simulate a period of two years and the time unit is in hours. A warm-up period is used so that the model does not start when the hospital is empty. A graphical method was preferred for estimating the warm-up period due to its simplicity; it involves visual inspection of the time-series output and human judgement. Robinson and Ioannou ranked this method the best however it has disadvantages and relies upon a subjective assessment and is probably affected by the experience of the analyst. The warm-up period was estimated to be six weeks by inspecting time-series of key output statistics such as occupancy levels of specialties.

5. SIMULATION SCENARIOS

Six possible scenarios were developed with the main variation represented in the configuration of the front door at the Ayr Hospital site. The different scenarios follow the description of the options. In addition, the models differ in the configuration of sub-specialty care behind the front door. Below the different scenarios are listed and briefly described by the main clinical characteristics that led modelling.

Scenario 7 has two ECFs led by an A&E consultant all of the time at Crosshouse and Ayr Hospital treating all patients coming from any source of referral.

Scenario 6 has the ECF at Ayr Hospital led by A&E consultants during peak hours with medical and surgical receiving.

Scenario 5 has an ECF at Ayr Hospital led by consultants. There is no Surgery department in Ayr hospital. So, non-self presenting patients would bypass Ayr Hospital and go straight to the Assessment Unit at Crosshouse. Self-presenting patients would be stabilised and treated and then transferred to the most appropriate facility.

Scenario 4 is the status quo scenario, the existing service model of care. It had previously been modelled in an earlier stage of the project.

Scenario 3 has an Acute Physician in the ECF, a Combined Assessment Unit and a surgical department at Ayr Hospital.

Scenario 2 has ECF led by Acute Physician during peak hours (10am to 10pm) supported by an Emergency Care Practitioner (ECP) at Ayr Hospital. There would be a medical assessment unit but no emergency surgical service in this model.

Scenario 1 has an ECF led by ECP/GP and there is no surgical department in Ayr Hospital. Ayr Hospital has no assessment unit but the provision of sub-acute beds for emergency patients with less serious acute medical conditions.

6. DATA AND ASSUMPTIONS

The model makes use of the most up to date validated data available to populate the pathways of care associated with each of the options. Whilst the model makes use of historical data, simulation interprets the patient flows in light of changes to the patient pathway as described in the proposals set out in each of the options.

The data used in the Simulation Modelling process was taken from A&E activity data at Crosshouse and Ayr Hospitals from April 2006 to March 2007 and inpatient activity from the Information Services Division validated SMR01 dataset from April 2006/ March 2007.

As with any model of service redesign a number of assumptions had to be made based on the best available evidence and intelligence. These assumptions are set out below.

Triage Patterns
It was assumed that past presentations at Ayr and Crosshouse A&E are representative of future patterns of demand in terms of volumes of patients and sources of referrals. It has been assumed that current triage proportions by source of referral into A&E would continue and current proportions of admissions to the inpatient sites depending on the triage category would also remain constant.

Community Casualty Facility Catchment
Within the simulation modelling patients have been rerouted to Community Casualty Facilities (CCFs) based on their home postcode sector and their triage category (triage category Blue and Green patients go to their closest CCFs).

Assessment Unit
In terms of the Assessment Unit, it has been assumed that 65% of Yellow patients go through this facility and stay in a bed for 24 hours and, that following this, 40% would be discharged and 60% become inpatients.

Inpatient Activity
It has been assumed that past inpatient activity is representative of future patterns of demand in terms of volumes of emergency and elective inpatients, specialities and lengths of stay.

Community Hospitals Activity
For this study, based on advice from GPs and activity at GP led services at East Ayrshire Community Hospital and Davidson Hospital, it has been assumed that sub-acute beds for model 1 would have a maximum length of stay of 2 weeks and 70% of patients would be discharged within 3 days.

GP Referrals
Based on past behaviour, it is assumed that there would be approximately 2000 GP direct referrals per annum to the inpatient services.

Specialty Activity Data
Patients were classified under specialties for the simulation modelling based on the data records and a set of assumptions to identify patients by diagnoses or procedures codes in the specialties under the proposals.

Bypasses or Transfers
Due to different configurations of the front-door services at Ayr Hospital, it has been assumed that different numbers of patients would bypass or transfer from Ayr Hospital to Crosshouse Hospital. Individual assumptions have therefore been made for each of the options modelled, based on how the front-door services operate, the needs of patients, as determined by triage category, whether they require surgical or medical care and the time of the day they present at the A&E department. The assumptions used are as follows:

-Model 1 rerouted all non-self-presenting Red, Orange and 50% of Yellow triaged patients to Crosshouse Hospital.

-Model 2 rerouted all non-self-presenting Red and Orange triage patients to Crosshouse. Patients triaged as yellow surgical patients are also re-routed or transfer to the Assessment Unit at Crosshouse Hospital.

-Model 3 all non-self-presenting Red and Orange triaged patients are re-routed to Crosshouse, plus Yellow triaged medical patients during the night.

-Model 5 rerouted non-self-presenting surgical patients to Crosshouse, with self-presenting surgical patients being transferred from Ayr Hospital to the Assessment Unit at Crosshouse Hospital.

7. ANALYSIS OF OUTPUTS

The results are of trials of 15 runs, being the most appropriate number of replications after testing outputs with diverse numbers of runs. As a result, 95% confidence intervals were generated for items entered in each of the facilities of interest and for the average and maximum queue size for each of the specialties for each of the scenarios developed. Volumes of patients for each of the triage categories under each scenario were given as well as volumes of patients attending each of the CCFs.

We explored the time graphs for each of the specialties, which represent the occupancy across two years, for instance we can see the occupancy of General Medicine beds in the time graph in Figure 2.

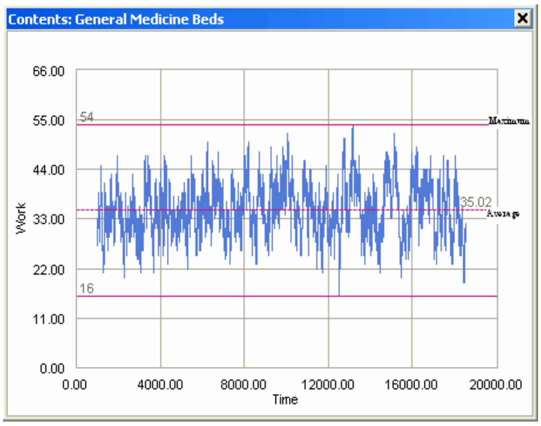

Figure 2: Time graph of the contents of the General Medicine beds

7.1 RECOMMENDED NUMBER OF BEDS

The average number that the model output suggests would not cope with the demand for services all the time. The maximum number of beds may only be reached on a limited number of occasions during a year. Due to an accepted degree of flexibility between specialties and bearing in mind that it is highly unlikely that all specialties would need their maximum number of beds at the same time it was considered inappropriate to use the maximum occupancy figure in planning bed capacity because it would overestimate bed requirements. Therefore, neither has been used in isolation to determine a recommended number of beds for each specialty or for a model.

An approach was used to calculate bed numbers that accounts for both average and maximum occupancy. Using the average as baseline for the recommended number of beds and taking into account the maximum requirement proposed by the models, the formula adds to the average half of the variation between the average and the maximum which results in the formula below and can be used to identify an appropriate number of beds for each specialty.

$$\textit{Formula} = \textit{Average} + (\textit{Maximum} - \textit{Average})/2 = (\textit{Average} + \textit{Maximum})/2$$

Accordingly, the predicted numbers of beds required for each of the specialties were provided for each of the models. These were re-arranged according to the preferred hospital under the proposals at that particular moment in time and so total number of beds per hospital was given for each of the models that represent a different model of care. This can be seen in Table 2.

7.2 SENSITIVITY ANALYSIS

A number of assumptions were made when building the model and the sensitivity of these assumptions was tested to assess the degree of uncertainty around estimations by changing different inputs to the model and assessing the impact this has on the results. For instance, exploring how changes in the percentage of patients discharged from the Assessment Units affects the inpatient activity and the resulting effects on capacity requirements. Specifically, the percentage of patients discharged from the Assessment Units was increased to 60% and reduced to 20% and 0%. The impact on the total bed number was limited. This amounted to be between 55 and 60 beds per 20% variation in the discharge rate.

The sensitivity of the number of attendances at A&E was tested with an increase of 10% of all attendances across the two hospitals for the scenario represented in model 7. The higher volumes reflected around 2800 more unscheduled admissions per year and an augment of 47 in the total number of beds required.

The sensitivity analysis explored the impact of a reduction of self-presentations at Ayr Hospital with increasing self-referrals at Crosshouse. This was undertaken to test the possibility that the local population might favour Crosshouse as it could be seen as the specialist centre with full range of specialist care.

To assess the impact of such a change on the capacity requirements of each model the number of self-presentations at Ayr Hospital was reduced by 10% with a corresponding increase at Crosshouse. This resulted in approximately 2000 additional patients attending A&E at Crosshouse Hospital. These patients represented a proportionate cross-section of triage category and had a minimal impact on the required number of Assessment Unit beds and inpatient beds.

	Model 7			Model 6			Model 5			Model 3			Model 2			Model 1		
Crosshouse Hospital	*Ave*	*Max*	*Prop*	*Ave*	*Max*	*Prop*	*Ave*	*Max*	*Prop*	*Ave*	*Max*	*Prop*	*Ave*	*Max*	*Prop*	*Ave*	*Max*	*Prop*
Emergency Surgery	27	46	**37**	29	49	**40**	41	63	**52**	29	49	**40**	41	65	**53**	38	59	**49**
Vascular Surgery				15	29	**22**	15	29	**22**	15	28	**22**	15	28	**22**	14	27	**21**
Cardiology	8	15	**12**	17	34	**26**	17	34	**26**	17	33	**25**	17	33	**25**	15	30	**23**
ENT	6	17	**12**	6	17	**12**	6	17	**12**	6	17	**12**	6	17	**12**	6	17	**12**
Elective Surgery	19	34	**27**	19	34	**27**	19	34	**27**	19	34	**27**	19	34	**27**	19	34	**27**
Acute Geriatrics	35	54	**45**	35	54	**45**	35	55	**45**	35	54	**45**	35	54	**45**	35	53	**45**
Haematology	3	9	**6**	3	9	**6**	3	9	**6**	3	9	**6**	3	9	**6**	3	9	**6**
Gynaecology	11	23	**17**	11	23	**17**	11	24	**18**	11	24	**18**	11	24	**18**	12	24	**18**
General Medicine	35	57	**47**	35	57	**47**	37	59	**48**	38	60	**50**	39	61	**50**	51	77	**65**
General Medicine over 65	37	58	**48**	37	58	**48**	39	61	**51**	40	63	**52**	41	65	**54**	42	64	**54**
Acute Elderly Rehab	104	134	**120**	104	134	**120**	110	140	**125**	111	141	**127**	114	145	**130**	115	146	**131**
Acute Stroke	6	15	**11**	12	25	**19**	12	25	**19**	12	25	**19**	12	24	**19**	11	24	**18**
Acute Stroke Rehab	18	31	**25**	18	31	**25**	18	31	**25**	18	31	**25**	18	31	**25**	17	29	**23**
Trauma	13	24	**19**	18	35	**27**	18	35	**27**	18	33	**26**	18	34	**27**	17	32	**25**
Orthopaedics	6	15	**10**															
GORU	19	33	**27**	19	33	**27**	19	33	**27**	19	33	**27**	20	33	**27**	19	32	**26**
Respiratory Medicine	64	86	**76**	64	86	**76**	64	86	**76**	64	86	**76**	64	86	**76**	94	126	**110**
Dermatology	7	16	**12**															
Assessment Unit	32	52	**42**	32	52	**42**	38	60	**50**	34	55	**45**	36	57	**47**	37	59	**48**
Total number of beds at Crosshouse	448	720	**593**	473	760	**626**	502	794	**656**	489	776	**642**	508	799	**663**	543	842	**701**
Ayr Hospital																		
Emergency Surgery	13	28	**21**	11	24	**18**				11	24	**18**						
Vascular Surgery	15	29	**23**															
Cardiology	10	20	**15**															
Elective Surgery	10	22	**17**	10	22	**17**	10	22	**17**	10	22	**17**	10	22	**17**	10	22	**17**
General Medicine	22	38	**31**	22	38	**31**	20	36	**29**	19	35	**28**	18	33	**26**			
General Medicine over 65	25	43	**34**	25	43	**34**	23	40	**32**	22	39	**31**	21	38	**30**	15	29	**23**
Acute Geriatrics	26	43	**35**	26	43	**35**	26	42	**35**	26	42	**35**	26	43	**35**	25	41	**33**
Acute Elderly Rehab	73	96	**85**	73	96	**85**	69	91	**81**	66	89	**78**	63	85	**75**	51	70	**61**
Acute Stroke	6	15	**11**															
Acute Stroke Rehab	14	27	**21**	14	27	**21**	13	26	**20**	13	25	**19**	13	25	**20**	12	24	**19**
Breast Surgery	3	11	**8**	3	11	**8**	3	11	**8**	3	11	**8**	3	11	**8**	3	11	**8**
Trauma	6	11	**9**															
Orthopaedics	8	16	**13**	15	28	**22**	15	28	**22**	15	28	**22**	15	28	**22**	15	28	**22**
GORU	14	27	**21**	14	27	**21**	15	27	**21**	15	27	**22**	15	27	**21**	14	26	**21**
Respiratory Medicine	36	48	**42**	36	48	**42**	36	48	**42**	36	48	**42**	36	48	**42**			
Dermatology				7	16	**12**	7	16	**12**	7	16	**12**	7	16	**12**	8	16	**12**
Urology	14	29	**22**	14	29	**22**	14	28	**21**	13	27	**21**	13	27	**21**	12	24	**18**
Ophthalmology	3	10	**7**	3	10	**7**	3	11	**7**	3	10	**7**	3	10	**7**	3	10	**7**
Assessment Unit 2	18	34	**27**	18	34	**27**	16	32	**24**	16	32	**25**	14	30	**22**			
Sub-Acute Beds																55	80	**68**
Total number of beds at Ayr	318	547	**442**	293	496	**402**	271	459	**371**	276	477	**385**	258	443	**358**	223	381	**309**
Total number of beds			**1035**			**1028**			**1027**			**1027**			**1021**			**1010**

Table 2: Average and maximum bed occupancy for each specialty and recommended number of beds for each scenario modelled. Totals for each hospital under each model ** Blank cells mean that the specialty would not be delivered in that Hospital under the specific model*

8. VALIDATION AND VERIFICATION

The A&E activity data came from two hospitals, and there were differences in the activity at the two hospitals for profiles of patients in terms of their gravity and source of referral. This led the RoS team to undertake an audit of the way patients are triaged in each of the hospitals and inconsistencies with the recommended Manchester triage.

The model was run with three variations on the data: (1) with the current triage data from the two sites for each of them, (2) assuming Ayr Hospital would behave as Crosshouse so using Crosshouse A&E data for the two hospitals and (3) using the average of the two current presentations profiles for the two sites. This was done to check the impact of the way that patients are triaged and the subsequent influence on the system in terms of volumes and bed capacity. It also allowed consideration and decision-making around the use of the datasets in the final model.

The outputs of the models have been compared against current performance, for instance the numbers of unscheduled admissions at both sites per year that would happen under each of the models against the number of admissions in one year worth of data. These verified the differences between the front door scenarios and the future effect on the inpatient sites.

Similarly the outputs generated were evaluated against the results from the modelling undertaken in earlier stages of the project and verified the differences due to variation in data and assumptions.

At various stages in the model building process time was taken to consult on the models themselves and the output that they were generating. The RoS team was asked to input to the assumptions used in the model and to comment on the output from the model in light of these assumptions. Using this feedback mechanism has developed a degree of confidence in the findings of the models and their use in the review process.

9. DISCUSSION

The data analysis undertaken for this study raised a number of irregularities in the current way of triaging patients at Crosshouse and Ayr Hospital. The fact that we used current data to run the models does not account for future agreement and equity of triage across the two hospitals. So, once the triage process is standardised new trials of the models will be run with the updated data.

It is assumed that past inpatient activity is representative of future patterns of demand in terms of volumes of emergency and elective inpatients, specialities and lengths of stay. However, currently elective care is affected by unscheduled emergency care and this is an issue that is expected to be resolved with the Review of Services project. Under the proposals, elective care would be better planned and work more independently and would not be affected by emergency activity. Therefore, a better use of the beds is expected with smoother occupancy levels when separating emergency and elective care.

After presenting the time graphs for the occupancy at the specialties, it became apparent that it would be useful to be able to see time graphs of the trials results. These would show confidence intervals represented in a graph with the variation over time. Unfortunately, the software does not provide these graphs and it would be extremely time-consuming to do it.

It is assumed that patients are rerouted to Community Casualty Facilities (CCFs) based on their home postcode sector and their gravity of illness (Blue and Green patients go to their closest CCFs). This analysis has caveats associated with the assumption made that people are at home when they have an accident or become unwell and they attend the closest CCF according to the grouping by postcode sector considered.

Based on the proposals from the RoS Project, the provision of services in the community is likely to have an impact on the number of patients going to the acute sites. Further analysis will be undertaken to account for those patients that would attend the community facilities rather than the District General Hospitals under the new proposals. The model will be re-adjusted to account for this and the additional rehabilitation capacity in the community setting.

It is anticipated that this Simulation study will be used for the Implementation stage of the project, the preferred model could be refined and improved by adding details on the flow of patients, identification of subspecialties and the use of updated data. Nevertheless, as Eldabi et al (2007) argues, “A major challenge lies in persuading service providers and clinicians that simulation, as system level tool, can make a critical contribution”.

10. CONCLUSIONS

The simulation model has been used to demonstrate the required number of beds at Ayr and Crosshouse Hospitals under each of the options for the future delivery of acute care in Ayrshire and Arran. The advantage of simulation modelling is that it enables the testing of a number of assumptions to inform decision-making.

The simulation models presented provide a sound basis for refinement and development of a model that can be used to inform the implementation phase of the review of services project. Using the model the required number of beds can be calculated and tested using differing triage data that will aid the implementation phase.

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