

# USING SIMIO FOR WARTIME OPTIMAL PLACEMENT OF CASUALTY EVACUATION ASSETS

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## ABSTRACT

This paper focuses on the use of a discrete simulation tool ( Simio ) to explore the optimal number of casualty evacuation assets within a theater of operations. Through the use of Simio simulation platform, visual simulation model of wartime casualty evacuation was developed, based on analysis and hypothesis of wartime patient evacuation processes. Then, the optimal placement of the evacuation assets was explored by simulation experiments. The simulation model developed will support transportation capacity estimation and evacuation assets allocation for medical support.

**Keywords:** Simulation; Optimization; Simio; Casualty evacuation assets

## INTRODUCTION

Medical evacuation is a central task of military medical service, and evacuation assets are essential to ensure patients reach a facility with the capability to render the required level of care in wartime. However, frequent requests of casualty evacuation in the future joint force may overwhelm the evacuation system. Accurate estimation of the transportation capacity and placement of evacuation assets ensure best treatment results. In the past, most researches for placement of evacuation assets adopted analytical model, which should make simplifying assumptions for the casualty evacuation system, thus influenced the validity of the developed model. On the condition of dynamic nature of casualty evacuation system with lots of random factors, simulation has its advantages on solving such problems.

Simio is a quite new simulation tool, which has functions of visual interactive modeling. Compared with other available simulation software, Simio has a unique architecture with “Agent-based”. Using Simio, modeling is based on describing system’s objects and evolution of system behavior by interaction of these objects. In addition, Simio provides the most advanced real-time 3D technology, which strengthens the interaction of simulation [1]. Thus, this research chose this software as the simulation platform. Through the use of Simio, this research modeled the wartime casualty evacuation processes between division and regiment medical aid station in PLA. Then, the optimal placement of the evacuation tools was explored by simulation experiments.

## LITERATURE REVIEW

There are many simulation researches in the medical area with interactions between patients, physicians, nurses, and technical and support staff both in China and abroad. However, there are only a few researches for the optimal placement of evacuation assets in wartime. To the best of our knowledge, there is no three-dimensional visualization simulation research in this field.

Reference [2] chose the Probabilistic Location Set Covering Problem as the core module for a linear programming to determine the optimal number and positioning of patient evacuation assets within a field of operations. Later, a medical planning tool for projecting the required casualty evacuation assets was developed using C and C++ programming languages by the Naval Health Research Center of US army based on this research. Reference [3] used Arena simulation platform to model

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the brigade casualty evacuation system of the Turkish Army, providing the necessary patient information to the commanders in a maneuver, logistics, and medical unit [3]. In recent years, the Navy Health Research Center of US army developed several simulation tools to estimate the medical requirements required to support patient treatment, such as the Estimating Supplies Program (ESP), the Medical Analysis Tool (MAT), and the Tactical Medical Logistics Planning Tool (TML+), all of which were developed by C and C++ programming languages [4].

### CASUALTY EVACUATION PROCESSES

Patients are treated at medical facilities organized into a series of echelons in wartime. The facilities at the forward echelons have the greatest mobility but least surgical capability [5]. Patients are evacuated from lower medical treatment facilities to the higher ones by transportation assets. Casualty evacuation system consist of loading area of the lower medical treatment facility, travel road, unloading area of the higher medical treatment facility, patients and transportation assets. Travel road is defined by a distance and a multiplier attribute, which represents such factors as curves in the road, bad road conditions, weather, etc.. Each type of patient is defined by an evacuation timeliness, a loading type (ambulatory or litter), a percentage among all patients, severity of injured or sick. Exponential random variables are often associated with a waiting time that precedes the occurrence of certain specific events. So, this research, like many others, uses exponential distribution to model wartime patients' inter-arrival time. Each type of asset is defined by an empty speed, a loaded speed, a maximum litter capacity (2 ambulatory seats equal 1 litter space), patient loading and unloading time, and a maximum wait time that the transporter remains waiting for a full patient load [4]. Fig. 1 depicts typical casualty evacuation processes.

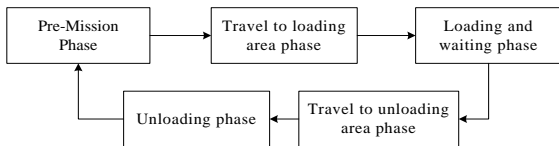


Fig.1 Casualty evacuation processes

1. Pre-mission phase: When the patients get to the system, evacuation calls will emerge and the transportation assets accept these calls. The transporter at the unloading area of the medical aid station could accept these calls and experience this pre-mission phase. During this period, this transporter could be refueling, changing personnel, performing maintenance, etc. The time of this phase could be modeled by a triangular distribution.

2. Travel to loading area phase: After the pre-mission phase, the transporter could travel to the lower medical echelon's loading area.

3. Loading and waiting phase: The transporter could load these patients still alive waiting at the loading area according to their arrival time and severity. The transporter's capacity could decrease by patient's ambulatory or litter condition. If the

transporter's capacity has not been reached, it could be waiting here for new patients arriving to the system until the determined maximum wait time.

4. Travel to unloading area phase: When the transporter's capacity has been reached, it could immediately travel to the higher medical echelon's unloading area.

5. Unloading phase: When the transporter arrives, patients could be unloaded. When all the patients get off, the transporter is free and could then accept new evacuation calls.

### SIMULATION MODELING UNDER SIMIO

In order to simplify this study, we make more simplifications and a more complex study will be presented later. After consulting with subject experts, we consider there are three types of patients: urgent, priority and routine. Obviously, we can see the evacuation ranks of them. The patient mix for the three part types is 30% urgent patients, 30% priority patients, and 40% routine ones. The evacuation timeliness of the urgent patients is 1 hour, and that of the priority ones is 1.5 hours, based on theory of treatment timeliness of field operations. Each patient arrives randomly with an exponential time between arrivals with a mean of 7.5 minutes. There are two types of assets in the system: type A and type B. The type A transporter could provide en route treatment and only load 2 urgent patients. While the type B transporter without en route treatment capability could only load 6 priority or routine patients. As the type B transporters are considered as assets equipped with special attachments, all patients are litter condition. The evacuation distance is 15 km.

In this research, some input data were directly entered into the modeling objects, while the others were defined in data table or entered into elements of processes, referenced by the model as shown in the Fig. 2.

Properties: A_Vehicle (MyVehicle)		PatientTable	
<b>Transport Logic</b>		Priorit...	Rate
Ride Capacity	2	1	0.4
Load Time	1	2	0.3
Unload Time	0.5	3	0.3
Task Selection Str...	First In Queue		
<b>Travel Logic</b>			
Initial Desired S...	30		
Units	Kilometers per		
Initial Network	Global		
<b>Routing Logic</b>			
Initial Priority	1.0		
Initial Node (Home)	TransferNode1		
Routing Type	On Demand		
Idle Action	Go To Home		
		<b>Properties: Delay1 (Delay Ste</b>	
		<b>Basic Logic</b>	
		Delay Time	0.7
		<b>Advanced Options</b>	
		<b>General</b>	

Fig.2 Parts of input data and representations in Simio

For the creation of this model, objects in Simio as Source, Vehicle, Server, Sink, Transfer Node were used, some of which were subclassed and some logical processes were overwritten as shown in the Fig. 3. They were connected by a set of paths.

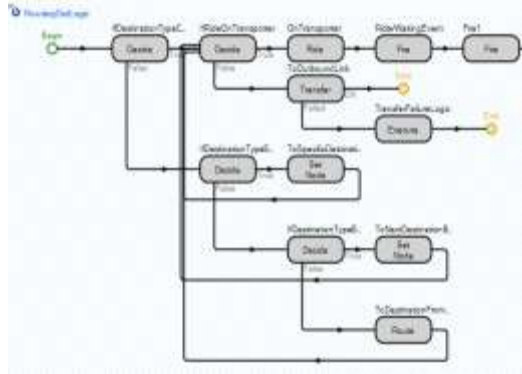


Fig.3 Overwritten routing out logic of Transfer Node object

Using the special add-on process method of Simio, the evacuation logical processes above mentioned and some data statistics processes were created as shown in the Fig. 4.

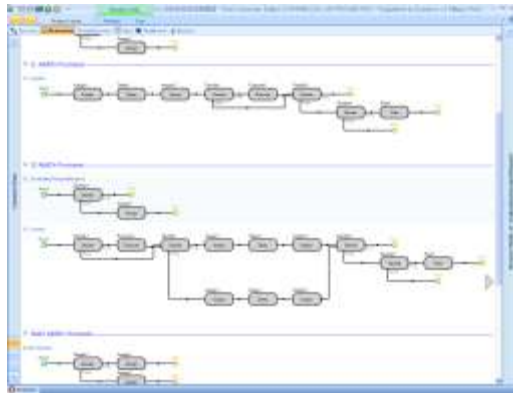


Fig.4 Add-on processes of objects

Simio supports 3D graphics and animation. It can import layouts of the casualty evacuation system in 'dxf' format, and insert 3D object models developed or directly downloaded from Google 3D Warehouse library in 'skp' format, creating realistic 3D evacuation system. In Fig. 5, there are some screenshot examples for this research.



Fig.5 Simio model with animation 3D

## SIMULATION EXPERIMENTS UNDER SIMIO

The model is run for 2 days, equivalent to model the supreme casualty days of the regiment medical aid station. Simio permits to define a table of different scenarios and run several experiments as shown in the Fig. 6. We take 100 replications for each experiments and the results are within the 95% confidence interval.

Scenario		Replications		Controls	
Name	Status	Required	Completed	BV Number In	AV
Scenario1	Idle	100	0 of 100	1	1
Scenario2	Idle	100	0 of 100	2	2
Scenario3	Idle	100	0 of 100	3	3
Scenario4	Idle	100	0 of 100	4	4
Scenario5	Idle	100	0 of 100	5	5

Fig.6 Experiments table

Then a comprehensive report is generated. In this research, the most important performance indicators are timeliness arrival rates of urgent and priority patients. In addition, usage of two types of transporters and waiting times of three types of patients for evacuation could also give us important information for the system. Parts of these experiment results are shown in the table in Fig. 7. Each row represents the results of one experiment according to parameters shown in Fig. 6.

Model	Output	Final Value		
Scenario	Data Source	Category	Average	Half Width
Scenario1	P2ArriveRate	Arrival rate	0.51401	0.00965
Scenario2	P2ArriveRate	Arrival rate	0.96017	0.00715
Scenario3	P2ArriveRate	Arrival rate	0.9843	0.00289
Scenario4	P2ArriveRate	Arrival rate	0.99215	0.0019
Scenario5	P2ArriveRate	Arrival rate	0.9928	0.0017
Scenario1	P3ArriveRate	Arrival rate	0.0759	0.00996
Scenario2	P3ArriveRate	Arrival rate	0.79729	0.01362
Scenario3	P3ArriveRate	Arrival rate	0.96003	0.00448
Scenario4	P3ArriveRate	Arrival rate	0.96701	0.0009
Scenario5	P3ArriveRate	Arrival rate	0.99035	0.00046

Fig.7 Parts of experiment results- timeliness arrival rates of urgent and priority patients

As the evacuation assets are scarce in wartime, the arrival rate of patients over 90% is appropriate. From the results shown in Fig. 7, it is possible to conclude that when there are 3 type A and 3 type B transporters in the system, the optimal placement of assets is emerged. At this time, the mean value of timeliness arrival rate of priority patients is 98.43 %, and that of urgent patients is 96.80%. If there are more transporters, the growth rates of system performance indicators are not significant. The rates of urgent patients under different placements of type A transporters are shown in Fig. 8.

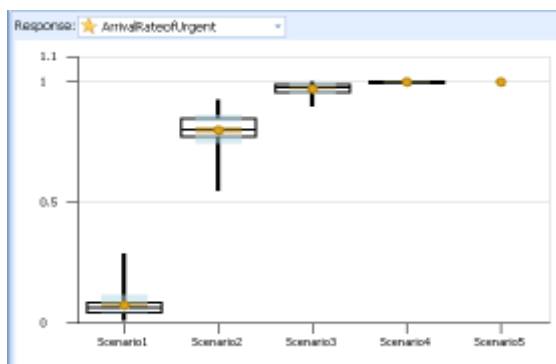


Fig.8 Rates of urgent patients under different placements of type A transporters

## CONCLUSION AND FUTURE WORK

In this research, through the use of Simio simulation platform, visual simulation model of wartime casualty evacuation was developed, based on analysis and hypothesis of wartime patient evacuation processes. Then, the optimal placement of the evacuation tools was explored by simulation experiments under Simio. Meanwhile, the 3D realistic detailed animation created could be used for presentation. The usage of Simio simulation platform for optimal placement of casualty evacuation assets seems to be a good approach. These first results do seem to be a good motivation for next steps in the use of simulation for wartime casualty treatment and evacuation. In the future, we will focus on getting more valid patient and transporter data in wartime for simulation analysis and conduct a comprehensive project from the point of patients injured.

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