Modeling Patient Transfer from Existing to Replacement Hospital: A Simulation Study

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Abstract **- The number of new hospitals being built in the USA is expected to increase over the next few years. As organizations open these new facilities they will be required to develop plans for moving patients from the existing facilities to the new facilities. We propose a simulation-based approach to model, evaluate, and plan the patient transfer process. In this paper, we present use of the simulation model to transfer of patients to a new, replacement facility in May 2011. Simulation determined the patient transfer process could be completed in six hours, given the organization's resources. The model allowed us to identify bottlenecks in the patient transfer process prior to the actual move, to validate outcomes, and to determine if the move process met the organization's goals.**

Index Terms **- discrete event simulation (DES); hospital transition planning; patient flow.**

I. INTRODUCTION

In-spite of the challenges the healthcare sector faces, construction of new facilities is occurring at a rapid pace, with around $200 billion in healthcare construction expected by 2015 [1]. Along with construction is the concurrent task of transition planning. This process includes transfer of patients and equipment from the existing facility to the new facility. Transition planning requires a significant amount of time to ensure success [2], [3]. A transition plan is defined as a 'success' only when all patients in the existing facility have been safely moved to the new facility on the first day of occupancy. The focus of this paper is limited to the patient transfer process.

Similar to any typical transportation problem, the 'move-day' process of relocating patients to the new facility was greatly dependent on the total number of patients to be moved (i.e., number of units to be transported). From historical trends, the move day census was estimated to be at most 225 patients and excluded any new arrivals during the move. Based on this information, a one-day patient transfer process was thought to be feasible. Thus, the goals of this study were to explore and analyze the factors that would impact the relocation of patients from the existing hospital to the replacement facility. The study focused on providing insight to issues pertinent to the 'move-day' operations, including:

1. Transferring patients between the facilities
2. Ensuring patients were safe during the move
3. Overcoming structural constraints in the existing facility
4. Planning and budgeting for the move-day (e.g., time and resource needs)

Goals of the Patient Transfer Process

The goals of the process are three fold: (1) ensure patients are transferred safely while maintaining appropriate level of care; (2) ensure a timely move (i.e., make sure patients spend the least amount of time away from the nursing unit); and (3) ensure all resources are used efficiently.

Role of Simulation

Discrete Event Simulation (DES) has been defined as an operational research technique which allows the user to assess the efficiency of a system and evaluate new designs. DES has found significant application in the complex, dynamic healthcare environment. In recent years, the application of DES has significantly increased, mainly due to the publication of studies showing the success of this technique especially in the area of healthcare decision-making. Researchers and hospital management have used DES to evaluate new methods to improve operational efficiency and reduce cost [11], study emergency rooms [10] and operating rooms [6], [12], [7], and determine bed capacity requirements of individual nursing units [8],[9] and the entire hospital [5]. It was concluded from the literature review that, even though there is a significant amount of research in the areas of capacity analysis and patient flow, there is limited reference to the use of simulation in patient transition modeling (intra or inter hospital).

Outline of the Paper

The remainder of the paper is organized as follows: Section II presents the methodology. Section III provides details on the patient transport models and identifies the various resources involved in the process. The modeling logic used for capturing different aspects of the simulation is presented in Section IV. Details regarding data collection and modeling are presented in section V. Section VI presents the results, followed by conclusions in Section VII and future work in Section VIII.

Outline of methodology

The methodology for this study is outlined this section. The first step towards modeling the patient transport process is capturing the actual process. This was done primarily by observing the transfer of patients from existing facilities to other hospitals, homes, nursing homes, etc. The various resources involved in the process were mapped and attributes pertaining to them were identified. Time studies were conducted to determine the process times for various steps. The data were stratified based on the patient and resource attributes. A simulation model of the traditional move process was then created, allowing planners to understand the pros and cons of this model.

II. Defining Patient Transfer Process

Move Process

Patients are routinely transported from hospitals, either on account of discharge or for transfer to another hospital. In this section, the details of the move process and resources utilized are presented.. The teams of trained individuals who perform this task are known as Emergency Medical Technicians (EMT).There are two types of ambulances utilized by these teams: Basic Life Support (BLS) and Advance Life Support (ALS). ALS ambulances differ from BLS ambulances because of the advanced monitoring and life support equipment. Since this move also involved transporting newborns as well as neonatal infants, incubators are a necessary and critical piece of equipment for this process. The summary of the generally utilized resources for patient transport process is listed in Table 1.

Table 1 Summary of Resources Involved

Resource Type	Role
EMT (Transport Teams)	Trained technicians who are licensed to transport patients in ambulances
Basic Life Support (BLS) Ambulance	Ambulance can transport patients with lower acuity and patients requiring no monitoring equipment
Advance Life Support (ALS) Ambulance	Ambulance can transport critical patients requiring monitoring
Stretchers	Beds used for transporting patients
Incubators	Equipment used to transport infants in critical care units
Parking Bays (Bays)	Locations where the ambulances can load and unload patients at the hospital

The typical process (Fig. 1) starts when the ambulance and EMT team arrive at the designated hospital entrance. The team unloads the stretcher and travels to the predetermined nursing unit. The time required to reach the nursing unit is determined by the distance of the unit from the entrance, as well as the elevator wait and traverse time (if required). Once the team reaches the nursing station, the EMT team, along with the nurse, prepares the patient for transfer by completing required paperwork and loading the patient onto the stretcher. Once this step is completed, the EMT team transports the patient back to the entrance, loads the patient into the ambulance, and transports the patient to the new facility. Upon arrival at the new hospital, the process is repeated. The EMT teams will then return to the original facility (hospital).

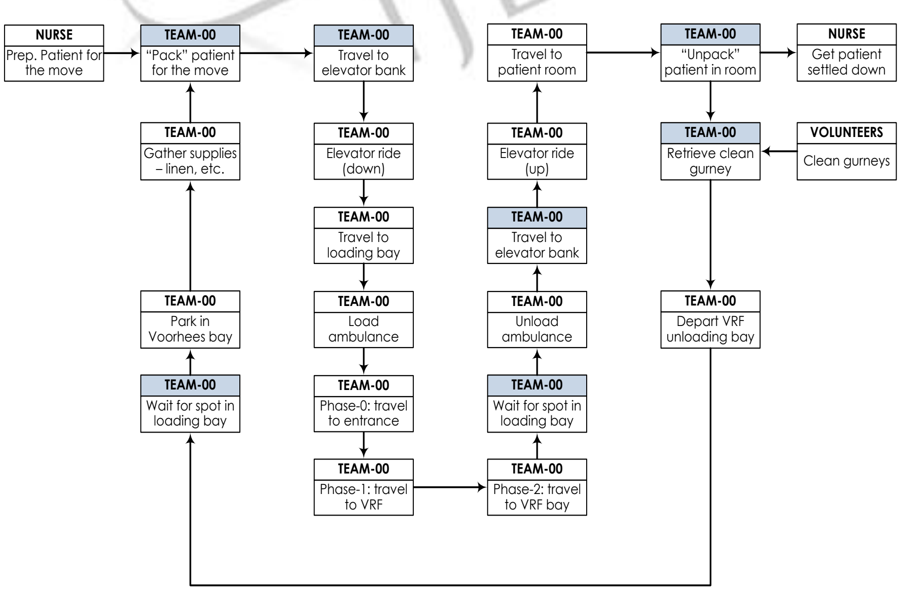

Figure 1 Patient Transfer Process

Patient Scheduling and Pathways

Patient departures from the units were scheduled at regular intervals to reduce the stochastic behavior of the system and to afford nurses a more predictable, manageable workload. Patients from multiple units were moved simultaneously to balance the need for safe patient transfer with the goal of minimizing the total move time. The schedule also ensured patient volumes were balanced over the entire move period. Patient pathways can be defined as the route taken to transport the patient from the existing facility to the new facility. Patients of similar clinical needs were clustered and assigned specific routes for transportation within the facility and specific exit and entry portals. Figure 2 presents a schematic of the patient exit and entry portals. The pathways for the patients within the current and new facilities are not presented here for the sake of brevity.

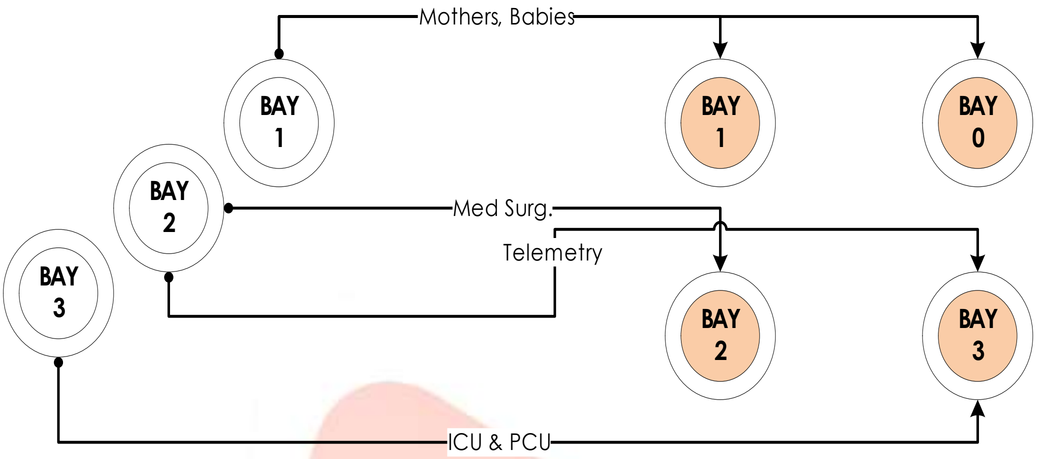

Figure 2 Patients and Truck Routing Logic

Resources Involved and Patient Attributes

Patients were classified by clinical status and resource needs. Clinical status was determined by the nursing unit of origin (e.g., medical patients, maternity patients, pediatric patients, neonatal). Patients also were assigned attributes to define their resource needs during the transfer. Highly critical patients would be transferred by ALS ambulances while medically stable, lower acuity patients would be transferred by BLS ambulances.

III. DATA COLLECTION AND ESTIMATION

Data required to model all steps in the transport process were collected by performing time studies. The transport process for multiple patients from the hospital to external destinations (e.g., home, nursing home, skilled nursing facility) was observed. It was assumed that the time required to perform various activities under normal circumstances would be a good estimate for the transport process during the actual relocation day.

Travel time for the EMT team within the hospital- Travel time for the team within the hospital is a function of the path taken (e.g., nursing unit, exiting bay); therefore, these times were modeled using a two-step approach. First, the travel time for the EMT team within the facility was calculated using detailed time studies (multiple replications). Triangular distribution was then used to model the speed. Next, using architectural diagrams, the distances between the various locations within the existing and new hospitals were determined and then captured as a distance matrix in the simulation software. The formula [Travel Time = Distance/ (Speed)] was then used to model transportation time between locations in the hospitals. A summary of the data estimations and modeling approaches is provided in Table 2.

Table 2 Summary of Data Modeling

<table>
<tr><th colspan="2">Process Step</th><th>Data Modeling Approach</th><th>Data Distribution</th></tr>
<tr><td colspan="2">Movement within the facilities</td><td>Time studies and dimensional estimates</td><td>150 Feet /{TRIA(1,2.5,4) Feet/Sec}</td></tr>
<tr><td colspan="2">Transportation between facilities</td><td>Time studies and geographical estimates</td><td>TRIA(7,9,11) Minutes</td></tr>
<tr><td colspan="2">Patient handling (hand-offs, loading /unloading)</td><td>Time studies</td><td>UNIF(10,15) Minutes</td></tr>
<tr><td colspan="2">Loading time for patients into ambulance</td><td>Time studies</td><td>UNIF(20, 30) Seconds</td></tr>
<tr><td rowspan="3">Elevator time</td><td>Travel time</td><td>Time studies</td><td>5 Seconds per floor</td></tr>
<tr><td>In and Out time</td><td>Time studies</td><td>10 Seconds</td></tr>
<tr><td>Wait time for elevator</td><td>Time studies</td><td>Rand() Seconds</td></tr>
</table>

IV. Simulation Model Logic

The simulation model was built in order to develop a close replica of the actual systems. Patients were modeled as the entities, while ambulances, EMTs, elevators and parking bays were modeled as resources of interest. This allowed performing sensitivity analysis by modifying the number of available resources. The simulation logic is shown in Fig. 3.

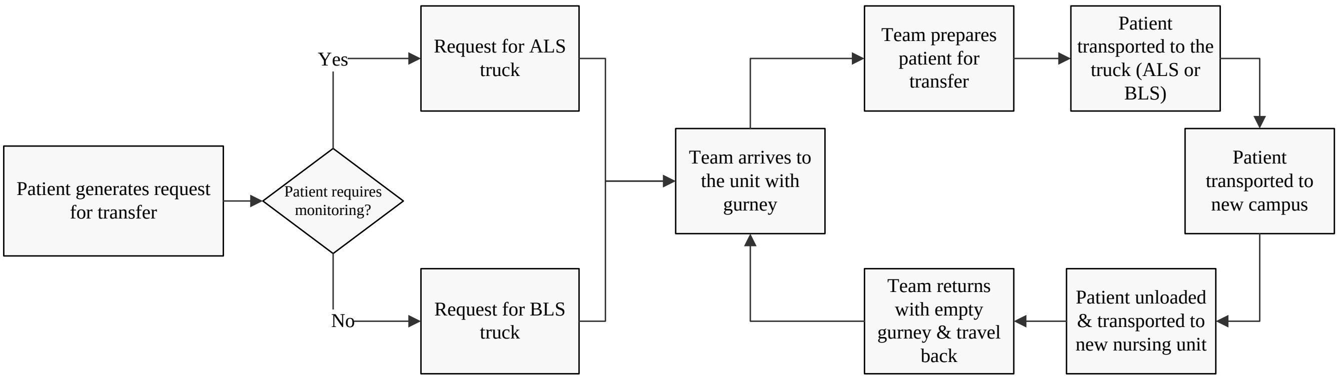

Figure 3 Simulation Model Logic

Simulation Model Assumptions

- It is assumed that patients are clinically ready to be transported at the start time of the simulation.
- The nursing staffs involved in patient transfer were not explicitly modeled.
- The Emergency Department (ED) at the existing facility was assumed to be closed during the move time (i.e., no additional flow of patients from the ED were modeled).
- Operating rooms were assumed to be closed prior to the move day to eliminate the need to model post-operative patients.
- Ambulance breakdowns were not modeled as a part of the simulation.
- Equipment transfer was not explicitly modeled as a part of this simulation.
- A variety of support teams (e.g., navigation, communication) would be required for a successful patient move. For the purposes of the simulation, these teams were not explicitly modeled.

Table 3 Summary of Resources Involved

Resources Used		**No. of Resources**
Total Patients		226
Equipment	Stretchers	42
	Incubator	8
Ambulances	ALS Ambulances	22
	BLS Ambulances	20
EMT Teams	ALS Transport Teams	22
	BLS Transport Teams	20
Elevators	Existing Facility	3
	New Facility	5

Verification and Validation

Validation and verification are pertinent steps in ensuring that the simulation model is performing similar to the actual system. One of the common methods of model validation is via statistical comparison of the data from the system and simulation. In the case of this study, statistical validation of this simulation could not be conducted because historical data do not exist. Hence, other approaches were used for validation. The logic of the model was thoroughly examined and reviewed with system experts. The animation options were used for this purpose. Also, estimates from similar intra hospital patient transfers were used to check if the outcomes from model were valid.

V. RESULTS

The results of the simulation are presented in this section. The resources used for the baseline model are presented in Table III. The number of patients was estimated based on typical weekend hospital occupancy rates. The key control variable was the number of ALS and BLS ambulances. The number of ambulances and the number of patients to be transported were based on actual data. Along with the total move time, other metrics were evaluated, such as:

- Time between requesting an ambulance and assigning an ambulance
- Idle time for ambulances
- Time required to move one patient from the current facility to the new facility

The results of the simulation are presented in Table IV and Table V. The total time required to complete the move is 366 minutes (6 hours, 6 minutes). This metric ranged from 340 minutes (5 Hours, 40 minutes) to 372 minutes (6 Hours, 12 minutes). The cycle times for different patient groups are also presented in Table IV. This metric represents the time between picking up a patient from the nursing unit in the existing facility and dropping off the patient in the corresponding nursing unit in the new facility. Cycle times for this process ranged between 30 and 40 minutes. Small variations in this metric can be explained by the differences in in-hospital travel distances. The small variation also highlights that move model ensures that all patients have a timely transfer between the facilities.

Table IV. Results of Patient Specific Metrics

Metrics	Patient Type	Average Time (Mins.)	Range (Mins.)	
			Minimum	Maximum
Time to Complete Move	Total (All Patients)	366	340	372
Cycle Time (Patient Pick-up to Drop Off)	Medical Patients	30.4	25.49	36.00
	ICU	31.4	26.57	41.59
	NICU	32.7	26.77	41.32
	Maternity	30.2	24.78	36.14
	Pediatrics	31.0	26.58	36.02
	PCU	34.2	29.10	42.87
Wait Time (Request to Assign Ambulance)	Medical Patients	3.84	0.00	24.70
	ICU	6.63	0.00	25.18
	NICU	4.70	0.00	25.23
	Maternity	6.83	0.00	24.54
	Pediatrics	9.15	0.00	25.10
	PCU	5.07	0.00	23.66

Table V. Results of Patient Specific Metrics

Facility	Metrics	Time (in Minutes)		
		Average	Minimum	Maximum
Existing Hospital	Bay 1	10.89	6.08	14.35
	Bay 2	11.00	7.73	15.23
	Bay 3	9.45	0.52	14.37
New Hospital	Bay 0	8.86	8.61	9.18
	Bay 1	12.05	11.64	12.40
	Bay 2	10.37	10.18	10.53
	Bay 3	9.51	9.05	10.28

Table V presents the time ambulances were idling at the individual facilities. This refers to the time the ambulance was unused while the EMT teams were transporting patients either to or from the nursing unit. This wait time ranged between 8 minutes and 15 minutes, with small variations at the different bays. Since the number of available ambulances is an important constraint for the move process, reduction in this wait time was necessary.

VI. CONCLUSIONS

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The paper outlines the use of DES for modeling patient transport from an existing hospital to a new hospital. Based on the simulation, it was concluded that the entire patient population (estimated at 226) could be transferred within 366 minutes (6 Hours, 6 minutes). It was also seen that the current move model allows each patient to be transferred within 30 minutes, ensuring none of the patients would undergo significantly long transfer times. It can be concluded that the total time is dependent on the discharge rate of patients from the existing facility (which is defined as per a schedule). Reductions in the move time can be achieved by either increasing the discharge rate (i.e., patients leaving the units at a shorter interval) or by eliminating/reducing any wait time incurred in the process.

It was possible to identify opportunities for improvement in the existing model using simulation. Based on the results, it was noted that ambulances experienced significant time idling at the hospital bays. Because these are critical resources, it was deemed necessary to identify methods to further reduce their idling time. Reduction in this metric would also allow a reduction in the wait time to make an ambulance available (Table V).

Future Work and Extensions

- Development of additional transportation models- Other models for transporting patients need to be developed. The performance of these models can then be compared to the baseline model to evaluate efficacy in terms of resource consumption, turnaround time, and other metrics defined in this paper.
- Optimization of resource requirements- The simulation model was carried out based on available resources in the system. The resource requirements can be optimized by using Op-Quest.
- Detailed modeling of elevator logic- The elevator component of transportation time was approximated in this model. The logic can be further expanded by incorporating the exact location of the elevator and calculating the travel time to the required floor.

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