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APPLICATIONS OF SIMULATION IN LOGISTICS COMBAT DEVELOPMENTS

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ABSTRACT

As the Army undergoes a transformation from the logistics intensive organizations that currently comprise the force to a more agile and sustainable force, changes in logistics concepts and organizations are inevitable. Because much of the Army's future equipment and most future organizations are still in the conceptual stages, these elements must be modeled. Simulation provides a valuable tool for not only modeling the structure or attributes of a future system, but also for comparing alternative concepts for how systems should be employed and equipped. In this paper, we present three applications of how simulation was used within the U.S. Army Combined Arms Support Command in the design and analysis of current and emerging logistical systems in the Army.

1 INTRODUCTION

The intensified pace of the ongoing Army transformation has created an increased demand for timely and defendable analysis within the combat developments community. Among other roles, combat developers are responsible for "analyzing, determining, documenting, and obtaining approval of concepts, future operational capabilities, organizational requirements, and materiel requirements" (U.S. Army Training and Doctrine Command 1999). Simulation has traditionally been a tool used in development of materiel requirements and in warfighting concept analysis. However, due to the proliferation of commercial-off-the-shelf simulation software packages and the myriad of successful applications in logistical services in the civilian sector, military logisticians have begun to realize the power that simulation offers in the development of future systems and organizations.

In 1999, analysts at the U.S. Army Combined Arms Support Command (CASCOM) began using Arena simulation software. Initial applications focused on the analysis of equipment requirements in material handling organizations. However, as the versatility and analytical power of simulation has proven itself in affecting logistical combat developments decisions, more requests for simulation analysis have surfaced. This paper presents three recent applications of simulation in Army logistics combat developments.

The first application examines the effects of various factors on the maintenance posture of the Interim Brigade Combat Team (IBCT). We then discuss the use of simulation in the analysis of the process of employing one of the Army's future fuel delivery systems, the Rapidly Installed Fuel Transfer System (RIFTS). Our third application uses simulation to determine container- and material-handling equipment requirements for an Army Cargo Transfer Company operating a container terminal at a seaport. We conclude with a brief discussion of ongoing and future simulation efforts.

2 MECHANIC WORKLOAD IN THE IBCT

The Army's Directorate of Combat Developments for Ordnance within CASCOM is responsible for analyzing the employment of maintenance personnel in the IBCT. As part of their analysis, they needed to determine what effect committing the maintenance platoon of the Combat Service Support Company (CSSC) to augment the mechanics within the IBCT has on equipment readiness. We built a model using Arena to simulate the failure of the various equipment in the IBCT and the ensuing repair actions. The measures of concern were the operational readiness (OR) rates and the utilization of mechanics required to support the generators and major vehicles in the IBCT: Interim Armored Vehicles (IAVs), Family of Medium Tactical Vehicles, Heavy Expanded Mobility Tactical Trucks, and High Mobility Multipurpose Wheeled Vehicles. A secondary goal of the analysis was to investigate the effects of vehicle and generator reliability and parts availability on the utilization of mechanics and fleet OR rates.

2.1 Construction of the Model

We constructed the model using entities to represent individual vehicles and generators, and resources to represent the IBCT mechanics. The entities had attributes to represent their reliability and maintainability characteristics, their priority of repair, and their unit of assignment. Mechanic resources were aligned in sets that either supported specific IBCT units in a Combat Repair Team (CRT) or in sets that supported all IBCT units in the brigade support area (BSA).

The basic model construct was a failure loop. A sub-model was built for each unit within the IBCT. Within each sub-model was a group of failure loops, one for each type of vehicle in the unit and one for all generators in the unit. Within each failure loop a number of vehicle/generator entities were created and constantly recycled through the logic to represent an entity's status cycle. The status cycle consisted of five states: operational, failed, recovery, repair, and return. After initial creation of entities, all entities continued through the status cycle until the simulation was terminated (combat damage was not considered).

Assumptions included a constant daily mileage for vehicles and 24-hour operations for generators. Based on the reliability attributes and either generator operating time or vehicle mileage and speed, the "operational" phase was modeled as delay time until failure. During this time, the vehicle or generator would be counted as operationally ready and would be reflected as such in the animated depiction of fleet operational readiness at the individual unit and overall IBCT levels. At the end of the entity reliability-based delay time, a failure would occur, the OR rate would be decremented, and the entity would proceed through the failure loop logic. In the "recovery" state, the entity would either self-recover (modeled as a delay to travel to the CRT) or require recovery by a vehicle of the same type as the failed vehicle. If the vehicle required recovery by another vehicle, the situation was modeled as a delay to travel to the CRT along with an additional decrement to the OR rate to reflect the non-availability of the recovering vehicle during the short recovery time.

In the "repair" state, mechanics were requested and repairs completed based on mechanic resource availability and parts delays. Business rules applied at the CRT determined whether vehicle repairs were attempted at the CRT's location or if the vehicle was further evacuated to the BSA (modeled as additional delay time). Business rules for this decision were based on supporting specific types of vehicles and on repair area space constraints. Generator repairs were all performed at the BSA. After an entity was repaired, it was delayed in the "return" state to account for the time required to return to it's assigned unit. Upon arrival, the entity was counted as operationally ready, and it reverted to the "operational" state to begin the countdown to the next failure.

2.2 Outputs and Insights

To provide the maximum visibility of model statistics, approximately 260 global variables were used. For example the number of Infantry Battalion IAVs that were awaiting parts for repair was represented by the variable INIAVPART while the number of all IAVs down waiting for parts was represented by the variable IAVPART. This variable naming convention was used throughout the model and allowed us to isolate and examine problems with specific units within the IBCT for the Ordnance Combat Developers. The global variables also lent themselves to animation on the model master screen where the instantaneous "state of the IBCT repair status" (shown in Figure 1) was constantly updated.

OPERATIONAL READINESS BY UNIT

	IAV	HEMTT	MTV	HMMWV	GENSETS
IN BNS	0.61		0.93	0.91	1.00
RSTA	0.64		0.80	0.89	0.94
FA BN	0.50		0.88	0.88	1.00
ENG CO	0.78	1.00	1.00	0.90	1.00
MI CO			1.00	0.79	1.00
SIG CO	0.80			0.83	1.00
BSB		0.70	1.00	0.86	0.96
AT CO	0.80		1.00	1.00	1.00
BDE HQ	1.00		1.00	0.91	1.00

Figure 1: IBCT Repair Status Display

We ran excursions where we varied vehicle/generator reliability and repair times as well as adjusted the part fill rate and the delay times for parts not on hand. The major insight gained through this simulation was the criticality of the part fill rate and the delay times for parts not on hand to the overall IBCT readiness level. The somewhat surprising insight was the fact that given the parts constraints, committing the mechanics from the CSSC (the primary reason for constructing the model) did not have any appreciable impact on improving the IBCT OR rate. The final recommendation based on this analysis was to increase the Authorized Stockage List (ASL) part fill rate and to reduce the customer wait time for parts not on the ASL.

3 EMPLOYING THE RAPIDLY INSTALLED FUEL TRANSFER SYSTEM (RIFTS)

RIFTS is the proposed next generation of the Army's Inland Petroleum Distribution System (IPDS). The existing IPDS pipeline system consists of rigid pipe with connections every 19 feet. RIFTS will replace this system with a continuous, reel-deployed conduit with connections every one-third mile. RIFTS will allow deployment of a conduit pipeline at a rate of 20 miles per day compared to the IPDS rate of 3 miles per day. This large increase in capability raises some questions on the logistics of installing pipeline at such a fast rate.

CASCOM's Directorate of Combat Developments for Quartermaster is responsible for determining the requirement for RIFTS as well as developing the concept for how RIFTS will be employed. We developed a simulation model to support requirements analysis for RIFTS. The goal of the analysis was to gain insight into the process of deploying and connecting the RIFTS conduit and to use animation to illustrate the installation process (see Figure 2). The primary measures of interest were the rate at which the conduit was laid and vehicle utilization.

3.1 Construction of the Model

The entities for this model represented flatrack-mounted reels of conduit. Transporters were used to represent the vehicles and trailers that deliver the flatracks to stations along the pipeline trace. For this analysis, the delivery vehicle was assumed to be the Heavy Enhanced Mobility Tactical Trucks-Load Handling System (HEMTT-LHS). Resources were used to represent the HEMTT-LHS that unrolled/installed conduit between stations along the pipeline trace. Resources with schedules were used to represent drivers for all trucks in the model.

The model was initialized with the creation of 150 entities at the marshaling area, each representing a flatrack containing 1.33 miles of reel-mounted high-pressure conduit. Entities at the marshaling area requested a transporter and driver. When a transporter and driver were available, two entities (one on the truck and one on the trailer) were then transported to the first station along the trace. One flatrack was dropped off at the first station, and the transporter proceeded to the next station to drop off the second flatrack. A delay was included to simulate retrieving an empty flatrack for retrograde (starting at station 2), and then the transporter returned to the marshaling area to drop off empty flatracks and pick up full flatracks to deliver to subsequent stations. The transporters continued this process until all 150 flatracks were dropped off along the pipeline trace.

Simultaneously, triggered by the delivery of loaded flatrack entities, a HEMTT-LHS and driver resource were seized and delayed to simulate the installing or "unrolling" of the conduit from the reel onto the ground along the pipeline trace from one station to the next. The entity was delayed to represent connection time and then disposed after incrementing the counter for completed pipeline segments. The HEMTT-LHS resource was then available to install the next consecutive available entity/reel of conduit. This process continued until the entire 200-mile conduit was installed.

3.2 Outputs and Insights

The analysis involving this model is still ongoing; however, the model has already provided the Quartermaster Combat Developers some interesting insights on the de-

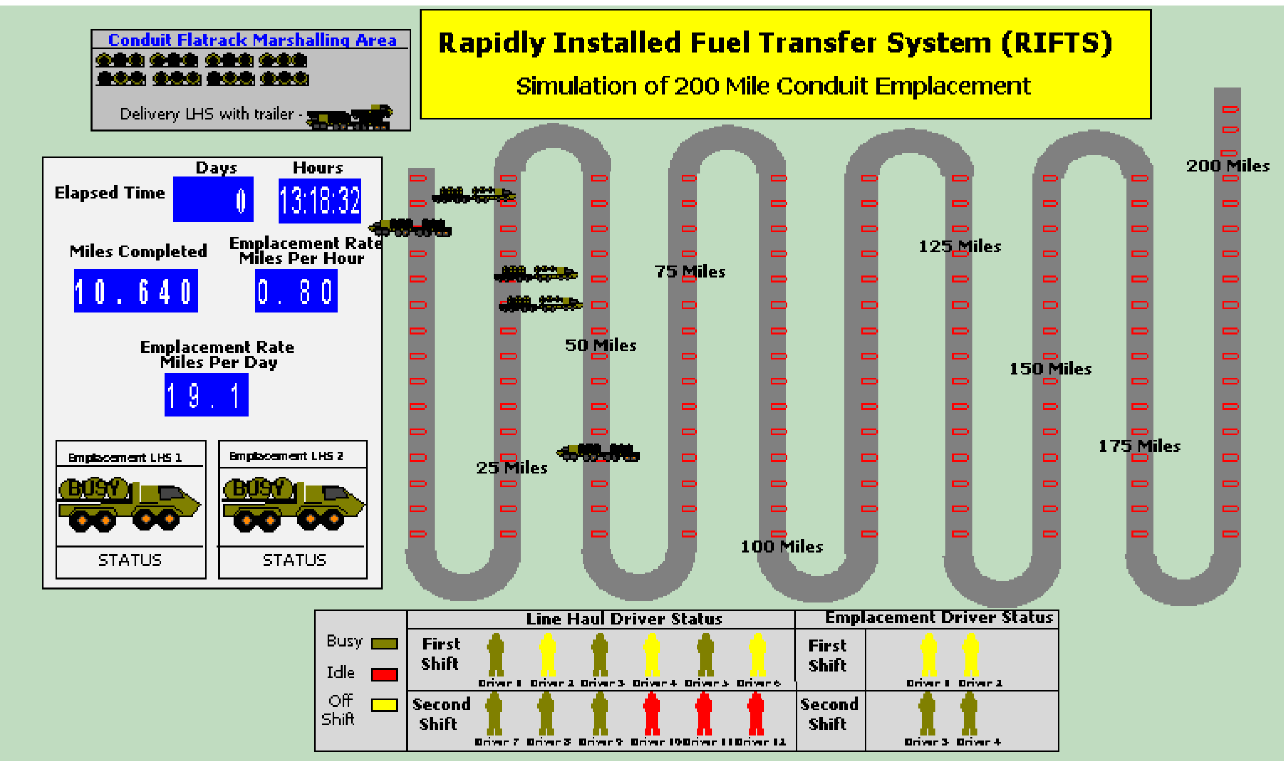

Figure 2: RIFTS Model Animation Screen

ployment process. The most notable insight concerned the utilization of the delivery drivers. The drivers in initial runs of the model were scheduled by shifts with the rule that a mission would run to completion even if a shift was technically over (using Arena's "Wait" Schedule Rule). The impact of this rule due to the increasing distance between the marshaling area and subsequent drop-off points was extremely long shifts for the drivers (beyond the maximum safe daily driving time that the Army allows) as the pipeline progressed toward the 200 mile mark. Future work on this model will look at different business rules and deployment concepts to allow the Army to meet its 20 mile per day conduit installation goal within the constraints of driver safety requirements.

4 CARGO TRANSFER COMPANY CONTAINER OPERATIONS AT A SEAPORT

Recent efforts within CASCOM's Directorate of Combat Developments for Combat Service Support have focused on the analysis of equipment requirements in material handling organizations. The latest of these analyses focused on container- and material-handling equipment (CMHE) requirements in the Transportation Cargo Transfer Company. This company may operate air terminals, ocean terminals, truck terminals, or rail terminals and must handle containerized and break-bulk cargo. Due to the Army's efforts to streamline its distribution processes, this analysis focused on handling containerized cargo at an ocean terminal. We developed a simulation model to assess the Cargo Transfer Company's ability to accomplish its ocean terminal mission of loading or unloading 500 containers per day and to determine the appropriate mix and quantity of CMHE to do so. The primary measures of interest for the model were the total container throughput and CMHE utilization.

4.1 Construction of the Model

The entities in the seaport model represented 20- and 40-foot standard shipping containers and trucks that are used to transport these containers from the port further inland. Transporters were used to represent Rough Terrain Container Handlers (RTCHs) and yard tractors, and resources were used to represent the two pier-side cranes assumed to be present at the port. The process modeled was a typical container terminal operation (see Figure 3). Containers were loaded directly onto yard tractors by the pier-side cranes and transported to the marshaling area. At the marshaling area, a RTCH would unload and move the container to storage to await the availability of a truck to transport the container from the port to a final destination. When the truck arrived, a RTCH loaded the container onto the truck, and the truck departed.

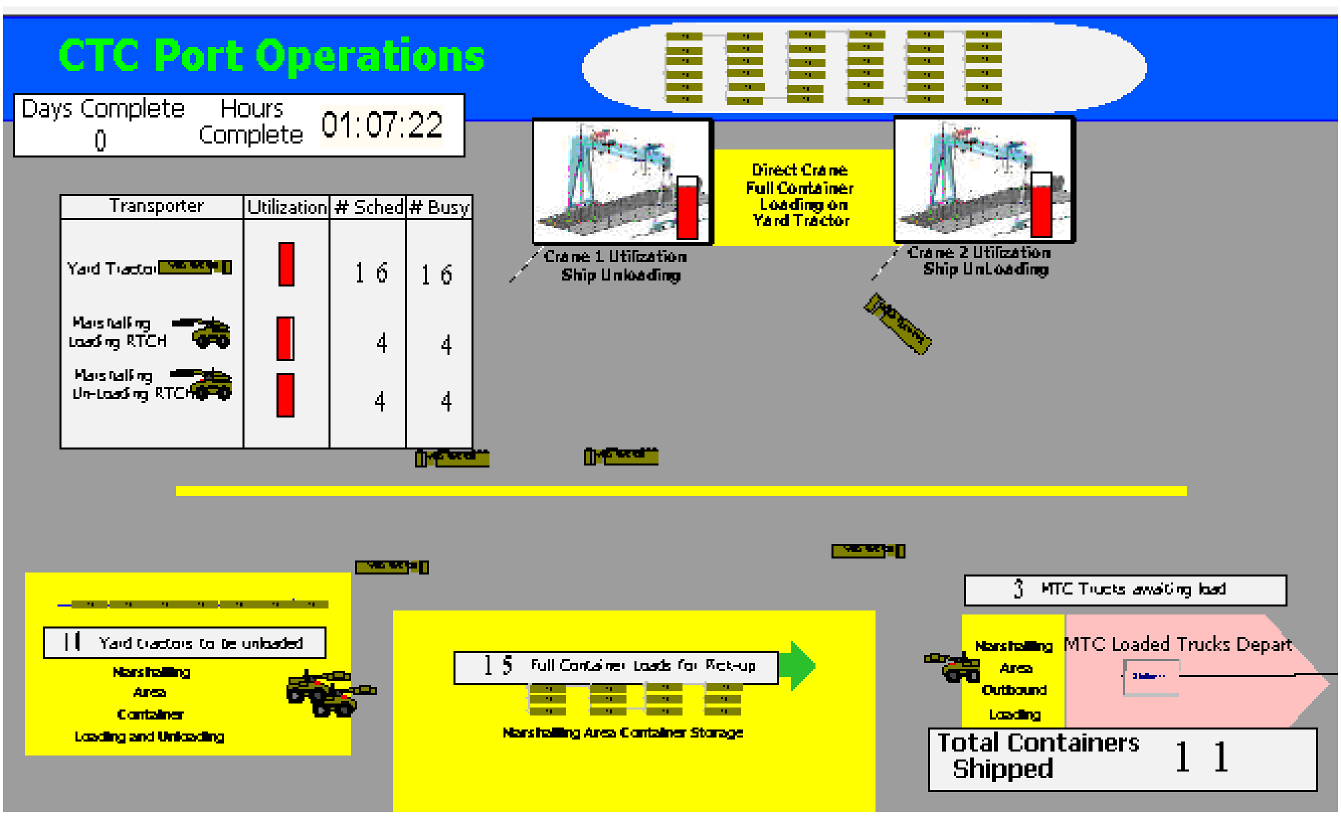

Figure 3: Seaport Animation Screen

The model runs began with creation of 2000 entities at the pier representing the arrival of a container ship with 20 and 40-foot containers that need to be off-loaded. For each container, a pier-side crane resource was seized, and a yard tractor transporter was requested. When both were available, a container entity was transferred (after a delay for loading) from the ship's queue to the yard tractor. The yard tractor then transported the container to the marshaling area where the yard tractor and container entered a queue awaiting the next available RTCH. When a RTCH became available, the yard tractor was unloaded and freed, and the RTCH then transferred the container to a holding queue. The container remained in the holding queue until an outbound truck arrived.

The outbound trucks were represented as entities and were created in batches to represent the arrival of convoys to transport containers inland. Upon creation of a batch of truck entities, each one was matched with a container in the holding queue. The matched pair then requested a RTCH, and when it became available, a delay time was incurred to represent the RTCH loading the container onto the truck. After this delay, the RTCH was released, the container/truck entity was disposed, and the throughput counter was incremented. Each simulation run continued until the company had completely off-loaded the ship or until a terminating time was reached.

4.2 Outputs and Insights

This model provided some interesting insights into the equipment requirements for the port operation. Initial quantities for the numbers of yard tractors and RTCHs required to accomplish the 500-container throughput capability were provided by the CMHE Assessment Tool previously developed at CASCOM. We discovered that the given quantities were not sufficient to achieve the throughput capability. A simple 2^2 factorial design was used to vary the quantities of equipment used by the company. Tables 1 and 2 show the factor levels and results for the experiment where r represents the number of RTCHs and y represents the number of yard tractors. The response variable was average daily throughput in containers per day.

The main effects were determined to be e_r = 160.28 and e_y = 0.02. The interaction effect was determined to be e_{ry} = 0.15. These results indicate that increasing the number of RTCHs was the primary cause of the increased throughput. Virtually no change in throughput was attributed to the change in the number of yard tractors.

Table 1: Equipment Factor Levels

Factor	**–**	**+**
r	6	8
y	16	20

Table 2: Design Matrix and Results

Design Point	***r***	***y***	***r* x *y***	**Response**
1	–	–	+	480.80
2	+	–	–	640.93
3	–	+	–	480.67
4	+	+	+	641.10

Future work on this model will look at different business rules for crane operations and allocation of RTCHs between the marshaling and dockside areas. We also plan to examine the process for simultaneous retrograde of empty containers back to the ship.

5 CONCLUSION AND FUTURE EFFORTS

The applications described above illustrate the potential impact that simulation can have on Army logistical systems in the future. These applications represent three of the primary logistics functions: supply, transportation, and maintenance. They cover the spectrum of the ongoing Army Transformation from a current transportation organization to the IBCT and on to how we will transfer fuel in the Objective Force. As the logistical concepts continue to evolve, simulation can continue to provide valuable insights into the capabilities required in or provided by new systems. An upcoming project involving the Directorate of Combat Developments for Combat Service Support plans to take advantage of this capability.

The Smart Distribution System is an emerging concept for providing sustainment support to the Objective Force. Initial analysis shows a potential reduction in cargo-handling man-hours and equipment-hours of over 70%. This concept represents a cooperative effort involving CASCOM and the Armaments Research, Development, and Engineering Center at Picatinny Arsenal, New Jersey. The Smart Distribution System will employ future truck systems, future material-handling technology, and future cargo platforms. Additionally, this system will support a force whose structure has yet to be determined. Despite the many unknown variables present, simulation of alternative systems will help to determine the physical and organizational characteristics required to make the concept a reality.

REFERENCE

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AUTHOR BIOGRAPHIES

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