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SIMULATING THE INFLUENCE OF A 45% INCREASE IN PATIENT VOLUME ON THE EMERGENCY DEPARTMENT OF AKERSHUS UNIVERSITY HOSPITAL

Lene Berge Holm
Fredrik A. Dahl

Helse Sor-Ost Health Service Research Centre
Akershus University Hospital
P.O. Box 95
Lorenskog, 1478, NORWAY

ABSTRACT

A 45% increase in patient volume will have significant influence on the patient flow of an Emergency Department (ED). This is expected for Akershus University Hospital in 2011 when the catchment area increases from 340,000 to 500,000 inhabitants. An important question for the hospital management is: What is the lowest number of additional resources that would be needed in the ED, due to the patient volume increase, which would not compromise the patient flow? This is evaluated through various scenarios of discrete event simulation models. The results show that increasing the nurse capacity from eight to nine nurses, and increasing from eight to 12 physicians is sufficient to meet these needs.

1 INTRODUCTION

The impact on hospital patient flow resulting from a significant increase in patient volume is difficult to predict. Akershus University Hospital (Ahus), which is one of the biggest hospitals in Norway, currently serves 340,000 inhabitants, but is expected to increase its catchment area with another 160,000 inhabitants by the beginning of 2011. This represents an increase in patient volume of 45% given that the new patient population has the same case mix as the current one . Further details on the hospital and its Emergency Department (ED) are described in Holm and Dahl (2009). It is an ongoing discussion whether the hospital will be able to handle this patient volume increase, and if so, how many additional hospital beds, staff and other resources will be required. Patient flow simulation models can be helpful tools for estimating consequences of this increase and can be used by hospital management in order to make qualified decisions on this resource increase.

The ED is the starting point for the patient flow through a hospital, and it is often a critical bottleneck which can lead to overcrowding and subsequently long waiting hours. This is a worldwide problem (Cowand and Trzeciak 2005), and has been an issue at least since the early 1990s (Andrulius et al. 1991). Increases in patient volume and shortages of examination space and staff are, in addition to hospital bed shortages and high medical acuity of patients, the main causes for ED overcrowding (Derlet and Richards 2002). Estimating the optimal staff and bed capacity increase of the hospital as a whole is a main goal for the hospital management due to the 2011 process. However, it is also relevant to look at the ED separately in this process. A discrete event simulation model of the ED has therefore been developed with a basis in the physician triage simulation model described in Holm and Dahl (2009). With this model the effect on patient flow due to the catchment area increase is evaluated for different scenarios of resource quantity.

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2 MATERIAL AND METHOD

2.1 Method

A discrete event simulation model of the ED of Ahus has been developed in the simulation software Flexsim Healthcare. The inputs for this model are based on data from 2009. After a thorough model validation of the 2009 model, as described in more detail in section 2.4 below, an increase in patient volume of 45%, which is expected in 2011 due to the increase in the catchment area is then applied and gives us the 2011 model. Ten different scenarios of varying numbers of treatment rooms and staffing are evaluated in the 2011 model. This is shown in section 2.2 below.

The simulation time for each model scenario is set to 805 days (115 weeks) with the first 259 days (37 weeks) considered a warm-up period and therefore discharged. These numbers are based on a calculation of simulation time as described in Holm and Dahl (2009).

2.2 Model input and outline

The outline of the model is shown in figure 1 below.

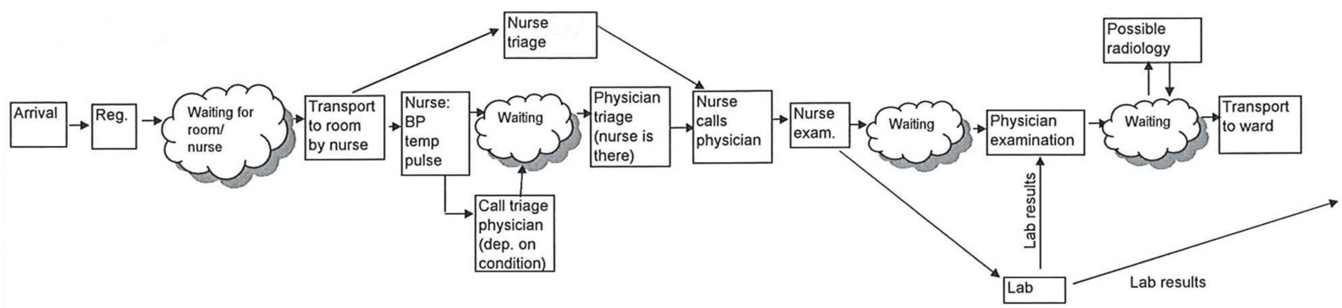

Figure 1: Model outline

There are two tracks in the model: the nurse triage track and the physician triage track. The basis for this is the sharing of triage responsibility between nurses and physicians depending on time of day. During peak times, every weekday between 10am and 7 pm, physicians do the triage while nurses do the triage outside this time frame. See Holm and Dahl (2009) for a more detailed description.

The main resource input of the 2009 model is shown in the first column of Table 1 below (baseline). In the 2011 model the number of arrivals are increased by 45%, and ten scenarios of a varying number of treatment rooms and staffing are shown in the same table.

Table 1: Resource input in ten different model scenarios

	Baseline	A	B	C	D	E	F	G	H	I	J
Number of treatment rooms	17	17	25	17	17	17	17	17	17	17	17
Number of regular nurses	8	8	12	12	10	8	8	8	8	8	9
Number of regular physicians	8	8	12	12	12	12	10	12	10	10	12
Number of triage nurses	2	2	3	3	3	3	3	2	2	2	2
Number of triage physicians	2	2	3	3	3	3	3	2	2	3	2

From observation and SME estimates, it is shown that the physicians in the ED are only able to work directly with patients about half of their time. We have therefore modeled half the volume of physicians but with the capacity of working with patients at any time. It is the actual number of physicians, not the modeled half volume that is shown in table 1 above.

2.3 Data collection

Data acquisition for these models is described in detail in Holm and Dahl (2009). Time spent on different activities in the ED was gathered through a combination of Subject Matter Expert (SME) estimates and manual data gathering. Data on arrivals was gathered from the patient database from all of 2009. Because peaks in the arrival patterns throughout the week and day are important to include in a model (Meng and Spedding 2008), we identified the distribution of patients each hour of the year from the electronic patient journal (EPJ). This made up the basis for the number of patients arriving each hour of an average week. The arrivals were then modelled as a time variable Poisson-process with constant intensities for each hour of the week. This was implemented through censoring as described in detail in Holm and Dahl (2009).

2.4 Model verification and validation

Verification and validation of a simulation model is important for the correctness and credibility of the model (Sargent 2009, Law 2009). According to Sargent (2009), model verification is to ensure that the computer program of the computerized model and its implementations are correct. Model validation makes sure that the model represents the system as accurately as possible for the particular objectives of the study (Law 2009). Results validation should be done if there is an existing system to compare the simulation model output with (Law 2009).

Verification of the computerized model has been performed thoroughly by different people with programming skills throughout the model building process. Further, the content of the simulation models has been validated through several weeks of observation of the ED, conversations with different staff and leaders, and through a full day workshop with nurses, physicians and leaders in the ED. In this case the 2009 model is validated on arrival frequency (figure 2) and the total number of patients in the ED for every minute of an average week of a whole year (figure 3). The model output “time from arrival to discharge” are also validated against real world data from 2009 (table 2).

Figure 2 below shows the arrival frequency in the model and real world data from 2009. The results are shown as the total arrivals within each week-minute over a full year.

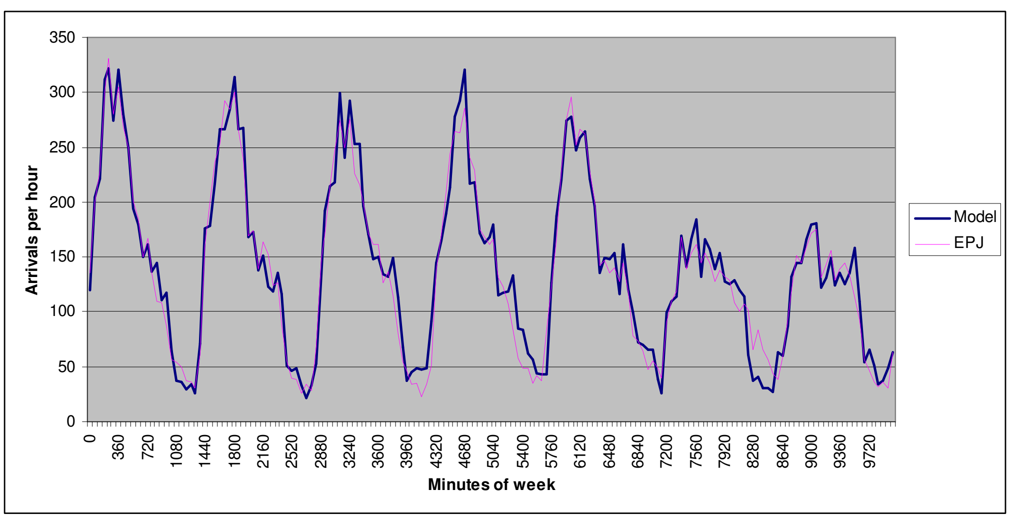

Figure 2: Arrival verification (sum of 52 weeks)

Comparing the total number of patients in the ED, each minute of an average week in the model with real world data is show in figure 3 below. The outputs are shown as averages of 52 weeks.

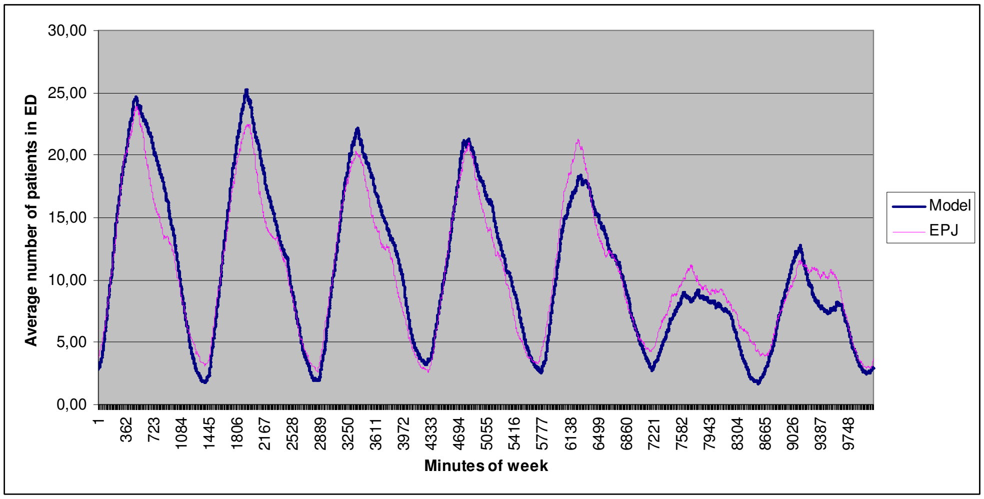

Figure 3: Validation of total number of patients in ED (average of 52 weeks)

The model output “time from arrival to discharge” is validated against data from the electronic patient journal (EPJ) from all of 2009. The results of this are shown in table 2 below. Ideally, the model output “time from arrival to nurse examination” and “time from arrival to physician examination” could also have been validated against EPJ if these data were accurate. However, the EPJ logged time for nurse and physician examination are not accurate enough as they represent the point in time when the physician or nurse logs on to the EPJ for a certain patient, which could be anytime from seeing the patient to when the patient is discharged from the ED. Therefore, only the time of arrival and discharge in the EPJ is good enough to be used as result validation.

Table 2: Results validation

	Model out-put	**Real world data**
Time from arrival to discharge from ED	236	241

If the output from the model and the real world data compare closely, then the model of the existing system is considered valid (Law 2009). Both the arrival verification figure and the figure of the total number of patients in the ED show that the model dataset and the real world dataset compare closely. While the arrival verification in figure 2 is mainly a control of the programming of the entities in the model, the validation of the total number of patients in ED in figure 3 is a validation of the model as a whole. The input behind this figure indirectly involves all processes in the model and compares this to the real world data. From the results validation we see that the differences in outputs from the model and the real word data is less than two percent. The conclusion from these validation processes tells us that the model of the existing system can be considered valid for the objective of this study.

3 RESULTS

The 2009 model (baseline) and the different scenarios of the 2011 model have all been run for 805 days (115 weeks) with the first 259 days (37 weeks) discharged as described in section 2.1 above. The results from these model runs are shown in table 3 below. Here, both time from arrival to different activities is presented as well as the average staff and bed utilization.

Table 3: Results

	Base-line	A	B	C	D	E	F	G	H	I	J
Beds	17	17	25	17	17	17	17	17	17	17	17
Nurses	8	8	12	12	10	8	8	8	8	8	9
Physicians	8	8	12	12	12	12	10	12	10	10	12
Triage nurses	2	2	3	3	3	3	3	2	2	2	2
Triage physicians	2	2	3	3	3	3	3	2	2	3	2
Time to complete activities:											
Time from arrival to nurse triage	32	366	29	44	43	42	88	48	95	92	44
Time from arrival to physician triage	22	219	19	37	36	35	49	38	49	50	38
Time from arrival to physician exam	188	542	174	175	176	174	227	177	233	231	177
Total time in ED	238	593	229	230	231	229	278	232	284	283	232
Utilization:											
Regular nurse	31%	43 %	31%	31%	36%	43%	43%	43%	43%	44%	40%
Regular physician	56%	73 %	58%	58%	58%	58%	65%	58%	65%	65%	58%
Triage nurse	45%	47%	33%	33%	33%	33%	33%	46%	47%	47%	46%
Triage physician	47%	46%	33%	33%	33%	32%	32%	47%	47%	32%	47%
Bed area	45%	91%	42%	56%	56%	56%	65%	56%	66%	66%	56%

In this analysis we experiment with five factors with more than two levels. In a full factorial analysis this would yield a very high number of runs and this was therefore not considered. The described ten scenarios were chosen based on clinical relevance and systematic experimentation.

The only difference between the baseline model and scenario A is the 45% increase in patient volume. We observe that due to overcrowding, a large queue evolves in the arrival area, and the total time spent in the ED increases by more than 150%. The utilization of regular nurses and physicians increases considerably as does the bed utilization. The triage staff utilization seems to stay stable during this patient volume increase. In scenario B we have increased all resources by 45%. The results from this scenario compare closely to the 2009 model as expected. However, for the hospital management it is important to find the lowest number of additional resources needed in the ED due to the patient volume increase in 2011, which would not compromise the patient flow. Scenarios C-J experiment with different levels of resource quantity. We observe that while increasing the triage staff does not seem to be important, the regular physician capacity seems to be the most important factor. We also observe that increasing the bed capacity is not necessary when increasing staff capacity. Scenario G seems to be the most cost effective scenario with only an increase of four regular physicians. However, in this scenario the regular nurse utilization is increased considerably. Therefore, scenario J seems to be the best scenario considered both results in waiting times and staff utilization given the resource increase. In this scenario the number of treatment beds and triage staff is not changed from the baseline model, while the number of regular nurses is increased from an average of eight to nine and regular physicians is increased from eight to 12.

4 DISCUSSION AND CONCLUSION

An important health policy question is whether Ahus will be able to handle the large increase in patient volume which is expected in 2011. Hospital management is currently discussing how to distribute additional resources within the hospital to meet the increased needs. This paper shows that the ED of Ahus will be able to handle the increased patient volume with a marginal increase in bed capacity and staff number. The impact on the rest of the hospital is currently being estimated in another simulation model of the hospital as a whole.

The simulation model developed in this analysis is validated thoroughly as shown in figure 2 and 3 and table 2. Its credibility and validity is therefore sufficient for the hospital management to use the results in their decision making on the future of the hospital. From observation and SME estimates, it is shown that the physicians in the ED are only able to work directly with patients about half of their time. We have therefore modeled half the volume of physicians but with the capacity of working with patients at any time. This simplification in the model is a conservative one, since a larger number of physicians will be more flexible to handle a high number of patients in peak time. From the results table (table 3) we see that the utilization of nurses is the lowest of the staff groups in the model. This is because nurse chores not directly related to patients in the ED are not estimated or included in the model. However, it is important to acknowledge this and not conclude that nurse utilization can be increased considerably in the experimental scenarios compared to the baseline values. Increasing the nurse capacity from an average of eight nurses to nine, and increasing from eight physicians to 12 will meet the needs of handling the increased patient volume without compromising the waiting time in the ED or the work intensity of the staff.

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AUTHOR BIOGRAPHIES

LENE BERGE HOLM is working for the Health Services Research Centre in the Research Department of Akershus University Hospital and is currently working toward her PhD degree in simulating patient flow in Norwegian Healthcare. She holds a Masters Degree in Pharmacy from the Danish University of Pharmaceutical Science with a specialization in Social Pharmacy. Prior to her PhD she worked with health economy and pharmacoeconomics. Her research interests include medical and pharmaceutical science, patient flow, and health economic analysis. Email can be directed to: <lene.berge.holm@ahus.no>.

FREDRIK A. DAHL is working for the Health Services Research Centre in the Research Department of Akershus University Hospital. He holds a PhD degree in informatics. He has previously worked with combat simulation for the Norwegian Armed Forces and Bayesian MCMC simulation. Email can be directed to: <fredrik.a.dahl@ahus.no>.