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In-Patient Flow Analysis Using ProModel^{TM} Simulation Package

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Abstract

This paper emphasizes the basic modeling approach of general in-patient flow in a major hospital in the East Coast region. Simulation was used to analyze the in-patient flow. The first objective of this study was to determine the bottlenecks for in-in-patient flow. In order to understand the general in-patient flow, some emphasis was also given to the other units such as Medical-Surgical, Telemetry, Intensive Care Units (ICU), etc. Second objective was to study the impact of bed availability on the waiting time of admitted patients in ED before being transferred to assigned beds in other units of the hospital. A preliminary model was developed and validated based on the data collected for the selected time periods (busy four months). Different "what-if" scenarios were studied. This paper presents the basic model and its results.

INTRODUCTION

This paper presents the simulation model of the general in-patient flow in a major hospital in the East Coast region. The in-patient flow through Emergency Department (ED) and through various units of the hospital was studied as a simulation project. Previously, studies have been done on simulation of ED [Kirtland et al. 1995] and simulation of various units of hospital [Mahachek & Knabe 1984]. In this study, we focused on determining the bottlenecks for in-patient flow for the whole hospital. Therefore emphasis was given to units such as Medical-Surgical, Step-down, and ICU units. Bottlenecks are the source of long waiting times for the admitted patients in ED. During the peak hours of the day, admitted patients in ED were experiencing long waiting periods for bed placement because of unavailability of beds in other units of the hospital. Each day approximately 20 % of ED patients are admitted to the various units of hospital and this number constitutes approximately 40 % of overall hospital admittance.

This paper describes the simulation project of in-patient flow analysis with model results and alternative approaches.

MODEL BUILDING

The simulation software ProModel ^{TM} was used for this project. The ED and other units of the hospital were considered as locations and patients were defined as entities. Patients coming through ED are treated in different units of ED and after treatment they are either discharged and left ED or admitted to one of the units of the hospital. Other patients coming through the main hospital entrance are admitted and after treatment they are discharged. The flowchart of the general in-patient flow was shown in Figure 1. To build the simulation model, considerable attention was given to determine what data was needed for modeling in-patient flow analysis. After determining the data needed, Information Systems database was used to gather the data for the selected time period (busy four months). First of all, data pertaining to daily volume of ED and other units of the hospital were collected. Based on this data, the percentages of admitted and discharged ED patients were determined. The distribution of the arrivals was determined as Poisson using the statistical software package STAT:FIT ^{TM}.

The daily volume (total number of arrivals) were segregated into percentages for each two- hour periods of day and then arrival cycles were defined for each patient type.

As in actual operation, the patients (entities) of ED were classified into six level-of-care (Levels 0-1-2-3-4-5) patient types. A patient who is classified at a higher level-of-care will stay longer in ED and will have a higher probability of being admitted to the main hospital. The average length of stay per level-of-care per patient was determined for both ED and other units of the hospital. In

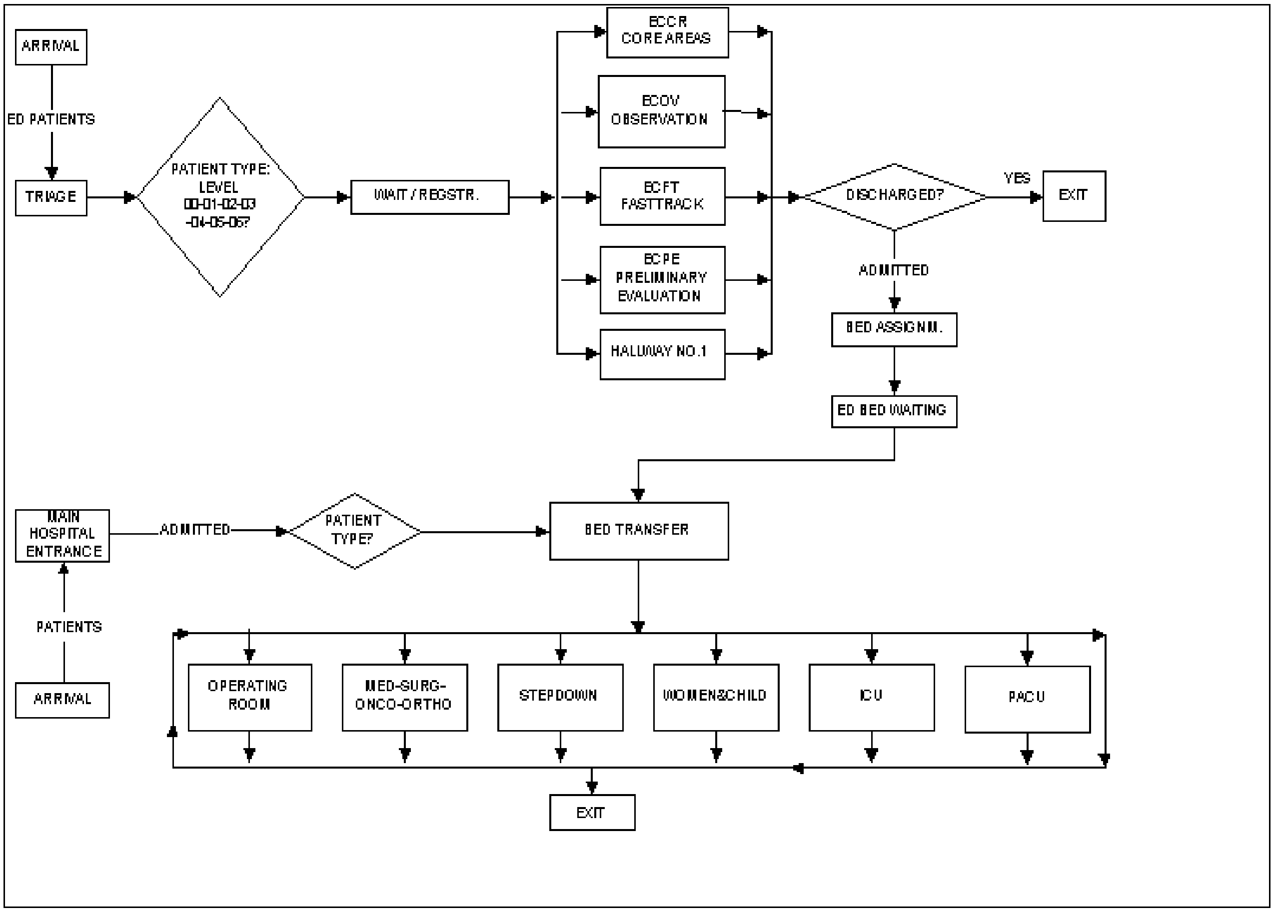

Figure 1. In-patient flow throughout the hospital.

order to include the transfers among the hospital units into simulation model, daily percentage of transfers was determined for each hospital unit. After determining the arrival data and entity data, model building was started by defining the locations. For ED, data was collected for the following locations:

- Core Areas
- Fast Track Area
- Preliminary Evaluation
- Observation Room

The corresponding entity type for each ED location was:

- Core Area Patients
- Fast Track Patients
- Preliminary Evaluation Patients
- Observation Room Patients

In order to keep the level of detail manageable, some of the hospital units were combined together and considered as one location. As an example; Medical, Surgical, Oncology, Orthopedic units were combined together and studied as a one unit (M/S/O/O). The other units were:

- Step-down Units (SD)
- Women-Children Units
- ICU
- Operating Room (OR)
- Post Anesthesia Care Unit (PACU)

Each location in the main hospital has its own entities as listed below:

- M/S/O/O Patients
- SD Patients
- Women-Children Patients
- ICU Patients
- OR Patients
- PACU Patients

For this project, we simplified the process of bed assignment for admitted patients. Patients were not classified as being teaching / non-teaching or male/female. The simulation project was modeled as a queuing model with capacity constraints at each location.

VERIFICATION AND VALIDATION

For the verification and validation of the model, the in-patient flow of the computer animation and the model behavior was discussed with the hospital unit administrators. The behaviors of different types of patients were followed through the model. The simulation model was run for a week after one month of warm-up period for 10 replications. The performance measure, average waiting time of admitted patients in ED before bed placement, was compared with the historical data. The histogram for historical data and that for simulation model results are shown in Figure 2 and 3, respectively. The two histograms had similar shapes.

In the light of these observations, we concluded that the model performed adequately well and provided results at the level of accuracy aimed for this project.

RESULTS AND DISCUSSION

The results of the baseline model, which represents the current system, are summarized in Table1.

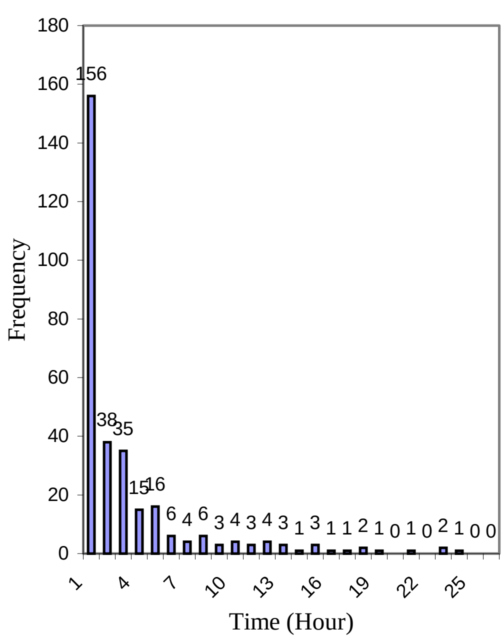

Figure 2. Histogram for average waiting time of admitted patients in ED (based on simulation model results).

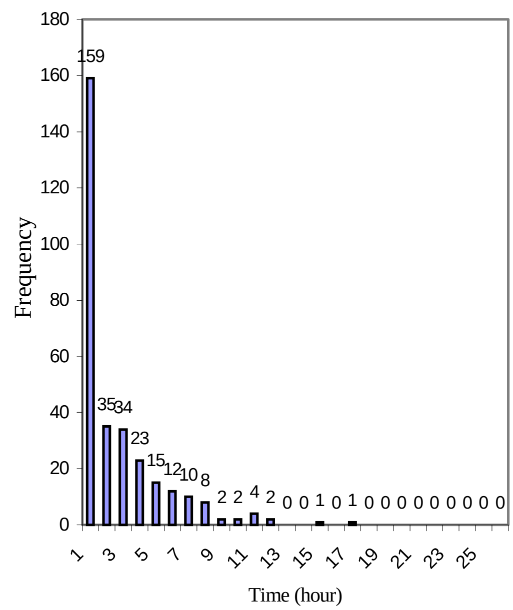

Figure 3. Histogram for average waiting time of admitted patients in ED (based on historical data).

The comparison of relative utility percentages of the different units provided us useful information about bottlenecks for in-patient flow.

Table 1: Percent utilization of various locations.

Locations	% Utilization
ED Core Areas	83
ED Observation Room	31
ED Fast Track	78
M/S/O/O	75
SD	83
Women-Children	24
ICU	89

In order to evaluate the impact of bed availability on average waiting time of admitted patients in ED before bed placement, different “what-if” scenarios were tried by adding additional in-patient beds to various locations. Each scenario was incorporated separately into baseline model. Table 2 presents each scenario with its corresponding effect on the average waiting time of admitted patients in ED before bed placement compared to baseline model result.

Adding 10 beds to SD units and 49 beds to M/S/O/O units improved in-patient flow by reducing the average waiting time of admitted patient in ED before bed placement by 24 % and 64 %, respectively. On the other hand, adding more beds to these units did not result in additional improvement.

Table 2: Scenarios with corresponding effect on average waiting time of admitted patients in ED before bed placement.

Scenario Models	**% Decrease**
SD 10 beds	24 %
SD 20 beds	24 %
SD 30 beds	24 %
M/S/O/O 49 beds	64 %
M/S/O/O 49 beds + SD 10 beds	64 %
M/S/O/O 49 beds + SD 20 beds	64 %
M/S/O/O 49 beds + SD 30 beds	64 %
M/S/O/O 60 beds	64 %
M/S/O/O 60 beds + SD 10 beds	64 %
M/S/O/O 60 beds + SD 20 beds	65 %
M/S/O/O 60 beds + SD 30 beds	65 %
M/S/O/O 70 beds	65 %
M/S/O/O 70 beds + SD 10 beds	65 %
M/S/O/O 70 beds + SD 20 beds	65 %
M/S/O/O 70 beds + SD 30 beds	65 %

CONCLUSION

We successfully determined the bottlenecks for in-patient flow affecting ED and other units in the main hospital by using simulation as an analysis tool. The different what-if scenarios could provide useful information to the hospital administrators for making management decision.

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