(4)

A RAND NOTE

Relating Selected Army Logistics Resources to Combat Performance Measures

James H. Bigelow

August 1988

40 Years 1948-1988

RAND

This research was sponsored by the United States Army under Contract No. MDA903-86-C-0059.

Published by The RAND Corporation
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90406-2138

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: N-2765-A	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Relating Selected Army Logistics Resources to Combat Performance Measures	5. TYPE OF REPORT & PERIOD COVERED: Interim
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): James H. Bigelow	8. CONTRACT OR GRANT NUMBER(s): MDA903-86-C-0059
9. PERFORMING ORGANIZATION NAME AND ADDRESS: The RAND Corporation 1700 Main Street Santa Monica, CA 90406	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Office of the Deputy Chief of Staff, Logistics Headquarters United States Army Washington, DC 20310	12. REPORT DATE: August 1988 13. NUMBER OF PAGES: 17
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

No Restrictions

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Combat Effectiveness, Army
Performance Tests, Decision Making,
Logistics, Mathematical Models,

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See reverse side

DD FORM 1 JAN 73 1473

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

This Note describes ALA-X (Army Logistics Assessment--Extended), a project to develop a prototype methodology to build the logistics portion of the Army five-year program. In particular, it describes the central model, the logistics decision model (LDM), among the many small models that are used in the ALA-X methodology. LDM is a highly aggregate, two-sided, deterministic simulation of a theater campaign. Once LDM is calibrated, a user can vary stocks of resources and capacities, and observe their effects on combat performance measures. An additional set of models, the logistics functional models, make it possible to bridge the gap between the physical resources of the Army program and the capacities measured by ALA-X. (Presented at the 56th Military Operations Research Society Symposium, held at the Naval Postgraduate School in Monterey, California, June 28-30, 1988.)

A RAND NOTE

N-2765-A

Relating Selected Army Logistics Resources to Combat Performance Measures

James H. Bigelow

August 1988

Prepared for
The United States Army

40 Years 1948-1988
RAND

PREFACE

This Note was prepared for delivery at the 56th Military Operations Research Society (MORS) Symposium, held at the Naval Postgraduate School in Monterey, California, on 28-30 June 1988. The work described here was done as part of Army Logistics Assessment - Extended (ALA-X), an Arroyo Center project sponsored by the Army's Office of the Deputy Chief of Staff for Logistics, Directorate of Plans and Programs (DALO-PLA).

THE ARROYO CENTER

The Arroyo Center is the U.S. Army's Federally Funded Research and Development Center for studies and analysis operated by The RAND Corporation. The Arroyo Center provides the Army with objective, independent analytic research on major policy and management concerns, emphasizing mid- to long-term problems. Its research is carried out in five programs: Policy and Strategy; Force Development and Employment; Readiness and Sustainability; Manpower, Training, and Performance; and Applied Technology.

Army Regulation 5-21 contains basic policy for the conduct of the Arroyo Center. The Army provides continuing guidance and oversight through the Arroyo Center Policy Committee, which is co-chaired by the Vice Chief of Staff and by the Assistant Secretary for Research, Development, and Acquisition. Arroyo Center work is performed under contract MDA903-86-C-0059.

The Arroyo Center is housed in RAND's Army Research Division. The RAND Corporation is a private, nonprofit institution that conducts analytic research on a wide range of public policy matters affecting the nation's security and welfare.

Stephen M. Drezner is Vice President for the Army Research Division and Director of the Arroyo Center Those interested in further information concerning the Arroyo Center should contact his office directly:

Stephen M. Drezner
The RAND Corporation
1700 Main Street
P.O. Box 2138
Santa Monica, California 90406-2138

Telephone: (213) 393-0411

SUMMARY

Army Logistics Assessment - Extended (ALA-X), a project sponsored by the Army DCSLOGs Directorate of Plans and Operations (DALO-PLA), seeks to develop a prototype for a methodology to help build the logistics portion of the Army five-year program. The methodology estimates the costs and benefits of investing in different logistics resources, where benefits are measured in terms of combat performance (e.g., FLOT[1] movement, Red and Blue weapons engaged and attrited, and Red and Blue resources consumed and personnel lost).

The ALA-X methodology is a tool kit of many small models;[2] the central model is the Logistics Decision Model (LDM). LDM is a highly aggregate, two-sided, deterministic[3] simulation of a theater campaign.[4] It is designed to produce results consistent with FORCEM (Force Evaluation Model), which the Army will use to estimate certain resource requirements for their program. LDM monitors the quantities of a variety of resources (e.g., ammunition, POL, equipment) at several echelons (e.g., theater, corps, division) as they are affected over time by a number of activities. The activities may consume, produce, repair, move, or otherwise change the status of the resources. Combat Service Support (CSS) units performing specific logistics functions (e.g., ammunition handling, transportation of dry cargo) are represented as upper bounds, or *capacities*, imposed on activities or groups of activities (e.g., the capacity in tons per day to move ammunition of all types from theater to corps).

Once LDM is calibrated, a user can vary stocks of resources and capacities, and observe their effects on combat performance measures. The user would seek resources or capacities to which combat performance measures were either exceptionally sensitive, or exceptionally insensitive. The Army might wish to structure their five-year program to favor the former at the expense of the latter.

---

[1]Forward Line of Own Troops.

[2]Each small enough to fit on a personal computer.

[3]That is, it has no random (Monte Carlo) elements.

[4]So far, I have calibrated LDM only for the NATO theater, but given the appropriate data, the model could be calibrated equally well to other theaters.

But the Army program is stated in terms of physical resources, not capacities. The bridge between the two is provided by a set of other models in the ALA-X tool kit, a set I call *logistics functional models*. A number of these models have been implemented in the form of spreadsheets (e.g., ammunition and POL distribution models, and a general truck transportation model). These models estimate the resources needed to perform the indicated functions, as well as the investment and annual operating costs of those resources.

So far, the ALA-X methodology has been well received by the Army. The Logistics Evaluation Agency (LEA) and the project sponsor are jointly devising ways to use it in support of the Army program. LEA has made substantial contributions to the methodology, including building a preprocessor to generate LDM input files, and modifying the representation of several logistics functions in the LDM input data. Given LEA's initiative in changing the ALA-X methodology to be more to their liking, I am optimistic that it will continue to be used and further developed once the project ends. There is a realistic chance, therefore, that the ALA-X project may lead to an improvement in the quality of the multi-billion dollar logistics portion of future Army budgets.

ACKNOWLEDGMENTS

I would like to thank Louis W. Miller for his thoughtful review of this Note, and his many helpful suggestions. Thanks also to my secretary, Irene Gordon, for guiding the Note through RAND's Publications Department.

OBJECTIVE OF ARMY LOGISTICS ASSESSMENT — EXTENDED (ALA-X)

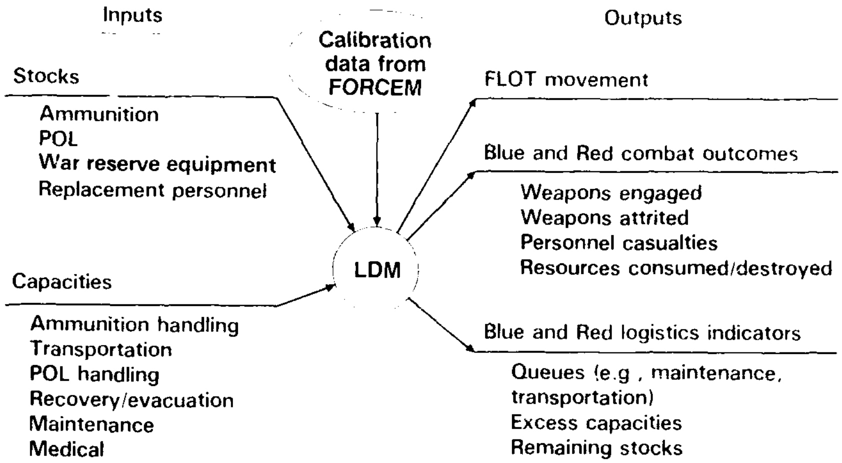
- To devise a methodology to help build the logistics portions of the Army five-year program (the POM)
- *The methodology estimates:*
  - Impacts on combat performance
    - FLOT movement
    - Red vs Blue losses
    - Red vs Blue forces engaged over time
  - Of alternative investments in logistics resources
    - People
    - Supplies
    - Equipment
    - CSS units
- The methodology is:
  - Fast enough (minutes per case) to permit extensive sensitivity analyses
  - Highly aggregate, small enough to run on a PC

Army Logistics Assessment - Extended (ALA-X), a project sponsored by Headquarters, Department of the Army (DALO-PLA), seeks to develop a prototype methodology to help build the logistics portion of the Army's five-year program. When building its program, the Army first estimates a requirement for each resource, but the cost of satisfying all requirements always greatly exceeds the amount the Army can spend. Thus, the Army must next decide how much of each requirement not to satisfy. Necessarily, the Army has always made these decisions, but on somewhat arbitrary grounds, for the Army has never succeeded in developing tools that would systematically and auditably rate different resources, intended to support disparate functions, on common scales.

The ALA-X methodology attempts to rectify this lack by estimating effects on combat performance of alternative investments in logistics resources. Combat performance measures thus become the common scales on which different resources are rated. If an increment of one resource has relatively little impact on combat performance, and an equal-cost increment of a second resource has a large impact, the Army may prefer to satisfy less of the requirement for the first resource and more of the requirement for the second. Combat performance is measured in terms of FLOT (Forward Line of Own Troops) movement, Red and Blue weapons engaged and attrited on both sides, and Red and Blue resources consumed and personnel lost. Logistics resources considered include stocks of ammunition, POL, war reserve equipment, and replacement personnel. Resources can also be entire Combat Service Support (CSS) units that perform such logistics functions as ammunition handling, transportation of dry cargo, and so forth.

To evaluate the effect of a resource increment on combat performance, one must generate at least two cases with the ALA-X methodology: a base case and an excursion in which the resource in question has been increased or decreased. Because there are many resources to be considered, hundreds of cases might be generated by the ALA-X methodology during the building of an Army program. I have therefore designed the methodology to be very fast (minutes per case) and to be highly aggregate (to reduce the difficulty of preparing inputs) and very small (to fit on the personal computers the Army is making readily available).

THE LOGISTICS DECISION MODEL (LDM): THE CENTRAL MODEL IN THE ALA-X METHODOLOGY



The ALA-X methodology is a tool kit of many small models, of which the central model is the Logistics Decision Model (LDM). LDM is a highly aggregate, two-sided, deterministic[1] simulation of a theater campaign.[2] It monitors the quantities of a variety of resources (e.g., ammunition, POL, equipment, people) at several echelons (theater to brigade) as they are affected over time by a number of activities. These activities may consume, produce, repair, move, or otherwise change the status of the resources. CSS units are represented as upper bounds, or *capacities* imposed on activities or groups of activities (e.g., the capacity in tons per day to move ammunition of all types from theater to corps).

[1] That is, it has no random (Monte Carlo) elements.

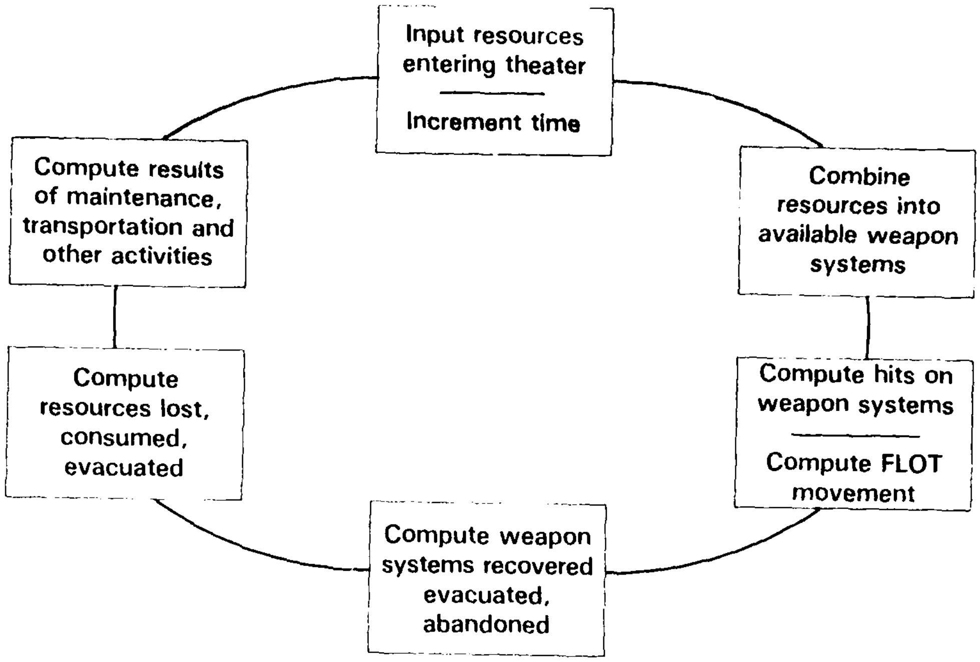
[2] So far, I have calibrated LDM only for the NATO theater, but given the appropriate data, I see no reason the model could not be calibrated equally well to other theaters.

LDM requires calibration, and I have been calibrating it to cases generated by the FORCEM[3] model.

Once LDM has been calibrated, a user can vary its inputs, including stocks of resources (e.g., ammunition, POL, equipment) and capacities (e.g., ammunition handling, transportation, maintenance). He can then observe the effects of these variations on combat performance measures (e.g., FLOT movement, Red and Blue weapons engaged and attrited) as well as on indicators of logistics "health," such as the buildup of queues (e.g., equipment awaiting maintenance, supplies awaiting transportation) and unused capacities. These indicators may help the user decide what stocks or capabilities to vary in succeeding cases.

[3]FORCEM (Force Evaluation Model) is in the late stages of development at the U.S. Army Concepts Analysis Agency (CAA). The Army intends to use FORCEM in a variety of studies that provide requirements information for building the Army program. Because FORCEM's intended use overlaps that of the ALA-X methodology, I designed LDM to produce results consistent with those from FORCEM.

THE LDM SIMULATION CYCLE



This slide depicts LDM's simulation cycle. Starting at the top, the model first sets the time to signal the start of a new time period (its basic cycle is 12 hours), and reads the amounts of resources that enter the theater during that period.

Next, the resources at the division echelon must be combined into weapon systems available for combat. For example, a tank cannot enter combat unless there is an available crew, and specified amounts of POL and ammunition. Shortages of resources thus reduce the number of weapon systems available for combat. Available weapon systems are calculated for both Blue and Red.

The combat module of LDM then estimates the outcomes of one 12-hour period of combat between the available Blue and Red weapon systems. The outcomes estimated are the number of hits on each weapon system, and the average distance the FLOT moves.

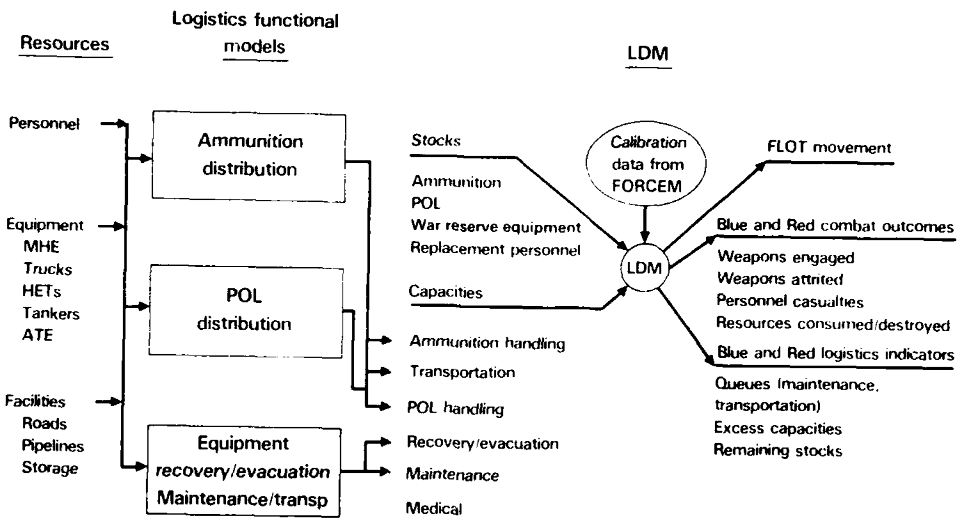
To complete the cycle, LDM calculates (for both Blue and Red):

- Number of hit weapon systems that can be recovered and evacuated, and the number that must be abandoned due to lack of sufficient recovery vehicles and Heavy Equipment Transporters (HETs);
- Ammunition and POL lost and consumed, and personnel lost or wounded;
- Equipment repaired at each echelon;
- Resources transported from each echelon to the next.

The resources transported to the division echelon will be available to be combined into weapon systems in the next time period, together with any resources that arrive from outside the theater.

Inputs to LDM are ASCII files that can be modified with most standard text editors or database systems, and the outputs can be manipulated and displayed with a commercial spreadsheet/graphics package.

THE OVERALL ALA-X METHODOLOGY

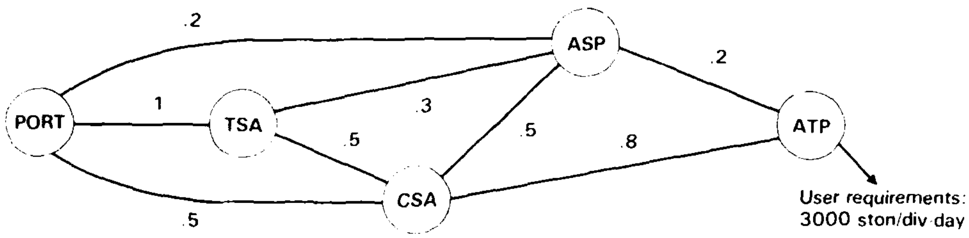


By itself, LDM cannot do all that is required of the ALA-X methodology. It can be used to estimate the effect on combat performance of varying the capacities to perform certain logistics functions, such as ammunition or POL handling. But those capacities do not appear directly in the Army program. The Army program is in terms of physical resources that together can be used to provide the capacities.

The bridge between physical resources and capacities is provided by a set of other models in the ALA-X tool kit, a set I call *logistics functional models*. For example, one logistics functional model relates ammunition handling capacity to forklifts and cranes, and their operators. These models also estimate the investment and annual operating costs of those resources.

LOGISTICS FUNCTIONAL MODELS
I. DEFINING THE CONCEPT

- A concept for a logistics function
  - Lays out the jobs that must be performed to accomplish the function
  - Specifies where and by what unit each job will be done
- An ammunition distribution example:



Job	Unit	SRC
Handle ammunition at TSA, CSA	GS Ammunition Co.	09487L000
Handle ammunition at ASP	DS Ammunition Co.	09488L000
Transport ammunition from Port or TSA	Theater TMT Co.	55727L100
Transport ammunition from CSA or ASP	Corps TMT Co.	55728L100
Break long links	Trailer Transfer Point	55540H5GE

A logistics functional model begins with a concept for accomplishing the function. The concept lays out the jobs that must be performed to accomplish the function, and specifies where and by what Army units the jobs will be done.

The Army typically lays out a concept in the form of a network. The above diagram, for example, shows the Army's standard concept for ammunition distribution. Users draw the ammunition they require from the Ammunition Transfer Point (ATP) at the right of the figure. The ATP in turn receives 80 percent of its ammunition from the Corps Storage Area (CSA), and the remaining 20 percent from the Ammunition Supply Point (ASP). (Note the distribution fractions on the network links.) Half of the ASP supply comes from the CSA, 30 percent comes directly from the Theater Storage Area (TSA), and the remainder directly from the Port. And so on.

The jobs involved in distributing ammunition are transporting ammunition along each link and handling it (e.g., loading and unloading trains or trucks) at each node. From the ultimate user requirement, plus the network with its distribution fractions, one can calculate the amounts of each job that must be done, i.e., how much ammunition must be transported along each link and handled at each node. Each job is assigned to a particular unit (see bottom of the slide), and it only remains to estimate how much of its job, in quantitative terms, a unit can perform—i.e., its capability.[4]

---

[4]GS = General Support, DS = Direct Support, TMT = Transportation Medium Truck, SRC = Standard Requirements Code.

LOGISTICS FUNCTIONAL MODELS II. RELATING UNIT CAPACITIES TO UNIT RESOURCES

- Universal (if crude) method uses Table of Organization and Equipment (TOE) and Unit Status Reporting System
  - TOE plus unit's Authorized Level of Organization (ALO) specify unit's authorized capacity
  - Unit Status Reporting System (AR 220-1) relates
    - Unit resources to C-rating
    - C-rating to ratio of actual/authorized capacity
- More accurate method for specific units mimics TOE building process
  - Identify pacing items and their maximum workloads
  - Develop factors relating people and nonpacing equipment to pacing items
- For either method, collect cost factors
  - People and equipment
  - Recurring and nonrecurring costs

There is a simple, if crude, method for estimating the capability of an existing Army unit. From the unit's Table of Organization and Equipment (TOE)—more accurately, a modified TOE, or MTOE specific to the unit—one obtains a statement of the design capability of the unit. This is reduced according to the unit's Authorized Level of Organization (ALO); a unit at ALO 1 has 100 percent of the design capability, a unit at ALO 2 has 90 percent, and so on. The MTOE also specifies the equipment and manpower the unit should have at each ALO.

The capability is also reduced according to the the unit's C-rating. Army Regulation AR 220-1, *Unit Status Reporting*, specifies how a unit should calculate its C-rating from the amounts and status of the equipment it has on hand, and from the numbers and level of training of its people. AR 220-1 also specifies what fraction of the design capacity each C-rating corresponds to. Thus one can use the unit's ALO and personnel and equipment inventories to estimate the unit's capacity, and how the capacity would change if equipment or people were added or taken away.

A more accurate approach estimates the capability of a unit from its inventory of pacing items—i.e., the two or three items that are most important for performing the job of the unit. For an ammunition handling company, for example, the pacing items are cranes and forklifts, whose capacities to lift and move ammunition determine the overall capacity of the unit in most circumstances. For a truck company, the pacing items are tractors and trailers. In the ALA-X project, we have used this approach to develop an ammunition distribution model and a POL distribution model using a commercial spreadsheet package. We are currently developing a major equipment items model that considers the functions of recovery, evacuation, repair, and transportation of major items.

For a unit to perform its job, of course, its pacing items must be supported. Operators must be provided, and supervisors for the operators. There must be a maintenance section, to keep the pacing items running. The Army provides factors and rules of thumb for developing a complete and viable TOE that contains all necessary people and equipment, once the basic quantities are stated in terms of the pacing items.

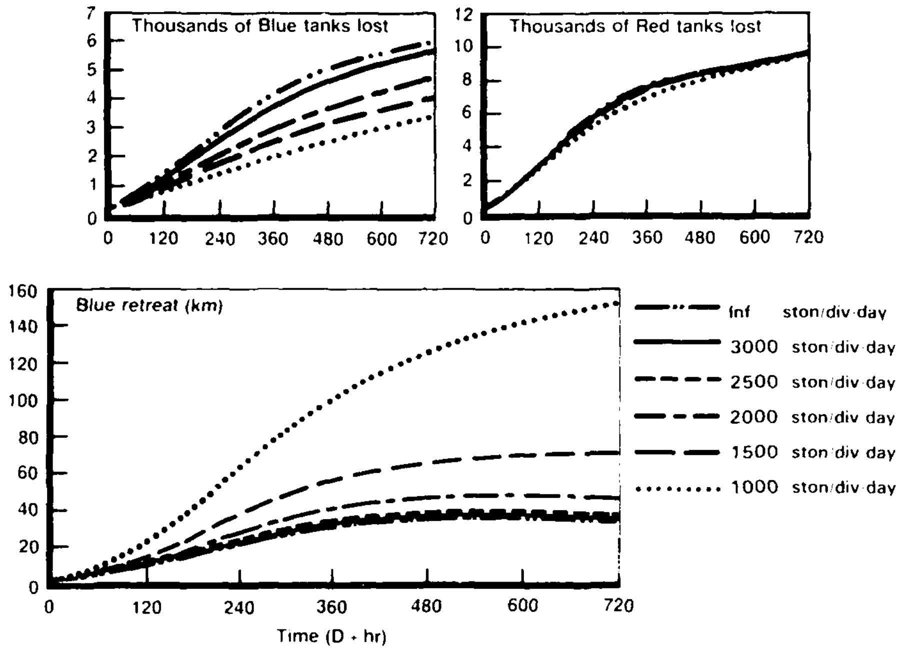
However one chooses to relate the capacity of a unit to the resources it has available, one must further estimate the dollar costs of the resources. In each of the spreadsheet models mentioned above, there is embedded a simple cost model that estimates the nonrecurring and annual recurring cost for the acquisition and the operation and support of the resources in a unit. The cost model can be used to estimate the overall cost of equiping and fielding a new unit, or it can be applied to incremental resources to estimate the cost of adding resources or people to an existing unit.

USING THE ALA-X METHODOLOGY

- Use LDM to estimate sensitivity of combat performance to:
  - Ammunition handling capacity
  - POL distribution capacity
  - Maintenance capacity
  - Stocks of war reserve ammunition
  - Other
- Identify targets of opportunity
  - If combat performance is especially sensitive, consider adding to capacity or stock
  - If combat performance is relatively insensitive, consider cutting back
- Use logistics functional models to estimate:
  - Resources needed to increase capacities or stocks by various amounts
  - Resources saved or liberated when capacities or stocks are reduced by various amounts
  - Cost increments and decrements, as functions of capacity/stock increases or decreases

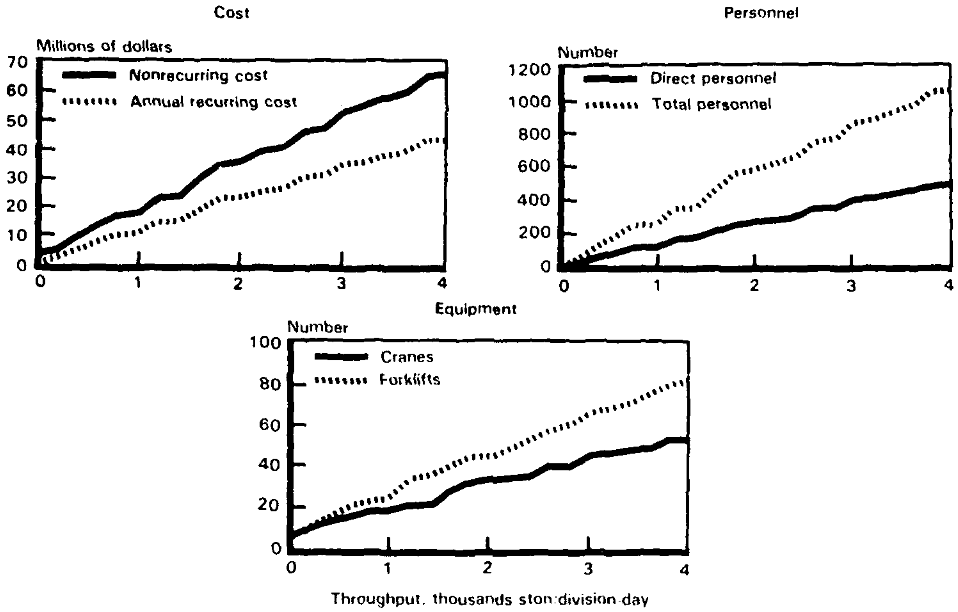
I anticipate the ALA-X methodology will be used as follows. A user first establishes a base case for LDM, in which the available resources and logistics capacities reflect the current situation or a specified future situation. Typically, this will closely match the FORCEM case to which LDM was calibrated. Then the user runs several LDM excursion cases in which various logistics capacities and stocks of resources are varied. He is seeking stocks or capacities to which combat performance measures are either exceptionally sensitive, or exceptionally insensitive. As discussed earlier, the Army might wish to structure their five-year program to favor the former at the expense of the latter. Once such stocks or capacities have been identified, the user can run the appropriate logistics functional models to determine what specific resources he might add to or delete from the Army program, and what effect these additions or deletions might have on cost.

SENSITIVITY OF COMBAT PERFORMANCE TO BLUE AMMUNITION HANDLING CAPACITY (from LDM)



This slide shows how several combat performance measures depend on Blue ammunition handling capacity. (In a real analysis, the user would employ LDM to generate many displays like this one, each showing the effects on combat performance of varying a different capacity or stock.) The version of LDM that generated these estimates is calibrated to a FORCEM test case, so the numbers should be considered illustrative only. Combat performance appears to be especially sensitive to ammunition handling capacity when that capacity is lower than 1500 tons per division per day. By contrast, once the ammunition handling capacity reaches 2500 tons per division per day, there seems to be little additional benefit to be derived from further increases.

RESOURCES IN DS/GS AMMUNITION COMPANIES (Heavy division slice)



For each of LDM's capacities or resource quantities the user varies in his analysis, he will run the appropriate logistics functional model. This slide is a sample output from the ALA-X ammunition distribution model, showing the numbers of pacing items (cranes and forklifts), people, and the nonrecurring and annual recurring costs of providing a range of ammunition handling capacities. These are the peacetime costs of creating and supporting entirely new DS and GS ammunition handling companies to provide the capacity. In this case, the costs appear to be proportional to capacity, amounting to about $17,000 nonrecurring cost and $10,000 recurring cost per year for each ton per day of capacity. The costs might well be different if one instead achieved capacity increases by modernizing existing units, or increasing levels of organization, or buying equipment they should have but do not.

The user would generate many displays such as this slide and the previous one, showing the benefits (FLOT movement, losses) and the costs (people, equipment, and dollars) of changing the Army program by adding or deleting a variety of capacities and stocks of resources. By comparing the benefits and costs across different capacities and stocks, he could arrive at a more balanced program, one that provides greater combat effectiveness for each logistics dollar spent.[4]

---

[4]To paraphrase something the reviewer of this Note wrote: "A user of this methodology will have an enormous data processing problem in managing an exercise—keeping track of runs and their data, knowing what he has learned, directing his search for superior alternatives. What is the possibility of a meta-model to assist?" This is a real problem, not only in this instance but in many others. But we have not addressed it in the ALA-X project.

ARMY ACTIVELY ADOPTING THE ALA-X METHODOLOGY

- Procedures for using methodology being jointly devised by
  - Project sponsor on the Army Staff (DALO-PLA)
  - Logistics Evaluation Agency (LEA)
- LEA has built a preprocessor to generate LDM inputs
  - Implements the "universal" logistics functional model based on TOEs, ALOs, and C-ratings
  - Has borrowed special rules for DS/GS ammunition company capacities from the ammunition distribution model
  - Will implement additional special rules for other units
- LEA is revising LDM's representation of many logistics functions
  - Requires changes to input data only

So far, the ALA-X methodology has been well received by the Army. The Logistics Evaluation Agency (LEA) and the project sponsor on the Army Staff (The DCSLOG's Director of Plans and Operations) are jointly devising ways to use it in support of the Army program. LEA has built a preprocessor for LDM that uses the dBase database management software package to prepare inputs from standard Army files. The preprocessor estimates most unit capacities by applying the "universal" logistics functional model discussed earlier—the model based on TOEs, ALOs, and C-ratings. But LEA has borrowed special capacity rules for selected unit types from the spreadsheet-based logistics functional models developed at the Arroyo Center. (LEA can also use the spreadsheet models independently to examine in greater detail the relation between physical resources and capacities, and to estimate resource costs by various cost elements and appropriation categories.) LEA is in addition revising the way a number of logistics activities are represented in LDM (it is possible to do this by changing the input data only, and leaving the computer program unaltered).

Given LEA's active participation in this project, and their initiative in changing it to be more to their liking, I am optimistic that the ALA-X methodology, or something descended from it, will continue to be used and further developed once the project ends. There is a realistic chance, therefore, that the ALA-X project may lead to an improvement in the quality of the multi-billion dollar logistics portion of future Army budgets.