A Systems Optimization Simulation Technique for Deployed Medical Support

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ABSTRACT[1]

This paper presents an optimization simulation model for Deployed Medical Support (DMS). When a deployed service member is injured in the battlefield or in a disaster area, he or she receives an immediate care provided by the medical team in order to get stabilized and be transported to a larger facility where a higher level of care is available. At this higher level the patient is further evaluated and treated, possibly undergoing surgery. The patient may be released to return to duty after treatment at the DMS or maybe moved to yet higher level of care. The primary objective of the DMS is to provide the initial care necessary to stabilize and prepare the patient for transport out of the field to a comprehensive medical facility. From the operational stand point, the mobility, the logistics, and resources required to support such a system is very complex and may be further subject to random constraints [1]. This research proposes a new approach focusing on the use of optimization techniques to determine optimal level of parameter values that must be incorporated into the corresponding simulated system. The method is illustrated through a prototype model developed and implemented in an ExtensSim [4] environment using an optimizer and discrete event simulation blocks.

INTRODUCTION

The ever increasing advances in computing power and development in storage media have opened up the possibility of optimizing simulation models. This development offers exciting opportunities in using simulation [5] in unfamiliar domains and implementation of systems which up to recent past considered impractical or computationally prohibitive.

Simulation is a commonly used technique in analyzing many natural phenomena and to study the behavior of complex systems, such as engineering systems, biological systems, genetic and manufacturing systems, logistic systems, and health care systems. When analytical techniques do not lead themselves to closed form expressions of the system solution, simulation often becomes the only means for describing the system behavior and for estimating major performance measures, such as throughput, response times, flow volume, utilization factors, and alike for these systems. Predicting the system performance in advance of its construction without the formalism of model formulation and defining complex mathematical equations is perhaps one of the major advantages of using simulation technique for modeling complex systems over other modeling approaches. The technique has recently been applied in the study of passengers' flow analysis and security issues in airport terminals [2-3] and airline security screening [7].

The operational focus of our DMS model is based on a recent study of the Air Force expeditionary medical system. [1] In this model, an injured patient enters the system, receives limited treatment and then is moved from the point of injury to a next care facility as quickly as possible. Then the patient is further evaluated, stabilized, triaged, treated, and transferred to a higher level of care and so forth. Each level of care is designed to be sufficient for immediate needs, but not to provide definitive care. The emphasis on flow streamlines capabilities that need to be deployed and places the definitive care in the most capable facilities.

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[1] This is an abbreviated version of the paper. The full paper is available from the authors upon request.

SIMULATION APPROACH

In spite of recent and rapid advances in computing and information technology, many companies and institutions still suffer from outdated equipment and inefficient work practices. This is due in part to the prohibitive expense and time required to explore alternative methods of operation and try out new technologies on real systems and processes. Simulating a system or process provides a quick and cost-effective method for determining the impact, value, and cost of changes, validating proposed enhancements, and reducing the resistance to change. Simulation models allow for time compression, are not disruptive of the existing system, and are more flexible than real systems. They also provide metrics for meaningful analysis and strategic planning.

As a powerful research method, simulation enables researchers to look at an artificial world move forward into the future, giving the user the unprecedented opportunity to intervene and attempt to make improvements to performance. As such it is a laboratory, safe from the risks of the real environment, for testing out hypotheses and making predictions. Computer models are used to learn about a real life situation that cannot be altered directly, either because the system does not yet exist or it is too difficult to change just for experimental purposes. Simulation models can help explain, understand, or improve a system as complex of the Internet or a large scale engineering project such as mission to Mars. The purpose of simulation modeling is to help the decision maker solve a business problem with more insight into to random phenomenon that is often cannot be captured, modeled, or treated by deterministic methods.

Our model for the deployed medical support system, henceforth DMS, is a stochastic discrete-event simulation tool to compute capacity and capability of deployed medical team. It incorporates concurrent optimization of the critical parameters with the overall objective of providing optimum level of operation. The model provides an independent analysis of policy alternatives and can be considered as a tool to provide base level support to locate the best or optimal mix of logistics resources to support a unit under a given operating condition.

Patients randomly arrive and enter the system where they are categorized as having one of the low, medium or high conditions according to a second random phenomenon. After being queued for some time, patients are moved to an Emergency Room (ER) for either minor or major treatment and then released to return to work. This is governed by a third random distribution. Patients with more sever conditions require more time for initial treatments at the ER facility, before they are transferred according to a forth probability distribution to either Operating Room (OR) or to an intensive care unit (ICU). Some patients may be moved to yet another facility for post operation (PostOP). Finally some patient may need a higher level of care. These patients are stabilized and then airlifted to their next destination. Every stage of the process within the care unit in the field have been simulated to optimize the care personnel and equipment required to minimize queue delay and smooth overall operation of the unit to achieve optimum performance. A snapshot of the Emergency Room (ER) operations, both major and minor cases is shown in Figure 1. Figure 2 is the top layer view of the overall system, embedding the entire networks of patients flow mechanism through different simulation modules.

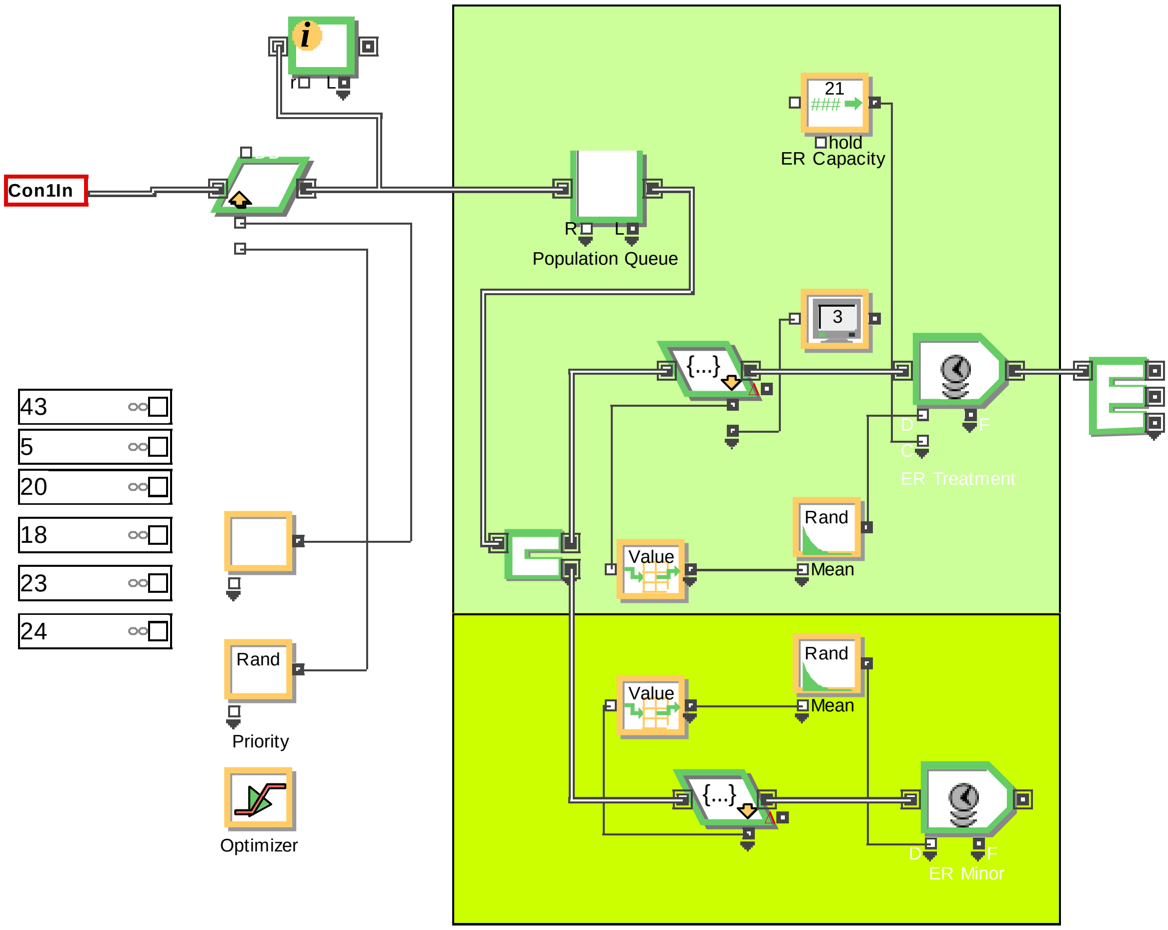

Figure 1: A snapshoot of ER operations

CONCLUDING REMARKS

To understand the implications of medical support in the future, we must not only study the past, but we must attempt to look to the future. This paper considered the medical issues associated with deployed units in the field or relief units operating in humanitarian efforts in natural disaster situations by applying a futuristic scenario and a systems analysis, thus capturing critical medical logistics associated with health care in the contemporary environment.

Reaching a surgeon within one hour of injury is not a valid expectation in a disaster or combat environment. Recent studies [6] shows when blunt trauma predominates and results in about 30% of deaths within one to three hours after injury. In natural disaster or combat trauma, 90% of the deaths will occur before arrival an emergency care. This is mainly due to rapid blood loss from a penetrating injury. Unless casualties receive stabilizing care within the first hour, many will not survive until surgery, even if after receiving adequate self/buddy aid at the point of injury.

Because of the complexity of patient movement and probabilistic nature of the process, deterministic approaches tend to lead to underestimation of the required resources resulting in an inefficient overall operation. This effort uses simulation coupled with optimizing capability which has provided, for the first time, a platform for more practical solutions to efficient planning of health care support units. A snapshot of the simulation run and resulting optimized parameters values is given in Figure 3.

Figure 2: A snapshoot of top layer DMS model

Optimal parameters and model set up

	ER_Treatment	ER_Minor	OR	ICU_BC	ICU_PostOp	ASF	MinCost	samples	±error
1	45	7	21	20	17	30	2	2	0
2	27	6	19	17	22	16	2.5	2	0.7071
3	12	1	21	13	15	24	3	1	
4	24	1	25	17	17	20	3	1	
5	47	10	28	8	21	17	3	1	
6	38	1	20	6	26	20	3	1	
7	23	10	12	17	26	16	3	1	
8	45	6	16	18	13	11	3	1	
9	45	7	21	18	17	29	3.5	2	0.7071
10					19	15	4	1	
11					13	10	4	1	

Figure 3: A snapshoot of DMS control panel

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