Proceedings of the 2009 Winter Simulation Conference
M. D. Rossetti, R. R. Hill, B. Johansson, A. Dunkin and R. G. Ingalls, eds.

SIMULATING THE EFFECT OF PHYSICIAN TRIAGE IN THE EMERGENCY DEPARTMENT OF AKERSHUS UNIVERSITY HOSPITAL

Lene Berge Holm

Helse Sor-Ost Health Service Research Centre
Akershus University Hospital
P.O. Box 95, NO-1478 Lorenskog, Norway

Fredrik A. Dahl

Helse Sor-Ost Health Service Research Centre
Akershus University Hospital
P.O. Box 95, NO-1478 Lorenskog, Norway

ABSTRACT

The Norwegian Board of Health Supervision has strongly recommended that all hospitals need to take action to improve the long waiting times before patients are seen by a physician in the Hospital Emergency Department. Akershus University Hospital has complied with this by introducing physician triage every weekday from 10am to 7pm. Because it is difficult to see the influence this has had on the patient flow in the ED, the Hospital Research Department has developed two simulation models to estimate the effect on patient waiting time by replacing nurse triage with that of a physician. The results of the simulations show that the waiting time for an initial physician evaluation was reduced from 117 minutes to 26 minutes, while the waiting time for a physician examination was reduced only by 7 minutes. The total waiting time in the ED was reduced from 297 to 288 minutes when introducing physician triage.

1 INTRODUCTION

1.1 Hospital background

Akershus University Hospital (AHUS) is a 615-bed hospital situated a few miles Northeast of Oslo in Norway, serving 340,000 inhabitants in the region. The hospital is operating in completely new facilities, as the new hospital was opened officially on October 1, 2008 (Ahus 2009a). The capacity of the hospital will be expanded with 100-175 additional beds serving another 130,000 inhabitants by the end of 2010 (Ahus 2009b).

AHUS is one of Europe's most modern hospitals with many technology solutions replacing human resources like robots, automatic transportation of clothes, transportation of specimen and test results, and more (Ahus 2007).
AHUS is organized into five main divisions including nurses, surgical, general medicine, pediatrics and psychiatric.

1.2 The Emergency Department

The Emergency Department (ED) of the new hospital opened November 1, 2008. The ED consists of an Emergency Room (ER) and two wards: Acute 24 (A24) and Acute 72 (A72). The aim of A24 is to offer a bed in a room to patients who are either waiting for a room at another ward, waiting for results of tests, or expected to be discharged within 24 hours. A72 has some of the same objectives, but with a timescale of 72 hours compared with the 24 hour maximum time of A24.

In Norway, walk-in patients normally do not show up at the Hospital Emergency Room without first being referred from other healthcare institutions. Most patients will first show up in special walk-in ER facilities called the Emergency Treatment Service (ETS), which is organised outside the hospital's regiment and where the least severe patients are treated and sent home. ETS patients who need more extensive medical care are sent from the ETS to the Hospital ED, either by ambulance or self transportation. Patients treated and sent home from the ETS are not included in this analysis. Most of the walk-in patients arriving at the Hospital ED first have been through a screening at the ETS (or by their general practitioners, at outpatient clinics, specialists' offices, etc.). Those patients are, therefore, more severe than the average ETS patient and normally would need hospitalization. Because of the severity of the Hospital ED patients, the "left without being seen" (LWBS) patients are seen very seldom in Norwegian hospital EDs and this was therefore not considered in this study. LWBS, however, represents a significant problem in the United States (Johnson et al. 2009) and many other countries (Kennedy et al. 2008).

1.3 Introduction of physician triage in the Emergency Department

Long waiting hours in the Emergency Departments of Norwegian hospitals is a common problem. Long waiting times and overcrowding is also a worldwide problem (Cowand and Trzeciak 2005), and has been an issue since the early 1990s (Andrulius et al. 1991). It is a problem that, in many cases, the time before a patient is examined or even met by a physician is unacceptably high. The main causes are well known for ED overcrowding, hospital bed shortages, high medical acuity of patients, increasing patient volumes, shortages of examination space and staff (Derlet and Richards 2002). Problems with overcrowding and long waiting times in Norwegian EDs have received much media attention lately. To meet some of these concerns, the Norwegian Board of Health Supervision has decided that all hospitals need to make the necessary changes to ensure that patients are introduced to a physician as soon as possible after arriving at the ED. From February 1, 2009, Akershus University Hospital has decided that the maximum patient waiting time for an initial physician evaluation upon arrival at the ED should be 10 minutes. In addition, the maximum patient waiting time for a physician examination should not exceed 30 minutes. To comply with these demands, the ED of AHUS has decided to replace the nurse triage with that of a physician triage during the busy hours of the ED, which are Monday through Friday from 10AM to 7PM. However, it should be mentioned that even though we named it physician triage in this paper, the acuity evaluation process done by a physician is not exactly equal to that of the nurse triage process. The difference lies mainly in that the nurses have to follow specific guidelines with subsequent careful documentations while this is not necessary for the physicians. However, to make it easier for the readers to recognise these processes, we have named it physician triage and nurse triage.

2 MATERIAL AND METHODS

2.1 Method

The aim of this project was to compare the differences in patient waiting times in a system with a traditional nurse triage to the new system with physician triage in peak hours in a Norwegian Emergency Department. Two discrete event simulation (DES) models have been developed, one representing the structure of the ED before the introduction of physician triage, (the nurse triage model) and one based on the structure of the ED after this organisational change (the physician triage model).

Many simulation studies for increasing the efficiency of Emergency Departments have been performed over the years, most of them with the aim of reducing patient waiting times and increasing service levels by improving the actual care process or by increasing the size and operation of the ED (Benneyan 1997). Introducing physician triage at Akershus University Hospital was a result of the demand from The Norwegian Board of Health Supervision to reduce the waiting time for a patient to be seen by a physician. How this structural change actually influenced the total waiting time for a patient in the ED was difficult to guess in advance. In a situation like this, a simulation model is a good tool for estimating waiting times when modelling the entire process from beginning to end.

The models were built with Flexsim Healthcare, which is newly developed simulation software specially designed for modelling patient flow in Emergency Departments (Flexsim 2009). Figure 1 below shows a picture of the Flexsim HealthCare Simulation Model. This simulation analysis is a preliminary analysis of a larger study yet to be performed on simulating patient flow in the ED of AHUS.

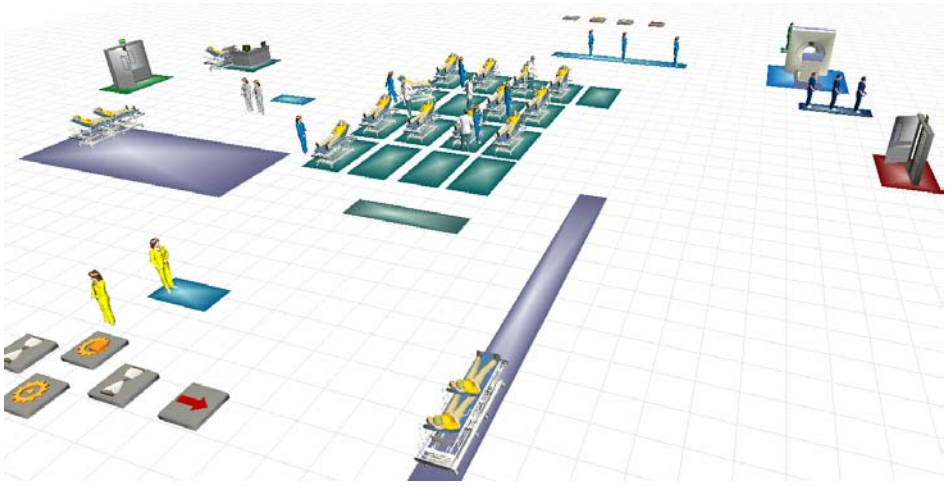

Figure 1: The Flexsim Health Care Model

For simulation models of non-terminating systems, like Emergency Rooms, only one replication is needed. However, for obtaining confidence intervals, the run has to have a duration long enough to obtain a steady state and long enough to make it possible to obtain statistically independent observations to yield confidence intervals (Centono and Reyes 1998). A warm up period, WT, can be estimated by counting the daily throughput over a short simulation period and plot this in a graph. The time at which the graph hits the steady state is the warm up time of the model. In this study a steady state was difficult to observe because of the weekly variations in admitted patients, and the fact that the ER will never have a constant flow of patients. An approximate model steady state was assumed to be reached after roughly 3 months model run. To be on the safe side however, when running the model, we chose to use a WT of 260 days, which was half of the generation time (see below). The duration of the model run was calculated based on the desire of a standard deviation of roughly 5.0 which would yield a confidence interval of +/- 10. The equation for standard deviation (1) is as follows:

$$SD = SD_0 / \sqrt{N}. \quad (1)$$

However, since all observations were not independent, we also needed to calculate the lag, k, which is the number of observations between two independent observations (observations with a minimum correlation, $\rho \rightarrow 0$) and include this in the equation for standard deviation (2) as follows:

$$SD = SD_0 / \sqrt{N/k}. \quad (2)$$

In an ER simulation model it will be impossible to obtain a correlation of 0, therefore a correlation of less than 0.1 was considered to be sufficient in this study. Estimating k can be done by creating a correlogram as described in Centono and Reyes (1998), or it could simply be estimated by calculating the correlations for lags of different sizes in a spreadsheet based on the simulated results of total time spent in the ER for each individual patient. The results from a short run of 100 days of our model showed that $\rho = 0.1$ when k was 60. In our model, one observation was the total time spent in the ER for one particular patient. In the short model run the standard error, SD_0, of all observations was 125. For a desired SD of 5.0, a SD_0 of 125 and a k of 60, we calculated the number of needed observations as follows:

$$SD = SD_0 / \sqrt{N/k}. \quad (2)$$

$$N = (SD_0 / SD)^2 * k = 37{,}500 \text{ observations.}$$

With three patients arriving per hour, this meant the generation time (GT) had to be 37,500 observations / 3 observations per hour = 12,500 hours, or 521 days. The simulation time (ST) had to be at least the warm up time plus generation time plus a safety time of 1% of the generation time as follows:

$$ST = WT + GT + 1\%*GT. \quad (3)$$

$$ST_{(days)} = 260 + 521 + 5 = 786 \text{ days.}$$

Based on these argumentations, both the nurse triage and the physician triage model were run with one replication for 800 days, with the first 260 days discharged.

An analysis of the actual differences in waiting times between the two structurally different ED systems also was performed. This analysis, based on actual data from the patients' database, was a good validation for the simulation models.

2.2 Model outline

Two DES models have been developed. Data was gathered over two time periods, weeks 3-5 (period 1), which represent the time period with nurse triage, and weeks 9-11 (period 2), which represent the time period with physician triage. However, the only difference in the two models was structural. An important thing to keep in mind when building simulation models is whether it is the intended or the actual workflow that makes up the basis for the model. In these models, it was the intended workflow that was modelled. Data inputs on arrival rate and 'waiting for ward' time was not expected to be influenced by the triage method and therefore, was based on data from all six weeks. Some data also was based on data from a survey performed in October and November 2008. (See further explanation of the data gathering in the next section.)

The main difference of the two models was at the organizational level. While nurse triage was occurring in the ER Hall directly after arrival, physician triage was done in treatment rooms. Patients, therefore, need to be transported to a room by a nurse before the physician performs the triage. In the ED the patients are separated into two main tracks depending on whether the patient is a surgical or medical case. Since the physician staffs are divided between the surgical and medical divisions, two physicians are responsible for performing the triage depending on whether the patient was a surgical or medical patient. While the medical triage physician's only responsibility in his shift is to do the triage, the surgical triage physician also is sometimes participating in surgery. At those times, it is difficult for the surgical triage physician to comply with the rules of performing the triage within 10 minutes upon the patient's arrival. At those times, a nurse will do the triage. This is the same nurse who is responsible for performing the triage before 10am. However, since the objective of this study was to model the intended workflow and not the actual workflow, it was assumed that the surgical triage physician did not participate in surgery and was therefore available for triaging his patients immediately. In the model, the two patient tracks, therefore, were considered as one since there should be no difference in the workflow if the intended organizational structure of the ER was followed. It is also worth mentioning that the nurses in the ER differentiate their responsibility between the self transporting patients and the ambulance patients.

Figure 2 illustrates the outline of the two simulation models. It is important to mention that this flow chart is a simplification of the process since trauma patients, level 1 severity patients, and patients who become outpatient cases do not follow the same tracks as shown in the figure below. Ambulance diversion was also not considered in this study.

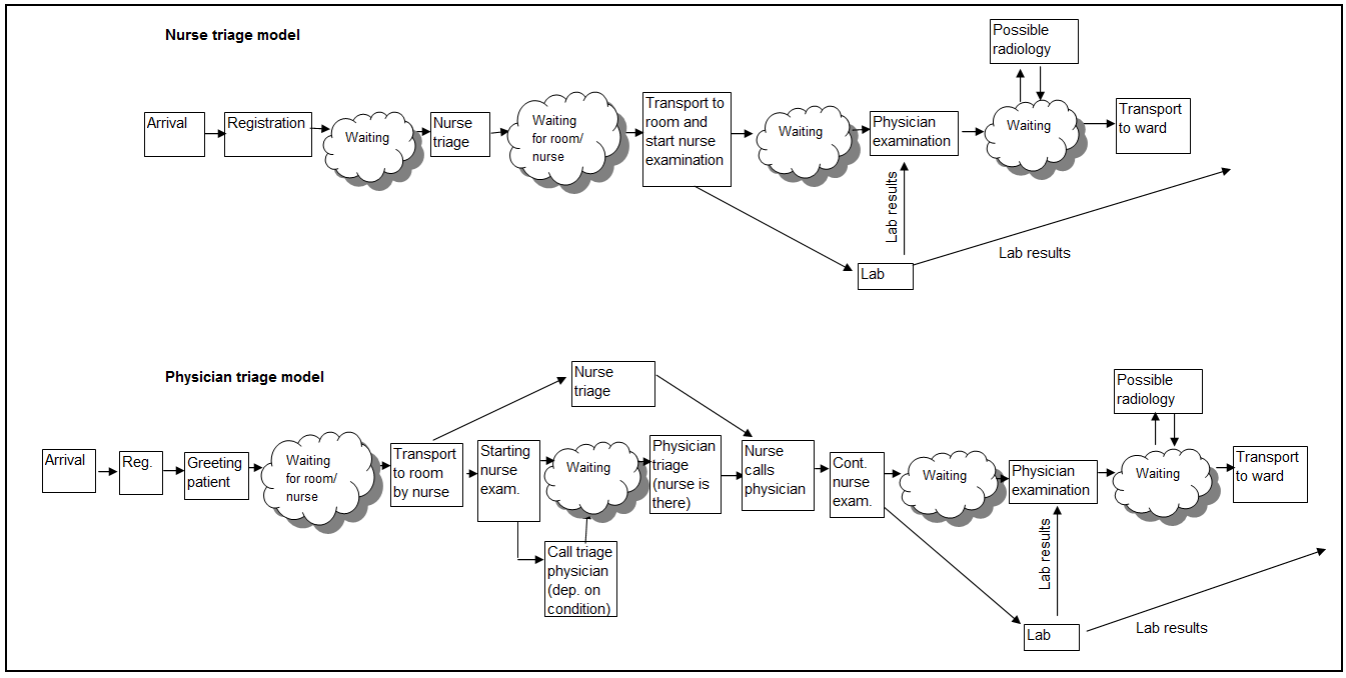

Figure 2: Outline of the Simulation Models

After the triage and room placement, the two models are similar. The patients are examined by a nurse and a physician, and specimens are drawn and sent to the lab. The lab results normally are not available by the time of the ER physician examination. Even so, the patient does not wait for lab results in the ER, they are analysed by the assigned physician at the ward to which the patient is admitted.

Some patients also are referred for a radiologic examination. The resources of this examination was not modelled in detail, but the duration of the radiology examination was modelled with a distribution fitted to empirical data.

2.3 Data collection

As a part of all the process changes that follow relocating to a new hospital facility, the Emergency Department has had some initial difficulties during the first few months in finding their optimal work flow. Due to this, data gathering for this particular model has been scarce and difficult. However, we believe that the main scope of the models is correct and the aim of the analysis, which was to study the differences in waiting times of the two structurally different models, was not compromised by these limitations.

The reason for choosing only a three-week timeframe for data acquisition for the simulation models lied in the limitation of the data from Unit for Patient Logistics (UPL), which was available only from the beginning of January 2009. Data for the nurse triage model was, therefore, from weeks 3-5, while the physician triage model was from weeks 9-11. The first three weeks after implementing the triage change was considered a try-out period; hence, data from these weeks were discharged.

Not all data was possible to obtain electronically, so manual data gathering and subject matter expert (SME) opinions were used in some areas. Table 1 gives an overview of all activities included in the model and how the data was recorded.

Table 1: Data Collection

Activity	*Data*	*Data gathering*
Inter-arrival time	19 min[2]	E[5]
Registration	2 min	SME[6]
Transport to room	0 min[3]	SME
Nurse taking blood pressure, temperature and pulse	5 min	SME
Call physician	1 min	SME
Nurse triage	9	M[7]
Physician triage	6	SME
Nurse examination	33	M
Physician examination	40	M
Possible radiology	15	SME
Frequency of radiology	54%	E
Ward waiting time (based on UPL[1])	44 min[4]	M
Staffing and other resources		M
Number of treatment rooms	17	
Average number of physicians	8 + 2	
Average number of nurses	8 + 2	

[1] UPL = Unit for Patient Logistics
[2] Different distributions for time of day and day of week, 19 min on average
[3] Walking time is included in the software
[4] Different distributions for time of day and day of week, 44 min on average
[5] E = electronically,
[6] M = manual data gathering
[7] SME = Subject matter experts estimates

The arrival rates for the two time periods were assembled electronically from the patient database (DIPS). For all six weeks, the distribution of patients each hour of the day and each day of the week was identified. By segregating the arrivals in this way, we took into account peaks in the arrival patterns throughout the week and day. Meng and Spedding (2008) argue further for the importance of this consideration. An exponential distribution of the inter-arrival times for each hour of the day and each day of the week made up the basis for the hourly arrival table. On average over the 6 weeks of data collection, from Monday to Sunday, 86, 79, 73, 83, 79, 64, and 61 patients arrived per day respectively with a mean of 19 minutes between each patient throughout the week.

Patient arrival was modelled as a time variable Poisson-process with constant intensities for each hour of the week. This was implemented through censoring. First, a (tentative) time until the next arrival was drawn from an exponential distribution with its parameter determined by the current hour. If this arrival time fell within the current hour, it was accepted. Otherwise, the part of the time-until-arrival that extends beyond the next full hour was censored, and then replaced with a duration drawn from an exponential distribution with parameter belonging to that following hour. If this new arrival time fell within that hour (e.g., it is <=60 min.), it was accepted. Otherwise, the part extending beyond that hour was censored, and then redrawn. The process continued until an arrival time fell within the hour for which its exponential parameter was valid.

We verified experimentally that our implementation was correct by measuring the total number of arrivals over a long simulation period, and observe that it agreed with the expected number of arrivals summed over each simulated hour. In our model, the crude approach of accepting each exponentially drawn durations without censoring would underestimate the total influx of patients by 3%.

An ED quality survey was performed in October and November 2008 where the amount of time spent on nurse triage, nurse examination, and physician examination was recorded (Ahus 2008). This data also was used in the model with a triangular distribution with a mode of 10 minutes for nurse triage, 30 minutes for nurse examination, and 37 minutes for

physician examination. For the rest of the activities, registration, transport to room, initial nurse exam (mini-triage with registration of blood pressure, temperature, and pulse), call physician, and physician triage, data were not available. Estimates from subject matter experts have, therefore, been used where the responses of the normal values were interpreted as the mode of a triangular distribution. Please refer to table 1 above for this information. The probability for a patient to be sent to radiology was obtained electronically from the patient database (DIPS). The estimation of an average radiology duration from subject matter experts from the radiology department was modelled rather than including staffing and other resources of the examination; hence, in this preliminary analysis, all radiology examinations were equal and a wide triangular distribution with a mode of 15 minutes took into account the variations in their durations. After the physician examination, the physician fills out a form with information on the ward to which the patients should be admitted. This form is given to the unit for patient logistics (UPL), which is responsible for finding an available bed for the patient. UPL logs the time it takes from when they receive these forms to when a bed is booked. These time intervals represent the waiting time for the patients after the physician examination and until they are admitted to the desired ward. In the model, different distributions for ward waiting time was modelled for each day of the week. The ward waiting time was also divided into before and after 4pm groups, as this marks the peak time of the number of patients waiting in the ER. The average ward waiting time throughout the week was 44 minutes. Finally, information on staffing and the number of treatment rooms in the ER was obtained manually by consulting relevant personnel within the ED. On average, 8 physicians are working with patients 50% of the time. In the physician triage model, 2 additional physicians with triage responsibility are working from 10am to 7pm. In the nurse triage model an average of 8 regular nurses and 2 triage nurses are on duty at all times. In the physician triage model, the triage nurses work as regular nurses in the physician triage hours (between 10am and 7pm).

As described in this section, there were some distinct data collection issues with this study. How they impact the validity of the results is difficult to say; however, since the aim of this study was to compare the differences in waiting time for the nurse triage model and the physician triage model, the validity of the main results was not extensively impaired by these limitations since the same limitations were implied for both models.

3 RESULTS

3.1 Results of the simulation models

The main reason for replacing the Emergency Room (ER) nurse triage with that of physician triage on the weekdays between 10am and 7pm was to include a physician in the patient's treatment at an earlier point in time. In the nurse triage model, patients waited an average of 117 minutes to be examined by a physician. In the physician triage model, the patients were introduced to a physician who did an initial evaluation of the patients after their first 26 minutes in the ER. The results of the two simulation models shown in Figures 3 and 4 below were achieved by running the model with one replication for 800 days as described in section 2.1. The columns of the histogram show the starting time of each milestone activity in the model. In the nurse triage model, triage was, on average, done three minutes after arrival. In the physician triage model, there were two patient tracks depending on the hour of the day. When the physician was performing the triage (between 10am and 7pm), the triage was on average done 26 minutes after arrival, and during the rest of the day where the nurse was performing the triage, it was done 58 minutes after arrival. The nurse examination started on average 55 minutes after arrival in the nurse triage model, compared to 33 minutes in the physician triage hours and 74 minutes in the nurse triage hours of the physician triage model. The average time from arrival to physician's examination was 117 minutes in the nurse triage model and 110 minutes in the physician triage model. The average total length of stay in the ER was 297 minutes in the nurse triage model and 288 minutes in the physician triage model. A confidence interval was calculated for the total time spent in the ER as described in section 2.1. With a standard deviation of 4.75 and 4.62, respectively, the confidence interval for the total time spent in the ER was for the nurse triage model 287.50 - 306.50 and for the physician triage model it was 278.76 - 297.24. This showed that the differences in total time spent in the ER were not significantly different between the two models.

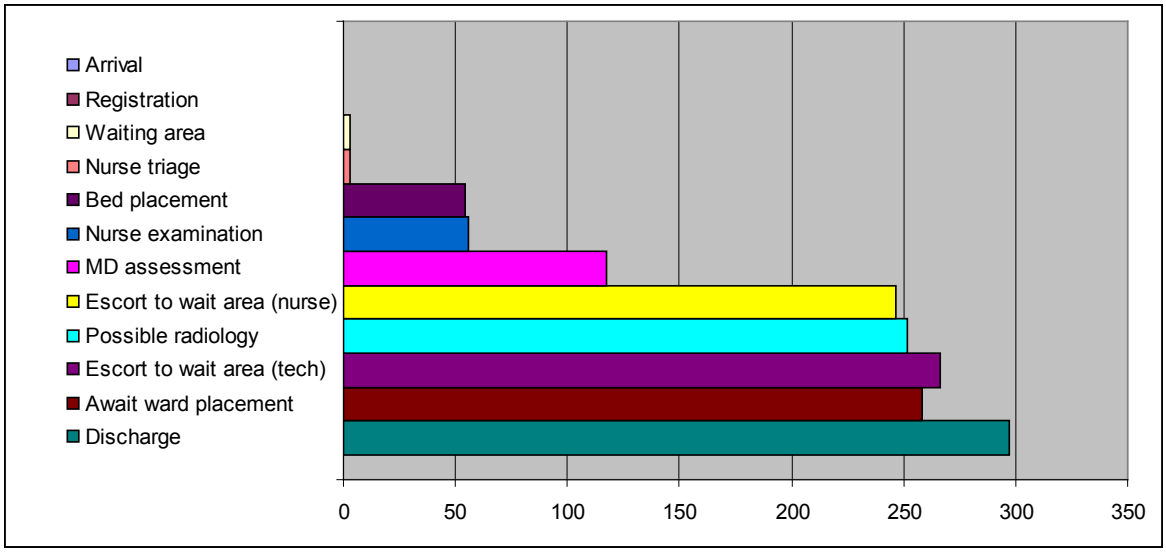

Figure 3: Time from arrival to activity start, nurse triage model

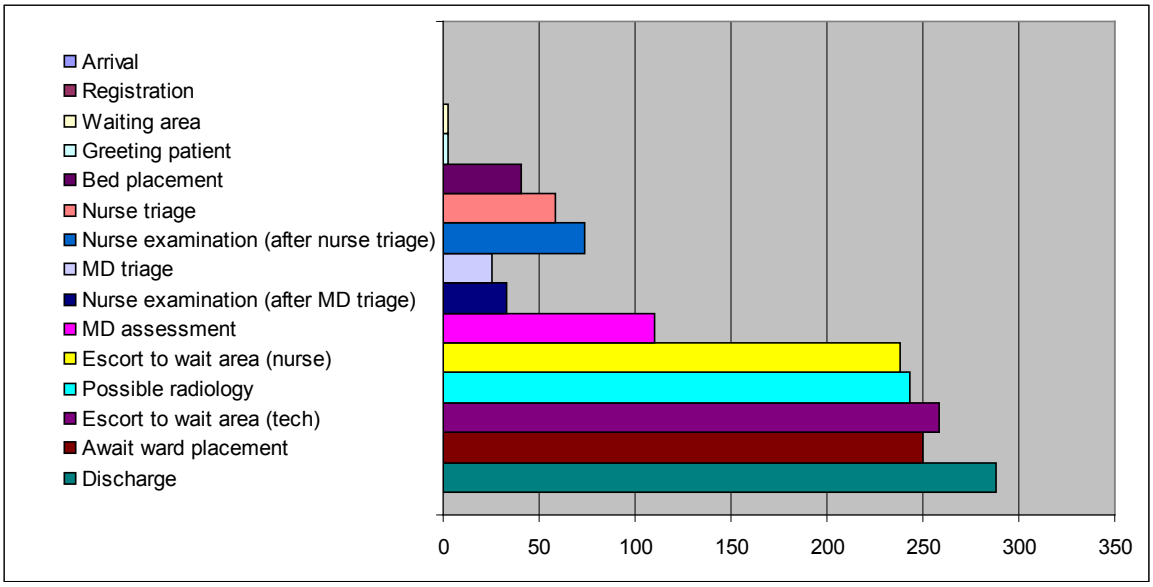

Figure 4: Time from arrival to activity start, physician triage model

The long waiting times after physician examinations and before patients are transferred to a hospital ward was due to the overcrowding in many wards of the hospital.

3.2 Analysis of actual waiting time

Data on waiting times from arrival to nurse and physician examination and the total time spent in the ER has been obtained from the patient database. These results can help validate the simulation models to some extent, but the values of the times to nurse and physician examination was not exact, as they were based on the hours where nurses and physicians made changes in patient records for the first time. This was not necessarily equivalent with the actual beginning of the examination hour, as the reporting routines were not completely standardised. The total stay in the ER obtained from the patient database should, on the other hand, be correct, as this was based on actual logged hours of arrival and discharge.

Statistical analyses of these waiting times showed that in the nurse triage time period the patients waited on average 141 minutes from arrival to nurse examination, 126 minutes from arrival to physician examination, and had a total stay of 281

minutes in the ER. In the physician triage time period, the patients waited on average 75 minutes from arrival to nurse examination, 117 minutes from arrival to physician examination, and had a total stay of 268 minutes. Unfortunately it was not possible to obtain the actual time from arrival to physician triage. This actual data from the patient database showed that introducing physician triage reduced the waiting time for nurse examination by 66 minutes (46.68%, p=0.251), but only reduced the waiting time for physician examination by nine minutes (6.93%, p=0.302). The total stay in the emergency department is reduced by 13 minutes (4.60%, p=0.260). None of these results, however, are significant.

4 DISCUSSION

4.1 Discussion of introducing physician triage

The implementation of physician triage in the ER of Akershus University Hospital has not been an easy process. Many communication problems between divisions and staff and leaders within the divisions have been observed in the data gathering part of this analysis. The profession struggle between nurses and physicians also is clearly visible in the ED in that the ownership and responsibility of the patients has shifted without this fact being clearly stated and accepted by both professions. Although all employees in the ED have had the opportunity to express their own opinions regarding this structural change, there seems to be general problems with the willingness to adapt to this new process, especially among the nurses on the floor. Another problem with introducing physician triage involves the Surgical Division. Here, the physician responsible for performing the triage is also participating in surgery. This makes it difficult for him to comply with the '10 minutes rule' all the time.

It needs to be stated that the physician triage organisation is in its starting period, and some initial problems with this system are to be expected. This, in combination with the above issues, might be the reason why the actual working process in the ED is different from the intended workflow. It is important to keep in mind that it was the intended workflow that was modelled in this study and not the actual workflow.

4.2 Discussion of method

As described earlier, data gathering for this particular model has been scarce and difficult; so, some limitations and simplifications had to be made in the simulation models. This, however, did not significantly influence the main results, which were based on the differences in patient waiting times between the two simulation models, since the same simplifications was made in both models.

The reason for choosing two times three week timeframes was because the data on ward waiting time obtained from UPL was available only from week 3, January 12, 2009. The physician triage was implemented in week 6, February 2, 2009. The three weeks after this implementation were excluded to avoid the initial organisational problems that always follow such an organisational change. Weeks 9-11 were, therefore, the natural choice for physician triage data gathering.

4.3 Discussion of results

The results of the simulation models showed that introducing physician triage only decreased the waiting time for physician examination by seven minutes and the total length of stay in the ED was only decreased by nine minutes. On the other hand, in the physician triage model the time from arrival to nurse examination decreased by 22 minutes on average in physician triage hours (10am to 7pm) but increased with 19 minutes in nurse triage. The triage process also was happening at a later point in time throughout the day in the physician triage model. However, in the physician triage model, during physician triage hours, the patients received an initial evaluation by a physician within 26 minutes of arrival, compared to waiting 117 minutes for a physician examination in the nurse triage model. It might be more important and comforting for the patients to be evaluated quickly by a physician at an early point in time even though the physician examination does not happen significantly sooner than in the nurse triage model. Also, even though the patients are receiving triage at a later point in time in the physician triage model, they already have had a mini-triage by a nurse after arrival and registration. Although the differences in time for the different activities in the two simulation models were small and insignificant, the quality of the service was meant to be improved by this structural change in that the physician was involved with the patient at an earlier point in time. The results of this simulation analysis was in accordance with the results of Han et al. (2009). They show that introducing a physician in triage did not influence the length of stay of admitted patients in the Emergency Department significantly. However, the "left without being seen" (LWBS) rate and the total time spent on ambulance diversion decreased in this study. Ambulance diversion and the LWBS rate are not considered in our study as this is something that does not happen very frequently at this hospital as described in section 1.2.

In the physician triage model we observed that the average time from arrival to triage in the time period where physicians did the triage was far less than the time from arrival to triage in the nurse triage time period. Even though patients

arrived with a higher frequency during the daytime, this effect was transferred forward to the evening and night and gave peaks in queues and waiting times in the nurse triage time period. This effect can also be seen in real life, although the effect is not as significant because of the fact that in situations of long queues and chaos staff will work more effectively, and this change in work intensity was not included in the simulation models.

The physician triage simulation model showed that the ED of AHUS in March 2009 was closer to the demand of initial physician evaluation within 10 minutes after arrival, although the maximum of 30 minutes from arrival to physician examination has not been achieved yet.

The results of the simulation models were, to some extent, in accordance with the analyses of the actual waiting times in the two time periods obtained from the patient database. These analyses showed an insignificant decrease in waiting times for the period of time where the physicians were doing the triage in peak hours (66 minutes decreased in waiting for nurse examinations, nine minutes decreased in waiting for physician examinations, and 13 minutes decreased in total time spent in the ER when replacing the nurse triage with that of a physician). There are many reasons for the differences in results on waiting times of the simulation analyses and the actual data from the patient database analyses. First of all, the data on waiting for nurse and physician examinations obtained from the patient database was not reliable because of the non standardised reporting routines as described in section 3.2. It was also a limitation that the two times three week time frames analysed were too short of a period to give significant information on the influence of the patient flow. The observations from the analysis of the data from the patient database also can be a result of the Hawthorne effect, where individuals increase their short time productivity by the psychological stimulus of being singled out and made to feel important (Franke and Kaul 1978). The effect of making an organizational change in the ER might not be the change itself, but the knowledge that something is being done to improve the workflow. The data obtained directly form the patient database showed a total stay in the ER of a little more than four hours in both time periods. In both simulation models the total stay in the ER was a little less than five hours. This difference is also the result of not modelling the work intensity among the staff in situations of long queues and chaos which in the models increases the average total waiting time in the ER.

Another reason why the analysis of the differences in the actual waiting times in the two time periods might not be reliable was the fact that the hospital was undergoing major changes due to the moving process discussed earlier. Ad hoc solutions was being implemented from week to week, and it was difficult to identify every small change that might have had an influence on the patient flow. In the same discussion, it is important to remember that these simulation models were based on the organisational structure of the ED at those two time periods, weeks 3-5 and weeks 9-11.

Compared to the analysis of data from the patient database, the simulation models gave a more reliable result because they took into account the entire process at a higher level of resolution and were not influenced by psychological stimuli and differences in reporting routines.

5 CONCLUSION

When running the Emergency Department with nurses doing triage, the patients' first meetings with a physician was on average 117 minutes after arrival. If the nurse triage was replaced with that of a physician triage from 10am to 7pm, the patients' first meetings with a physician was after 26 minutes on average. The waiting time for nurse and physician examinations, however, was not influenced significantly by introducing physician triage. The total stay in the ED was a little less than five hours in both simulation models.

An analysis of the actual waiting times in the ED obtained from two 3-week time periods representing nurse and physician triage, respectively, showed that the average total waiting time in the ED was a little more than four hours. This was to some extent in accordance with the results of the simulation models.

Knowing if implementing a structural change will influence the patient flow significantly is not easy. A simulation model can help decision makers in situations like this by visually showing the effect that a particular change might have before implementing the actual change.

ACKNOWLEDGMENTS

We would like to express our appreciation to the staff of the Emergency Department at Akershus University Hospital for providing us with data and participating in discussions regarding the organisation of the ED. We also would like to thank Regan Blackett and Cliff King with Flexsim for helping to build the simulation models. This study is a part of a doctorate project funded by the Norwegian HELTEF fund.

REFERENCES

Ahus. 2009a. <http://www.ahus.no/modules/module_123/proxy.asp?D=2&C=1050&I=17142&mids=a2650a>

Ahus. 2009b. Considering the bed capacity of Ahus 2011. Internal report.

Ahus. 2008. Valuating the patient flow in the Emergency Room in the new facilities of AHUS. Internal report.

Ahus. 2007. Akershus University Hospital Annual report 2007 <http://www.ahus.no/modules/module_123/proxy.asp?D=2&C=1050&I=18471&mids=a2650a2675a>

Andrulius, D. P., E. Kellerman, E. A. Hintz, B. B. Hackman, and V. B. Weslowski. 1991. Emergency Department and overcrowding in United States teaching hospitals. *Annals of Emergency Medicine* 20(9):980-986.

Benneyan, C. J. 1997. An introduction to using computer simulation in healthcare: Patient wait case study. *Journal of the Society for Health Systems* 5(3):1-15.

Centono, M. A. and M. F. Reyes. 1998. So you have your model: What do to next. A tutorial on simulation output analysis. In *Proceedings of the 1998 Winter Simulation Conference*, eds. D. J. Medeiros, E. F. Watson, J. S. Carson and M. S. Manivannan, 23-29. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

Cowand, R and S. Trzeciak. 2005. Clinical review: Emergency Department overcrowding and the potential impact on the critically ill. *Critical Care* 9(3):291-295.

Derlet, R. W. and J. R. Richards. 2002. Emergency Department Overcrowding in Florida, New York and Texas. *Southern Medical Journal* 95(8):846-849.

Flexsim. 2009. Flexsim Health Care. <http://www.flexsim.com/products/healthcare/>

Franke, R.H. and J. D. Kaul. 1978. The Hawthorne experiments: First statistical interpretation. *American Sociological Review* 43:623-643.

Han, J.H., D. J. France, S. R. Levin, I. D. Jones, A. B. Storrow and D. Aronsky. 2009. The effect of physician triage on emergency department length of stay. *The Journal of Emergency Medicine* Jan 24. [Epub ahead of print].

Johnson M, S. Myers, J. Wineholt, M. Pollack and A. L. Kusmiesz. 2009. Patients who leave the emergency department without being seen. *Journal of Emergency Nursing*. 35(2):105-8.

Kennedy M, C. E. MacBean, C. Brand, V. Sundararajan and D. McD Taylor. 2008. Review article: Leaving the emergency department without being seen. *Emergency Medicine Australasia* ;20(4):306-13.

Meng L. Y. and T. Spedding. 2008. Modelling patient arrivals when simulating an accident and emergency unit. In *Proceedings of the 2008 Winter Simulation Conference*, eds. S. J. Mason, R. R. Hill, L. Mönch, O. Rose, T. Jefferson, J. W. Fowler, 1509-1515. Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.

AUTHOR BIOGRAPHIES

LENE BERGE HOLM is working for the Health Services Research Centre in Research Department of Akershus University Hospital and currently is working towards 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. For the past five years she has been working on 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. >