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AMMUNITION UPLOAD AND DEPLOYMENT V2.0: A SIMULATION ANALYSIS

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ABSTRACT

A simulation model capable of analyzing the deployment strategies of combat, combat support, and service support units is developed. Currently the model is programmed for a field artillery battalion uploading ammunition from an ammunition supply point, (ASP). The model can be adapted to represent a brigade element or other units as directed.

The program is user formulated, with 100 variables of which are defined prior to execution of the simulation. The algorithm simulates the model with ten replications, each replication initiated with a new random number seed. The data is stored after each replication, averaging the results after the tenth simulation. Stochastic interface representing traffic and weather conditions is also modeled. Optimization is accomplished through sensitivity analysis by selecting change options for the input variables and running the simulation with the new data base.

1. INTRODUCTION

A simulation model involving the deployment of field artillery ammunition carrying vehicles to an ammunition supply point has been developed. The model has been formulated using the 'J' series table of organization and equipment, (TOE), for a 155mm self propelled howitzer battalion with a direct support mission in the Federal Republic of Germany. The model is easily modified by the author to emulate other combat and combat support units as directed. The use of the field artillery battalion in this paper is based upon personal experience in deployment strategy in the Federal Republic of Germany.

The model is written in Simulated Language For Alternative Modeling, (SLAM II), courtesy of Pritsker Corporation. Subroutines are written in Microsoft Fortran 77.

There is no substitute for actual training in the deployment of combat units. However, when the actual deployment cannot be accomplished, due to insufficient funds, nonpermissible by the host country, or other factors beyond our control, we must look towards other solutions to actively portray the missions of the unit.

Through simulation the pieces of the scenario can be constructed with limited resources, and these resources combined to effectively analyze the deployment process.

2. OBJECTIVES

First: Promote the future development of simulations to be used at the user level on personal computers, unlike large mainframe models, for the purpose of providing process oriented solutions to current problems. Commanders and their staff may acquire first-hand knowledge of the training status of their units and make appropriate considerations in the strategic and tactical planning of their units for future operations. Knowledge of these operations is critical, particularly when coordinating the combined forces concept of deployment.

Second: Develop a simulation model which can enhance the deployment criteria and strategy of the armed forces in Europe. Simulation will become more important as an operations analyst's tool as funds for real world training diminishes. This simulation provides accurate user level information on the length of time such deployments will take whereas previously we could only estimate the deployment times.

3. THE DEPLOYMENT MODEL

3.1 Model Synopsis

The scenario modeled is generic and input variables are defined by the user. Typical alert status begins with higher headquarters notifying the units to recall personnel to garrison for deployment to their prospective battle positions.

Figure 1 depicts units divided into two basic elements. The first element consist of the combat vehicles which move to the local dispersal area, (LDA). Typically this convoy consists of combat vehicles, supply, the fire direction center, and communications.

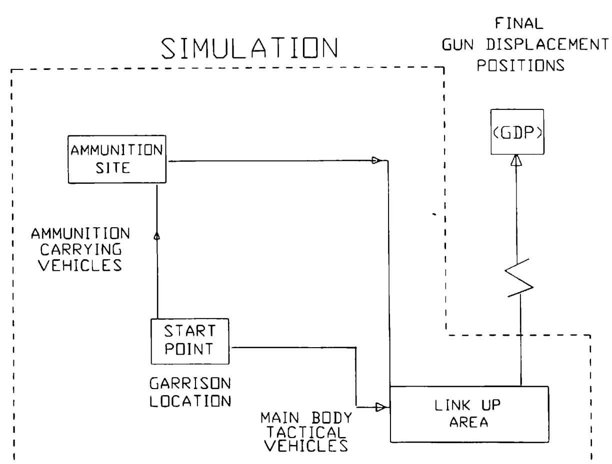


Figure 1. Generalized Deployment Scenario of Tactical Combat Units

The second element consists of the ammunition carrying vehicles which travel or convoy to the ammunition supply points, (ASP's), located in remote and secured positions. Typical of this convoy are the field artillery ammunition supply vehicles (FAASV's), and the heavy equipment mobile tactical transports (HEMTT's). The convoy routes or travel to the ASP may be the same for each unit or each unit may have a different route based on tactical considerations.

The model allows for each unit or convoy to choose different routes and additionally provides for each unit to accommodate the possibility of adverse weather or traffic conditions that prevail during the deployment. Traffic considerations may be extremely critical if deployment occurs during rush hour or if the convoy is routed through a heavily populated city. Weather conditions may also be extremely hazardous particularly during the winter months.

As previously stated, the second convoy, the ammunition carriers, figure 2, move to the ammunition site and are secured outside the site until the loading berths inside the site are prepared for loading. The loading berths are actually queues or waiting lines for each unit. Initially an open berth will immediately accommodate an ammunition carrier while the remaining vehicles wait beyond the site for a vacancy at the berth to occur. Once a vehicle is loaded another empty vehicle is exchanged at the berth until all vehicles for that unit have been loaded. The berths are the resources in the simulation. Vehicles, the entities, wait outside the ASP until all vehicles are completely loaded. Movement is then initiated for the convoy to travel to the next position, or local dispersal area, to link up or combine with the combat units currently in a wait status. Again, traffic routes, traffic variability, and weather conditions are considerations for convoy movement.

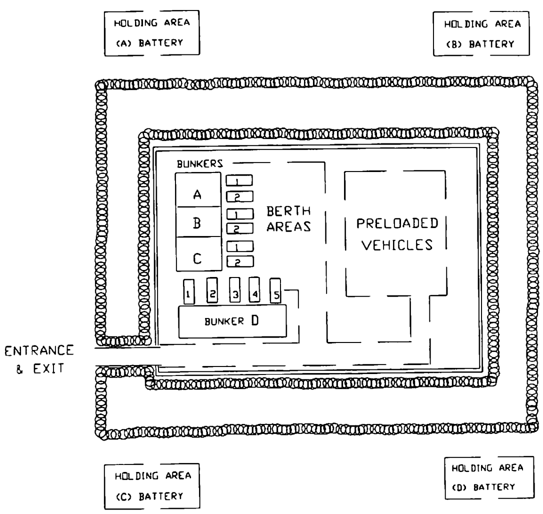


Figure 2. Typical Ammunition Bunker Depicting Loading Berths

3.2 Assumptions

In addition to the model described above, certain basic assumptions are mandated.

First: The current deployment strategies of units in Europe depict units deploying to the ammunition sites to upload a unit's basic load, or (UBL). The UBL is defined as: "The amount of ammunition necessary to allow a unit to accomplish its mission until it can be resupplied. It is designed to meet initial combat needs until normal resupply is accomplished. A unit's combat and organizational vehicles must be able to carry the unit's basic load UBL in a single lift." Therefore, unit's will not return to the bunkers after the available vehicles have been loaded and depart towards the LDA.

This assumption is critical because the ammunition carrying vehicles load according to maximum vehicle capacity, regardless of the method of loading. This assumption helps accommodate the different methods of ammunition retrieval, such as hydraulics, or manual labor.

Second: Travel times of vehicles arriving to the ASP and the LDA follow a uniform distribution. This assumption stems from the fact that convoys move toward the ASP, and the LDA, in tactical convoy intervals, traveling at uniform speeds. This distribution may be modified with updated information to change the distribution with actual on site data, through accurate goodness-of-fit testing procedures.

Third: The commander's priority is currently preset for the loading of the HEMTT first, and the FAASV second. The model searches the vehicles and insures that this priority is followed until all HEMTT's have been loaded with ammunition. The priority is necessary since HEMTT's carry more ammunition than a FAASV, and consequently the commander's priority is to remove as much ammunition as possible, expeditiously, in case of a premature hostile act against the ASP, or the personnel.

Fourth: The vehicles wait in a holding pattern outside the ASP, insuring unit integrity, until all vehicles have been loaded for the unit. This insures that the unit's vehicles will not be separated in the event the unit's mission has been changed.

Fifth: Commanders at all levels actively take part in building the data base. Commanders are active during the training of their units gathering the process times of the simulation input variables. For example, in the absence of evaluating the convoy times to the ammunition supply point, the commanders will, as a minimum, travel the route themselves several times and acquire the travel time for his command vehicle to the site. Such information is critical in developing the model input variables. At the site it may not be feasible to upload an entire unit; however, it may be possible to upload one or two vehicles during a training exercise and calculate a best and worst load time for each type of vehicle for each battery or unit.

3.3 The SLAM II Model in Language Code

The simulation language used to model this particular project was *Simulation Language For Alternative Modeling II*, SLAM II, by Pritsker Corporation. Figure 3 provides a detailed drawing of the model. All subsequent subroutines were written in *Microsoft Fortran 77.*

4. OUTPUT ANALYSIS

4.1 Input Report Identification

The program is designed to provide the commanders and his staff an easily read and well defined copy of the input variables used in establishing the data base. The purpose of the input report is for future reference so that commanders and staff may document changes in their deployment strategies as they attempt sensitivity analysis. A copy of the input summary report is found in the example.

4.2 Output Report Identification

4.2.1 Results

The program follows the standard output of SLAM II by presenting the output statistics in an easily read output menu. The following categories of statistics are currently available to the user at the menu:

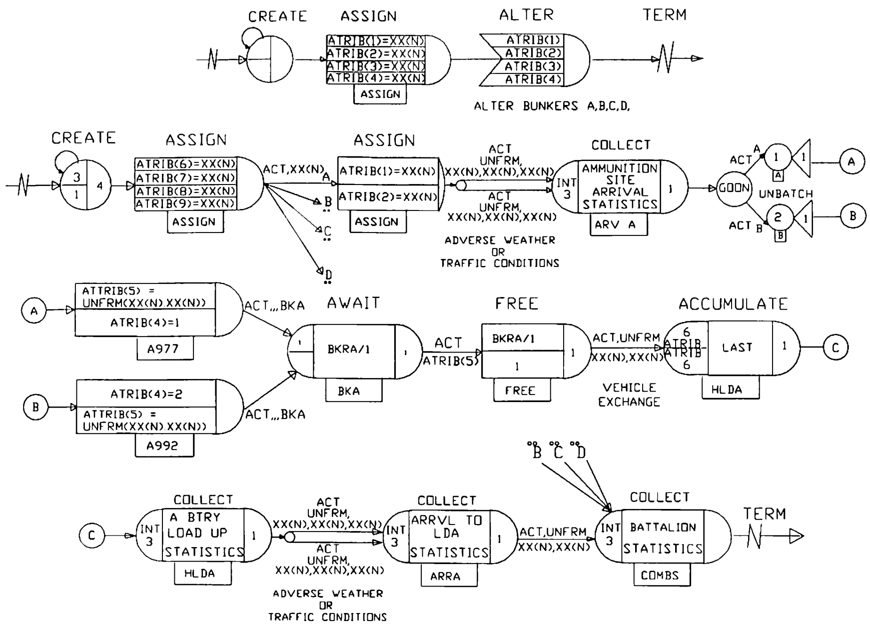
A. SUMMARY OF ALL REPORTS - (*all reports are given*)
B. HISTOGRAMS - (*histograms of all units depicting all phases of the units deployment*)
C. STATISTICS FOR VARIABLES BASED ON OBSERVATION - (*time statistics for all phases of the deployment operation*)
D. FILE STATISTICS - (*statistics for vehicles outside the ASP in a wait posture*)
E. RESOURCE STATISTICS - (*statistics for vehicles inside the the ASP at the loading berths*)

The example which follows includes the output data as a reference in which to analyze the results. A graphical representation is also included.

4.2.2 The Need For Replication

The simulation model is preset to perform ten replications of the simulation model with each replication beginning with a new random number seed. The purpose is to perform each observation, or simulation, as a separate run. With each run starting with the same initial conditions but with a different sequence of random numbers we are assured that our observations are in fact independent and identically distributed, (IID).

Figure 4 reflects the need for replication. The example data was used for ten separate simulations. Each replication is plotted on the graphs. The observer can see the resulting variation of initiating each simulation with a different random number seed. The simulation model will calculate the average of ten simulations or observations. The resulting statistics are the mean, standard



RESOURCES			
BUNKER	A	XX(N)	1
BUNKER	B	XX(N)	2
BUNKER	C	XX(N)	3
BUNKER	D	XX(N)	4

PRIORITY		
PRIORITY/1	LVF	4
PRIORITY/2	LVF	4
PRIORITY/3	LVF	4
PRIORITY/4	LVF	4

Figure 3. SLAM II Symbolic Language Code of Deployment Strategy

deviation, absolute minimum value, absolute maximum value, and the coefficient of variation for each unit or battery during each phase of the ammunition upload over ten simulations.

Figure 5 provides similar information in regards to the effects of replication. The ten simulations treat each unit or battery as a separate observation. Thus, the effect of the battalion arrival to the LDA is in fact forty observations (four units; A, B, C, D times ten).

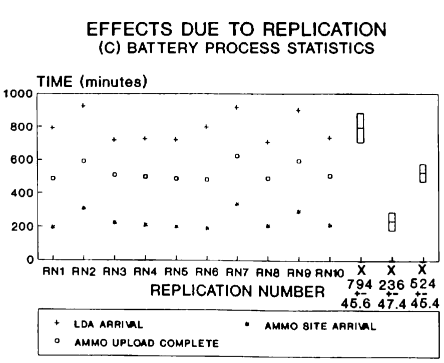


Figure 4. Results of Simulating Model For Ten Replications

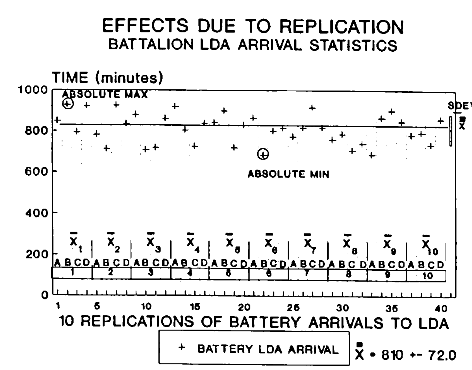


Figure 5. Results of Simulating Model For Forty Replications

5. A NUMERICAL EXAMPLE

The following example provides user input variables as defined as a basecase scenario, BASECASE.DAT, to allow the user the opportunity to "play" with the model to become familiar with it's contents. The Input Data Summary Report provided, is the same as produced during the simulation.

5.1 Input Data Summary Report (BASECASE.DAT)

AMMUNITION UPLOAD AND DEPLOYMENT V2.0
BY PARKER

******INPUT DATA SUMMARY REPORT******

DATE: 13 JANUARY 1990
UNIT: 2-19th F.A.

LOADING BERTHS AVAILABLE AT AMMUNITION SITE

A BATTERY: 2.000
B BATTERY: 2.000
C BATTERY: 2.000
D BATTERY: 2.000

VEHICLES AVAILABLE FOR EACH BATTERY

A BATTERY HEMTTS: 4.000 FAASVS: 8.000
B BATTERY HEMTTS: 4.000 FAASVS: 8.000
C BATTERY HEMTTS: 4.000 FAASVS: 8.000
D BATTERY HEMTTS: 4.000 FAASVS: 8.000

INITIAL DEPARTURE TIMES FOR EACH BATTERY

A BATTERY: .000 MINUTES
B BATTERY: 20.000 MINUTES
C BATTERY: 40.000 MINUTES
D BATTERY: 60.000 MINUTES

TRAFFIC OR ADVERSE WEATHER PROBABILITY FACTOR FOR TRAVEL TO AMMUNITION SITE

A BATTERY: .650
B BATTERY: .650
C BATTERY: .650
D BATTERY: .650

TRAVELING TIMES FOR EACH BATTERY TO AMMO SITE
(NORMAL TRAFFIC CONDITIONS)

A BATTERY: 150.000 TO 180.000 MINUTES
B BATTERY: 150.000 TO 180.000 MINUTES
C BATTERY: 150.000 TO 180.000 MINUTES
D BATTERY: 150.000 TO 180.000 MINUTES

LOAD TIMES PER VEHICLE AT AMMUNITION SITE

A BATTERY HEMTTS: 60.00 TO 70.00 MINUTES
A BATTERY FAASVS: 30.00 TO 40.00 MINUTES

B BATTERY HEMTTS: 60.00 TO 70.00 MINUTES
B BATTERY FAASVS: 30.00 TO 40.00 MINUTES

C BATTERY HEMTTS: 60.00 TO 70.00 MINUTES
C BATTERY FAASVS: 30.00 TO 40.00 MINUTES

D BATTERY HEMTTS: 60.00 TO 70.00 MINUTES
D BATTERY FAASVS: 30.00 TO 40.00 MINUTES

SWITCH TIMES FOR EXCHANGE OF FULL VEHICLES FOR EMPTY VEHICLES

A BATTERY: 15.000 TO 18.000 MINUTES
B BATTERY: 15.000 TO 18.000 MINUTES
C BATTERY: 15.000 TO 18.000 MINUTES
D BATTERY: 15.000 TO 18.000 MINUTES

TRAFFIC OR ADVERSE WEATHER PROBABILITY FACTOR FOR TRAVEL TO LDA/ALTERNATE POSITION

A BATTERY: .400
B BATTERY: .400
C BATTERY: .400
D BATTERY: .400

TRAVELING TIMES FOR BATTERY/UNIT TO LDA OR ALTERNATE DESTINATION
(NORMAL TRAFFIC CONDITIONS)

A BATTERY: 210.000 TO 240.000 MINUTES
B BATTERY: 210.000 TO 240.000 MINUTES
C BATTERY: 210.000 TO 240.000 MINUTES
D BATTERY: 210.000 TO 240.000 MINUTES

5.2 Output Data Summary Report (BASECASE.DAT)

Having completed entry of the Input Data Summary Report information the simulation will run following the instructions provided with the software. The output data provided will be calculated and displayed as follows:

SLAM II SUMMARY REPORT

SIMULATION PROJECT AMMO UPLOAD BY PARKER

DATE 1/ 2/1990 RUN NUMBER 10 OF 10

CURRENT TIME .8594E+03
STATISTICAL ARRAYS CLEARED AT TIME .0000E+00

****STATISTICS FOR VARIABLES BASED ON OBSERVATION****

	MEAN VALUE	STD DEV	COEFF. VAR	MIN VAL	MAX VAL	NO. OBS
A BTRY ARVL TI	.257E+03	.315E+02	.123E+00	.173E+03	.296E+03	10
B BTRY ARVL TI	.257E+03	.537E+02	.209E+00	.174E+03	.314E+03	10
C BTRY ARVL TI	.236E+03	.535E+02	.227E+00	.190E+03	.335E+03	10
D BTRY ARVL TI	.293E+03	.474E+02	.162E+00	.221E+03	.345E+03	10
A BTRY LOAD TI	.547E+03	.324E+02	.593E-01	.464E+03	.591E+03	10
B BTRY LOAD TI	.550E+03	.522E+02	.949E-01	.473E+03	.615E+03	10
C BTRY LOAD TI	.524E+03	.540E+02	.103E+00	.478E+03	.620E+03	10
D BTRY LOAD TI	.585E+03	.454E+02	.777E-01	.511E+03	.639E+03	10
A BTRY LDA TI	.813E+03	.683E+02	.840E-01	.687E+03	.918E+03	10
B BTRY LDA TI	.799E+03	.821E+02	.103E+00	.684E+03	.927E+03	10
C BTRY LDA TI	.794E+03	.884E+02	.111E+00	.708E+03	.924E+03	10
D BTRY LDA TI	.836E+03	.456E+02	.545E-01	.740E+03	.921E+03	10
BN ARRIVAL TI	.810E+03	.720E+02	.889E-01	.684E+03	.927E+03	40

****FILE STATISTICS** (Vehicles outside the ASP)**

FILE NUM	LABEL/TYPE	AVG LNG	STD DEV	MAX LNG	CUR LNG	AVG WAIT TIME
1	BKA AWAIT	1.851	3.356	10	0	132.572
2	BKB AWAIT	1.881	3.361	10	0	134.673
3	BKC AWAIT	1.851	3.343	10	0	132.552
4	BKD AWAIT	1.849	3.343	10	0	132.441

****RESOURCE STATISTICS** (Vehicles at the loading berths)**

RES NUM	RES LABEL	CUR CAP	AVG UTIL	STD DEV	MAX UTIL	CUR UTIL
1	BKRA	2	.61	.916	2	0
2	BKRB	2	.61	.916	2	0
3	BKRC	2	.60	.913	2	0
4	BKRD	2	.61	.915	2	0

RES NUM	RES LABEL	CUR AVAIL	AVG AVAIL	MIN AVAIL	MAX AVAIL
1	BKRA	2	.6578	0	2
2	BKRB	2	.6600	0	2
3	BKRC	2	.6243	0	2
4	BKRD	2	.7244	0	2

5.3 Graphical Representation Of Output

Figures 6 and 7 depict a graphical representation of the results obtained from the output data summary report. Commanders and staff may desire a graphical analysis in order to compare the unit's deployment efficiency.

Each battery or unit is graphed with all three phases clearly displayed (i.e., Ammunition Site Arrival, Loadup Phase, and LDA Arrival). Additionally, the overall battalion arrival data is displayed. The additional information displayed in figure 7, displays the resource statistics at the bunkers. In the example the commander will notice that the wait times for each battery are extremely high, approximately 1.5 to 2.0 hours, for batteries A, B, and C respectively. However, D battery shows a much lower wait time primarily due to the greater number of loading berths available at their location.

Additionally, the model provides output results in the form of histograms. Figure 8 provides information in the form of a histogram depicting the deployment times of the unit by phase. The histogram captures the ten replications providing to the user the deployment phase times with a propability of occurance for each phase.

Significantly the results reflect the deployment times of the units under the current configuration and strategy of the unit. Therefore the commander is afforded the opportunity, through sensitivity analysis, the ability to test "what if?" and "why not?" scenarios if these times and strategies do not integrate into the overall scheme of maneuver of the higher echelon plans for deployment.

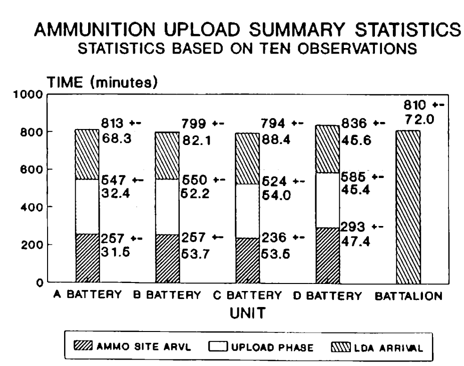


Figure 6. Unit Comparisons For Ammunition Site Arrival, Ammunition Loading, and Arrival to the LDA

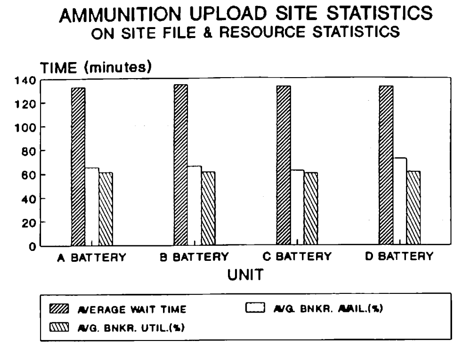


Figure 7. Unit Efficiency Comparisons of the Loading Berth Operations

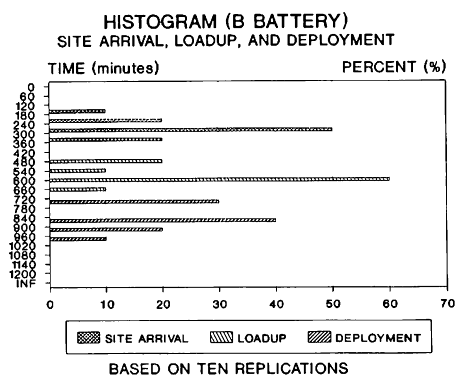


Figure 8. Histogram Statistics and Comparisons For Ammunition Site Arrival, Ammunition Loading, and Arrival to the Local Dispersal Area Based on Ten Replications

5.4 Verification and Validation

Verification was performed painstakingly by a careful analysis of the output data. This verification was achieved by performing hand calculations of the ten replications to insure that the statistics achieved in the final stages of the simulation are accurate. Calculations of the mean, standard deviation, coefficient of variation, absolute minimum values, absolute maximum values, and queue statistics were checked meticulously. The model performs as intended. The reason behind the ten replications as opposed to twenty or more is simple. After running the simulation as high as 100 replications the means and variances varied only slightly. The simulation was backed off until the number of replications emulated that of 100 replications. Thus, ten replications became the solution. Additionally, standard computer memory was considered, therefore a realistic replication was an essential consideration.

Validation is more difficult to achieve. I am skeptical at authors who frequently boast a quick validation. Validation, or testing and checking all known assumptions, and deficiencies of the model is ongoing. It is hopeful that current units in the field will test and allow refinement of the model. Additionally, data, possibly classified secret, may be used as a comparison to test and compare deployment times, strategies, and considerations of applicability.

6. CONCLUDING REMARKS

A simulation model analyzing the deployment strategies of field artillery units has been developed. The capabilities of the model go far beyond that of conventional or standard models in that this model is a stand alone version requiring only a personal computer, i.e., a laptop model, in which to gain sufficient and detailed information of a unit's deployment capabilities.

This model additionally incorporates the ability to perform sensitivity analysis after a data base has been established. Further, the model adds realism with a subroutine to model adverse weather and traffic conditions, based on conditional probability theory, which may be extremely critical in the movement of tactical convoys.

The model can easily be adapted to model other combat units, combat service support units, as well as combining several modules of this program together to incorporate deployment scenarios of brigade size elements.

The model has momentous appreciation for use in the civilian market as a user friendly model to analyze agricultural transportation procedures such as harvest and market distribution. Other uses include transportation analysis, particularly for grocery chains, moving and storage facilities, and other trucking and distribution applications.

I have made every attempt to insure that this model truly represents the system under observation. Secondly, great consideration is taken to insure that the model is timely and extendible, and third that the model is understandable.

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DISCLAIMER

The views, analyses, and findings in this report represent the views of the author below, and do not represent the official position of the United States Army or the Department of Defense.

This research is original, and solely my own work except where noted.

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