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DISCRETE SIMULATION APPLICATION - SCHEDULING STAFF FOR THE EMERGENCY ROOM

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ABSTRACT

The Emergency Room Services (ER) of a hospital is a complex probabilistic system where discrete event simulation can be applied. This paper presents the simulation analysis of the ER at Georgetown University Hospital (GUH), using a unique approach to schedule nursing staff.

The analysis was accomplished in three phases as follows:

a) Patient Classification system: A patient classification system, consisting of five patient acuity levels, was designed to identify degrees of resource needs by objectively delineating the nursing tasks at each acuity level.

b) Data Collection and Data Base: A PC based database was specifically designed to collect ER workload information such as patient arrival time and acuity of patient by hour of the day.

c) Modeling and Simulation: The model was designed to be sensitive to hourly patient acuity mix levels, since the workload in the ER is primarily dictated by this.

The simulation was conducted using SIMAN, a PC based language for a period of 1,000 hours. The first 120 hours of the simulation run were ignored to allow the system to reach steady state. Upon arrival the patients were assigned an acuity, triaged and based on acuity sent either directly to the treatment area or to registration and then treatment area.

In the treatment area a patient was seen every hour by the nurse staff till the length of stay was completed. The number of nurses and amount of direct nursing care provided to a patient depended upon the acuity level.

Auxiliary patient care such as nurses accompanying a patient to the CT SCAN unit was also incorporated into the model after the treatment block. The auxiliary care parameters were based on probabilities derived from the database.

The current schedule was first simulated to validate the model by comparing simulation output with real time data. Ten different types of schedules such as all 8 hour shifts or all 12 hour shifts with lesser number of staff were simulated to examine the impact these schedules had on the ER patient workload.

The primary outputs of the SIMAN simulation reports were; patient wait time prior to being seen in the treatment area, patient queue lengths in the waiting area and staff utilization by time of day.

Based on the simulation experiments a feasible cost effective schedule consisting of 12 hours shift is being implemented. The Information System designed in Phase II is now being integrated with the Hospital Information Systems ER Log to provide periodic decision support reports to the ER managers.

INTRODUCTION

Discrete event simulation treats time as a continuous variable such that changes in the system occur at particular discrete points in time. Continuous simulation is when alterations to the model occur continuously as time varies. Discrete event simulation has historically been applied to manufacturing in Production Control, Materials Handling and Inventory Systems. There has been limited use of simulation analysis in service sector operations, particularly in the health care environment. Typically, simulation in the service sector is used to model queues for a transportation system, bank or a hospital admissions department.

The Emergency Room (ER) at Georgetown University Hospital (GUH) is a complex probabilistic system treating both trauma (15%) and non-trauma patients (85%) twenty four hours a day. If traditional queuing network analysis is used to assess the dynamic workload in the ER, the mathematical formulation needed to reflect the actual workload will be very complex and time consuming. In comparison, a discrete event simulation model will be an appropriate tool to capture the dynamic nature of the workload and experiment different staffing patterns in conjunction with system behavior outputs such as staff utilization and patient queues and delays for each schedule.

METHODOLOGY

1. PROBLEM/OBJECTIVES

The ER administration needed an effective staff schedule to meet the "unpredictable" workload patterns. Hence, the objective of the ER simulation analysis was to evaluate the effects of nurse staffing levels on quality of service with different feasible schedules involving all 8 hour, 12 hour or mixed shifts; and recommend the most cost effective nursing schedule with an optimum patient turn around time.

2. PATIENT FLOW MODEL FORMULATION

The patient flow in the ER was modelled using SIMAN - a PC based language. Patient flow from arrival through discharge or admission was analyzed in order to identify workload requirements as a patient is treated in the ER system. (See schematic representation of the model in Exhibit A)

The following process points in the patient flow were identified as key variables upon which staffing requirements are determined:

A. Triage: Patients are assessed upon arrival by the Triage nurse and urgency of care is prioritized. Depending upon the patient's acuity (ranging from I, least serious, to V critical) the patients are either sent for registration or directly to the ER treatment area.

B. Registration: Patients with acuity levels I through III must register with the clerk and wait in the patient waiting area until the treatment area and/or staff are available.

C. Treatment Area: The RN initially assesses the patient and obtains baseline information such as vital signs and chief complaint. The Physician then examines the patient - the immediacy dependent on severity of the patient's condition.
In a nutshell, patients receive a certain amount of direct care every hour during their length of stay based on their acuity.

For purposes of simulation, after the initial nursing assessment/treatment, the patient is placed in a hold block (outside the treatment block) for an hour and sent back to the treatment block for direct nursing care. This cycle is continued till the patient's length of stay (LOS) in the ER is completed.

D. Ancillary Service: Patients of acuity I through III have a probability of leaving the ER for periods of time to go to ancillary departments such as the X-Ray or wait in the waiting area outside the treatment room for Lab results to be processed. During this time the patients require no direct nursing care but become the responsibility of the Charge Nurse. Hence, their LOS in the ER is effectively shorter. This is accommodated in the model by processing such patients through an ancillary treatment block with a reduced LOS.

E. Auxiliary Service: Patients who are more acute may be accompanied by an RN for out-of-ER treatments. Patients admitted to the hospital after treatment in the ER may require an RN to accompany them to the unit. The nurse, as part of a patient's care, may need to go to another department for needed supplies or medications. In these instances, the RN becomes directly involved on a one to one basis with a specific patient's needs. This is categorized as auxiliary service in the model.

In the simulation model, patients go through the block "auxiliary care" with a certain probability. Within auxiliary service, the patients have a probability of involving a RN for transportation accompaniment or assistance to reach restrooms or pick up drugs from the pharmacy.

F. Discharge/Admission: Patients leave the ER system one of two ways: discharge to home or admission to the hospital. In either case they leave the model/system and they no longer require care from the ER staff.

3. DATA COLLECTION

The lack of in depth information on patient visits needed for a simulation analysis required the design of a data collection tool and a repository for this data. An ER Management Information System (ERMIS) was designed using Dbase III to automate the data collection and analysis. A patient classification or acuity system was developed to identify five significant patient groups based on their resource consumption in the ER. The objective was to identify degrees of resource needs by objective delineations of the tasks/functions the nurse was performing at each acuity level.

For purposes of simulation, the classification system was designed to address acuity by each hour of the patient's stay rather than for the entire visit. This approach was used because a patient's acuity could shift hour by hour, affecting total workload requirements.

Once the Classification levels were defined by hour of stay, time standards for each acuity grouping per hour of stay were developed. Care requirements included all direct and patient-related indirect activities.

Information on patient arrivals and direct nursing care for each patient in the ER was collected for a five week period. This data was collected on a specially designed collection sheet attached to each patient's chart. Data was collected on 2435 patients seen in the ER during the study period and the observations were input to the database through user friendly screen interfaces specifically designed for this purpose.

Once the model was formulated, raw data from the data base was extracted in report form and input into the simulation model:

A. Arrival of patients by hour and day.

B. Acuity of patients by hour and day.

C. Length of stay of patients by day.

D. Additional Nursing personnel required for higher acuity patients. (function, type of personnel and time)

E. RN time for auxiliary care by patient acuity level.

F. Patients leaving the ER without an RN for ancillary care by patient acuity level.

4. DATA ANALYSIS AND INPUT TO MODEL

The data from the database was analyzed to evaluate theoretical distributions representing the system with the aid of inferential statistics.

Patient Arrival Pattern:

Based on Pearson's Chi Square Goodness of Fit Test each hourly arrival pattern followed a Poisson distribution with an unique arrival mean for each hour. Thus mean time between arrivals was equivalent to an Exponential distribution varying for each hour in a 24 hour day. One-way analysis of variance confirmed that mean number of admissions by hour were not significantly different by day of week.

Patient Acuity Pattern:
It was verified by the Chi Square Contingency Test that patient acuity distribution of the ER significantly shifted in three hour increments. Shifting each patient's acuity classification during each hour of the stay in the model was found to be complex and impractical for determining staffing levels. Therefore, composite acuity distribution of all patients in the system was re-calculated in three hour intervals in the model.

In conclusion, the dynamic nature of the ER was captured by altering the time between arrivals by hour of the day and re-assigning the composite acuity distribution of all patients in the system in three hour intervals based on the time of the day.

Length of Stay:
The Kolmogorov-Smirnov Test verified that the average LOS of a patient was a normal distribution with a mean LOS of 2.5 hrs and a standard deviation of 0.5 hours.

Need for Additional Nurse - Direct Care & Auxiliary Service:
The probability of a patient requiring auxiliary service (additional RN support) was 23%, calculated from the database reports. The time involvement for each type of auxiliary service was assumed to follow an exponential distribution.

Ancillary Service:
From the database reports, it was found that the probability of patients (Acuity I,II & III) leaving the ER for ancillary service was 31.5%. The time for which these patients were out of the ER receiving no direct nursing care was found to be an average of 0.52 hrs. Thus, the LOS of patients receiving ancillary care was effectively reduced by 0.52 hours.

The remaining 68.5% of patients go through the normal Bed Block and have a complete LOS. Patients of acuity type IV and V, because they are more acute, do not pass through the ancillary service block. If these patients need to go outside the ER for treatment, care is assumed to continue and the nurse is still utilized.

Auxiliary Service:
23% of the patients in the ER required auxiliary service. The probability distribution and time involvements by acuity for each type of auxiliary service were also determined from the database.

Daily Patient Volumes:
An average of 71 patients a day visited the ER.

Triage and Registration Time Standards:
Registration time of 0.17 hrs/patient was obtained from time studies. Triage processing was estimated to follow a triangular distribution. Time to triage a patient upon arrival ranged from 0.03 hrs to a maximum of 0.25 hrs with a mean range of 0.08 hrs.

The current schedule of the staff was used to determine the number of staff nurses scheduled at every hour of the day. The SCHEDULES Block in the SIMAN Experimental Frame was used to alter the number of nurses available during different hours of the day. Staffing can only be reduced to a minimum of 2 nurses, impeding the true optimization of the staff since workload can require less than two nurses.

5. SIMULATION

The ER model was simulated in SIMAN, changing the staff schedules with each run, for over 41.7 days or 1000 hours. Of the 1000 hours, the initial 120 hours of run time observations were ignored to allow the system to achieve a steady state.

Outputs from the simulation runs included the following statistics:

1. Patient Wait: Waiting time hours for patients of acuity levels I through III. This is the time spent awaiting entry to the treatment area. Analysis of the data collection revealed an average patient wait time of 15.5 minutes with the current staffing level. This was in accordance with the average wait time from the data collected in the database.

2. Nurses Busy: Average number of nurses that were busy in the simulation run. This is the average nurse utilization.

3. Triage Busy: Average number of times a triage nurse is busy. The nature of the triage function necessitates 24 hr/day coverage, therefore, unless patient arrival rates are continuous, this position will be underutilized.

4. Waiting Area Queue: Average number of patients waiting in the waiting area to be seen by the treatment area.

6. MODEL VALIDATION

The model was initially validated by comparing the output of the simulation using the current staff schedule with the real time data collected in the database. The patient wait time and queue lengths were found to be the same.

7. EXPERIMENTATION

Simulations were run with the alternative schedules input into the model. The aforementioned outputs provided a comparative basis for selecting the 'optimal' schedule - one in which the patient wait time and patient queue length were within acceptable ranges and nurse utilization was optimized as best as possible.

The output processor of SIMAN was used to determine the patient wait time frequency distribution for each schedule using the HISTOGRAM routine. The FILTER routine generated the average number of nurses busy every half hour for the 1000 hour run.

This was transferred to a LOTUS spreadsheet via the EXPORT routine and further grouped by 24 hour periods for a comparative analysis. A comparison of the staff available from the schedule and staff busy from the simulation sums can be seen in exhibit B.

Nine other schedules were examined and simulated. Of the nine, two were selected as feasible schedules in terms of affect on patient wait times and their cost effectiveness.

The simulation model simulated only the variable workload (direct patient care) as it affected the utilization of the staff nurses. Summary of the outputs from the simulation runs for three feasible schedules is listed in Table 1.

IMPLEMENTATION

The ER administration is in the process of implementing the 12 hour shift schedule. A cost/benefit analysis comparison of the three options with the current schedule yielded that this was the best suited schedule for the ER at GUH.

The PC based ER Management Information System (ERMIS) integrated with the hospital mainframe computer registration system provides intensive and external management reporting tools such as hospital mobility/mortality and patient census and mix by time of day.

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SIMULATION MODEL
OF THE EMERGENCY ROOM

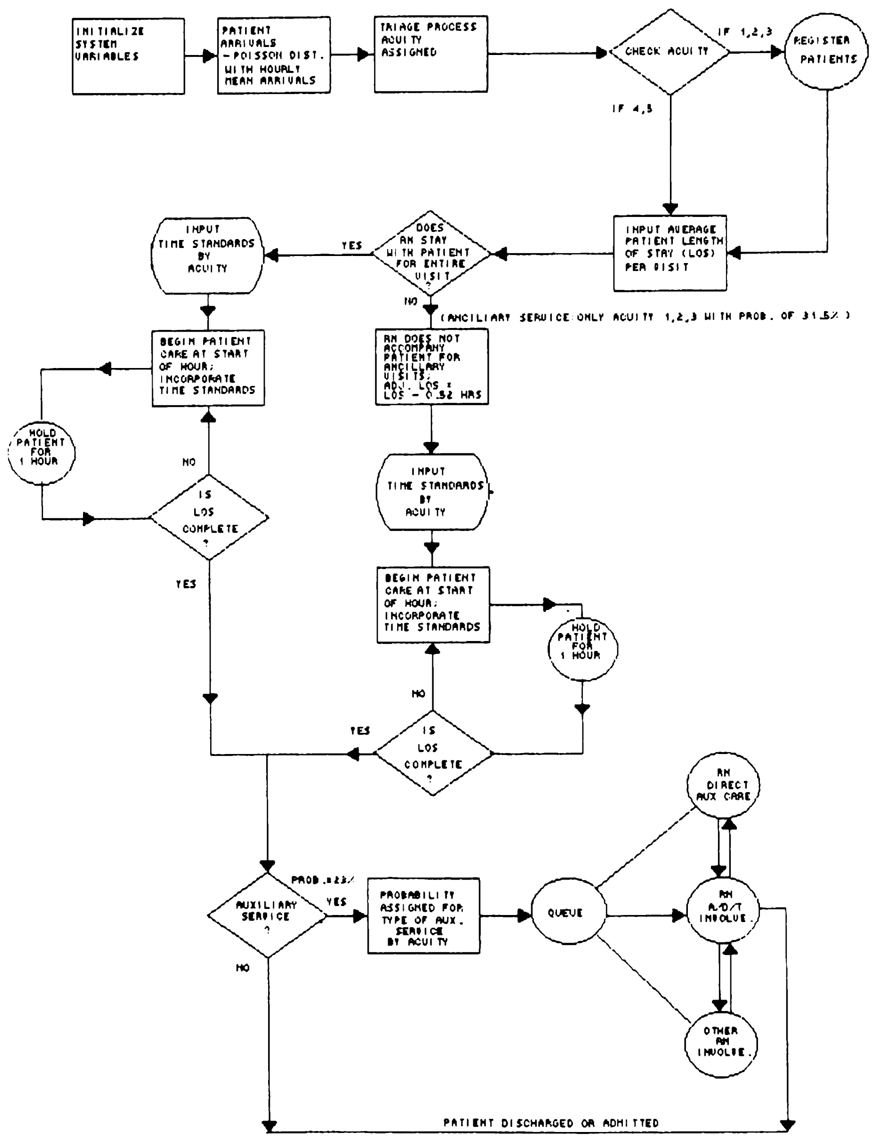

EXHIBIT A

TABLE 1

SUMMARY OF STAFF NURSE (DIRECT CARE) UTILIZATION
(SIMULATION RUNS WITH DIFFERENT SCHEDULES)
DAILY DIRECT CARE SCHEDULE

SCHEDULE OPTION: SHIFT BEGINS	NUMBER OF RNs TYPE OF SHIFT 8 HR	12 HR+	VL SCHED FTEs*	AVERAGE PT WAIT WAIT-MIN	AVERAGE #PT IN QUEUE	AVG RN UTIL%
Current:						
7 am	1	2				
10 am	0	1				
3 pm	1	0				
7 pm	0	2				
Total	2	5	14.5	20.7	0.84	68
Option A:						
7 am	0	2				
10 am	0	1				
11 am	0	1				
7 pm	0	2				
Total	0	6	14.0	18.9	0.77	69
Option B:						
7 am	2	0				
9:30 am	2	0				
3:30 pm	2	0				
11:30 pm	2	0				
Total	8	0	11.2	22.6	0.90	72
Option C:						
7 am	0	2				
9 am	1	0				
11:30 am	1	0				
7 pm	0	1				
7:30 pm	0	1				
Total	2	4	13.1	19.8	0.81	69

+ In the 12 hour Schedule the nurses work 4 days a week which is equivalent to 36 hours a week.

* VL (Variable Labor) scheduled FTEs in the table above do not address FTE requirements for Indirect and other patient related care activities, such as cleaning, shift report and stocking supplies, nor include 13% allowance for non-productive time in the three schedule options.

COMPARISON OF HOURLY WORKLOAD
SCHEDULE OPTIONS

HRS	(A) NUMBER OF RNs AVAILABLE IN SCHEDULES			(B) NUMBER OF RNs BUSY IN SCHEDULES			(C) DIFFERENCE (A - B)			(D) HRS AVAILABLE (C*0.5)		
	A	B	C	A	B	C	A	B	C	III	IV	V
12-12.5	2	2	2	1.55	1.60	1.81	0.45	0.40	0.19	0.23	0.20	0.10
12.5-1	2	2	2	1.58	1.47	1.59	0.42	0.53	0.41	0.21	0.27	0.21
1-1.5	2	2	2	1.41	1.58	1.48	0.59	0.42	0.52	0.30	0.21	0.26
1.5-2	2	2	2	1.39	1.59	1.37	0.61	0.41	0.63	0.30	0.20	0.32
2-2.5	2	2	2	1.39	1.39	1.44	0.61	0.61	0.56	0.30	0.30	0.28
2.5-3	2	2	2	1.14	1.31	1.40	0.86	0.69	0.60	0.43	0.34	0.30
3-3.5	2	2	2	1.10	1.29	1.34	0.90	0.71	0.66	0.45	0.35	0.33
3.5-4	2	2	2	1.16	1.30	1.16	0.84	0.70	0.84	0.42	0.35	0.42
4-4.5	2	2	2	1.08	1.30	1.01	0.92	0.70	0.99	0.46	0.35	0.49
4.5-5	2	2	2	0.95	1.12	0.98	1.05	0.88	1.02	0.53	0.44	0.51
5-5.5	2	2	2	0.79	1.06	1.15	1.21	0.94	0.85	0.60	0.47	0.42
5.5-6	2	2	2	0.72	0.96	1.05	1.28	1.04	0.95	0.64	0.52	0.47
6-6.5	2	2	2	0.78	1.15	0.74	1.22	0.85	1.26	0.61	0.42	0.63
6.5-7	2	2	2	0.70	1.06	0.68	1.30	0.94	1.32	0.65	0.47	0.66
7-7.5	4	4	4	1.96	2.04	1.61	2.04	1.96	2.39	1.02	0.98	1.20
7.5-8	3	2	2	1.58	1.25	1.19	1.42	0.75	0.81	0.71	0.38	0.40
8-8.5	3	2	2	1.40	1.01	1.18	1.60	0.99	0.82	0.80	0.50	0.41
8.5-9	3	2	2	1.25	0.84	1.11	1.75	1.16	0.89	0.87	0.58	0.44
9-9.5	3	2	3	1.20	0.77	1.67	1.80	1.23	1.33	0.90	0.61	0.66
9.5-10	3	4	3	1.23	1.39	1.38	1.77	2.61	1.62	0.89	1.30	0.81
10-10.5	4	4	3	1.64	1.41	1.50	2.36	2.59	1.50	1.18	1.29	0.75
10.5-11	4	4	3	1.77	1.41	1.53	2.23	2.59	1.47	1.11	1.30	0.73
11-11.5	4	3	3	1.83	1.37	1.68	2.17	1.63	1.32	1.08	0.81	0.66
11.5-12	3	3	3	1.79	1.61	1.98	1.21	1.39	1.02	0.61	0.70	0.51
12-12.5N	3	4	3	2.35	2.05	2.16	0.65	1.95	0.84	0.32	0.97	0.42
12.5-1	3	4	4	2.55	2.27	2.80	0.45	1.73	1.20	0.23	0.86	0.60
1-1.5	4	3	4	2.85	2.08	2.90	1.15	0.92	1.10	0.58	0.46	0.55
1.5-2	4	3	4	2.90	2.22	3.07	1.10	0.78	0.93	0.55	0.39	0.46
2-2.5	4	4	3	3.05	3.06	2.63	0.95	0.94	0.37	0.47	0.47	0.19
2.5-3	4	4	4	3.07	2.80	3.01	0.93	1.20	0.99	0.46	0.60	0.50
3-3.5	3	4	4	2.55	2.83	2.90	0.45	1.17	1.10	0.23	0.58	0.55
3.5-4	4	6	4	3.46	3.87	3.00	0.54	2.13	1.00	0.27	1.07	0.50
4-4.5	4	6	3	3.33	3.66	2.54	0.67	2.34	0.46	0.33	1.17	0.23
4.5-5	4	6	4	3.05	3.36	3.06	0.95	2.64	0.94	0.48	1.32	0.47
5-5.5	4	5	4	3.39	3.04	3.07	0.61	1.96	0.93	0.30	0.98	0.46
5.5-6	4	5	4	3.17	3.12	3.20	0.83	1.88	0.80	0.41	0.94	0.40
6-6.5	4	4	4	3.20	2.81	3.09	0.80	1.19	0.91	0.40	0.60	0.45
6.5-7	4	4	4	3.33	2.81	3.09	0.67	1.19	0.91	0.34	0.60	0.46
7-7.5	5	4	5	3.95	3.00	3.70	1.05	1.00	1.30	0.53	0.50	0.65
7.5-8	4	2	4	2.74	1.99	3.04	1.26	0.01	0.96	0.63	0.01	0.48
8-8.5	4	2	3	2.99	1.74	2.43	1.01	0.26	0.57	0.51	0.13	0.29
8.5-9	4	2	3	2.69	1.83	2.40	1.31	0.17	0.60	0.66	0.09	0.30
9-9.5	4	2	2	2.70	1.85	1.84	1.30	0.15	0.16	0.65	0.08	0.08
9.5-10	3	2	2	2.38	1.79	1.60	0.62	0.21	0.40	0.31	0.11	0.20
10-10.5	3	2	2	2.50	1.72	1.54	0.50	0.28	0.46	0.25	0.14	0.23
10.5-11	3	2	2	2.69	1.80	1.63	0.31	0.20	0.37	0.16	0.10	0.19
11-11.5	3	2	2	2.45	1.83	1.63	0.55	0.17	0.37	0.27	0.08	0.19
11.5-12	2	4	2	1.80	3.28	1.67	0.20	0.72	0.33	0.10	0.36	0.17

EXHIBIT B