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Data and models to build supply blocks for deploying Marine Corps units

Gue, Kevin R.

Monterey, California. Naval Postgraduate School, Department of Systems Management

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Data and Models to Build Supply Blocks for Deploying Marine Corps Units*

by

Kevin R. Gue

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1100 23rd Ave.
Port Hueneme, CA 93043

NAVAL POSTGRADUATE SCHOOL
Monterey, California 93943-5000

RADM Robert C. Chaplin
Superintendent

Richard Elster
Provost

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This report was prepared by:

Kevin R. Gue
Assistant Professor
Department of Systems Management

Reviewed by:

Reuben T. Harris
Chairman
Department of Systems Management

Released by:

David. W. Netzer, Associate Provost and
Dean of Research

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Kevin R. Gue

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Naval Postgraduate School
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Abstract

We describe a methodology for developing repair parts inventories for deploying Marine Corps units, including data collection and sparing models. Deployed units provide an excellent opportunity to make local corrections to systemic data collection and maintenance problems. We show how to use that data to establish spares levels for Class IX repair parts with an availability-based sparing model.

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Kevin R. Gue

Department of Systems Management

Naval Postgraduate School

Monterey, CA 93953

`krgue@nps.navy.mil`

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1 Building a supply block

For decades military and academic logisticians have worked on the problem of stocking deployed units that cannot be resupplied. The problem is currently solved in the context of aviation packup or fly-away kits, submarine parts inventories, and has even been extended to the space shuttle, where periodic resupplies are allowed [5].

A deploying Marine unit is similar in many respects to these applications. The unit must choose a group of items to support random failures of multiple weapons systems, with the goal of providing the "best support." Resupplies are possible but sporadic; and the unit must maintain the highest possible state of readiness, in case of a contingency. Unlike most problems in the inventory literature, issues of holding, ordering, and shortage costs are essentially irrelevant. The measure of success is simply having the part when it is needed. The Marines call the list of items taken on deployment a *supply block.*

In the past, supply blocks have been assembled by a process that incorporates relatively crude historical information with several iterations of manual review of thousands of individual line-items. Lack of decision support tools and the large number of items have forced planners to use personal experience and anecdotal advice to construct the supply block, rather than sound methodology.

The resulting supply blocks typically perform poorly. The First Force Service Support Group (FSSG) at Camp Pendleton reports that fill rates from supply blocks are typically less than 40%.

We make two contributions in this paper: First, we describe a simple inventory model, based on maximizing end-item availability, that represents an improvement over the current program for generating supply blocks. Second, we describe the data collection requirements for the model, and argue that the Marine Corps should use deployed units to begin implementing availability-based models throughout the Fleet Marine Force.

2 A sparing model

Sparing models can be divided roughly into two types: demand-based and availability-based. Demand-based models set inventory levels for individual items based on demand and holding, ordering, and shortage costs. These models are often inappropriate for military systems because inventory investment is an *output*, and because shortage cost is usually difficult to specify. Availability-based models set levels for a *group* of items (typically for a specific weapon system) simultaneously, and are based on demand and a budget constraint or target *availability*, which is the fraction of time that a system is available for use.

The recent proliferation of inventory models based on availability has led to some ambiguity of terminology; thus, we define for our purposes a demand-based model to be any inventory model whose primary goal is minimizing cost. We define availability-based models to be any model having the primary goal of achieving the maximum availability of some system. (We avoid the common term *Readiness-Based Sparing*, because it is often associated with a specific *implementation* of availability-based modeling used by the Navy.)

In 1985, the Department of Defense (DoD) directed the Services and the Defense Logistics Agency (DLA) to begin managing and determining levels for spares using methods based on readiness. This is in contrast to traditional methods based on demand, which are commonly found in commercial firms. Since that time the Services have been moving steadily, albeit slowly, toward such methodologies. The Navy, Air Force, and Army have all made progress in the past several years, and they have encountered immense challenges, mostly relating to data quality and availability.

The Marine Corps is just beginning to consider availability-based models, and so finds itself behind the other Services in model development, data collection, and cultural acceptance. Recently, the Deputy Chief of Staff, Installation and Logistics commissioned the Center for Naval Analyses (CNA) to study a number of issues in inventory support, including the transition to readiness based methodologies. CNA has issued a number of reports [2, 3, 6] from that study.

Several variations of availability-based models exist in DoD and industry. The Army has developed the SESAME and OSRAP models; the Navy uses RBS WORKSTATION and, for aviation applications, PC-ARROWS; the Air Force uses the AAM model. A commercial package called VMETRIC by Systems Exchange, Inc. of Pacific Grove, CA was developed by Dr. Craig Sherbrooke, who developed the theoretical foundations for all availability-based models.

2.1 Availability-based models

Availability-based models seek to maximize the availability of an end-item by constructing the best mix of repair parts for a given budget. We give a brief description of the theory as background to the proposed model for deployed Marine Corps units. A thorough treatment of the theory behind availability-based models can be found in [5]. Williamson et al. [6] give a shorter presentation.

The distribution of random failures for low-demand items, such as those found in repairable systems, is often modeled with the Poisson distribution. If the number of failures per year has mean m, then the probability of observing x failures in time T is

$$p(x) = \frac{(mT)^x}{x!} e^{-mT}.$$

We can show that maximizing the availability of an end-item is equivalent to minimizing the number of expected backorders over time. Naturally, the expected backorders for an item depends on how many of that item are in stock; the higher the stock level, the lower the expected backorders. The expected backorders for an item having stock level s is

$$EBO(s) = \sum_{x=s+1}^{\infty} (x - s)p(x).$$

To find an optimal mix of items for a system, we calculate the total expected backorders assuming no stock ($s_i = 0$) for all items i. We then add one unit of that item having the greatest marginal reduction in expected backorders per unit cost c_i; that is, we choose that item maximizing the expression,

$$\frac{EBO(s_i) - EBO(s_i + 1)}{c_i}.$$

We continue in this way until the available budget is exhausted.

The theory for availability-based models can be extended to include multiple echelons of supply and multiple indentures of components, as well as many other system characteristics [5].

2.2 BlockBuilder: Sparing for deployed units

We propose for deploying Marine units a model that minimizes expected backorders during the deployment; or equivalently, maximizes the number of requisitions filled out of the supply block. The model, called BLOCKBUILDER, is based directly on the theory of availability-based models, except that it treats total system cube as the constraint, rather than system cost. This is consistent with interviews we have had with several logistics planners at Camp Pendleton.

We implement the theory as given above, slightly modified to include a multiplier for essentiality: We compute marginal benefit with the expression

$$e_i \left(\frac{EBO(s_i) - EBO(s_i + 1)}{v_i} \right).$$

At each step, the model adds to the supply block an additional unit of that item that yields the greatest marginal benefit. It continues until the maximum volume of the block is reached. We use a simple heuristic at the end of the search to use up as much of the available volume as possible.

We develop the essentiality multipliers e_i by assigning to each end-item a code representing one of the following categories: CRITICAL, VERY IMPORTANT, IMPORTANT, or DESIREABLE. Each importance rating is associated with a multiplier between 0 and 1. For example, CRITICAL might be 1, VERY IMPORTANT 0.7, and so on. If the HMMWV is deemed CRITICAL for an upcoming operation, then the alternator that supports it would have multiplier $e_i = 1$. If a secondary item supports more than one end-item, we assign to it the multiplier of the highest importance code among all the end-items it supports. Given a set of importance codes specifically developed for a deploying unit, the model customizes the block to meet its mission.

The model also easily handles minimum and maximum quantities. For example, suppose that planners know for certain that they will need 2 units of a certain gasket for maintenance. The model begins with those units in the block and proceeds as before. If there are only 8 of the gasket available in the entire intermediate-level inventory, then planners can establish this as the maximum quantity. The model will calculate quantities as normal, and if it reaches 8 gaskets, that NSN is deleted from the candidate list. Laforteza [4] gives further detail of the model and its implementation for a deployed Marine Expeditionary Unit.

We implemented the model in a computer program written in Java. We chose the Java language because it is object-oriented and relatively easy to translate into other languages. We also wanted to enhance the possibility that it might be used in an Internet application in the future. Having the code in Java would make it easy to modify the application to operate on the web.

2.3 Assumptions

There are important assumptions in the model. First, we assume that the failure of any item has the same effect on unit readiness as the failure of any other item. This assumption is reasonable when considering only Combat Essentiality Code (CEC) 5-6 items. If lower CEC's are considered, we could set aside a certain portion, say 80%, of the block to accommodate CEC 5-6 items, and fill the balance with lower codes. This would ensure that most of the block was devoted to critical items.

We also assume that there is no resupply for the block. While this is certainly not the case in practice (units receive resupplies at almost every port call), planning for the no resupply case is appropriate because the mission of the MEU requires that it be self-sustaining for a defined period of time, typically 30 days.

3 Data requirements

One of the major obstacles to implementing availability-based methodologies for the military services has been data availability and quality. We describe the requirements for availability-based models and suggest a new way to stratify data to better plan for deployments.

Data requirements for demand- and availability-based sparing models are listed in Table 3. For intermediate-level stocks, the Marine Corps uses a demand-based sparing model (DBS) that computes a required days of supply (DOS) for each item and a reorder point (ROP) at which to order. Other data items are required, as indicated in the table.

An equivalent availability-based model (ABM) would require readiness or cost goals, as well as information about failure rates. Ivancovich et al. [6] gives a detailed discussion on the use of failure rates and demand data for availability-based models.

Also listed in Table 3 are the two possible methods of specifying supply blocks. Data requirements for the current GenPak program are a subset of those kept for the DBS model, with the exception of needing to know the density for all deploying end-items.

The BlockBuilder model uses the same input as the GenPak, with the exception of needing cube information for every item and the total cube for the block.

3.1 Data sources and quality

The Marine Corps uses several logistics information systems. All of them are being tied together with the Common Data Repository (COMDAR), which provides a way for each system to talk to the others. Ivancovich et al. [2] reports the four sources of data for an availability-based system in the Marine Corps:

- Marine Corps Integrated Maintenance Management System (MIMMS),

Data Element		*Model*			
Support Policy Data	Source	DBS	ABM	GenPak	BBuilder
Operating level	M,S	●			
Safety level	M,S	●			
OST level	M,S	●			
DOS		●		●	●
RO	S	●			
ROP	S	●			
Repair Cycle Level	M,S	●			
A_o goal			●		
Budget goal			●		
Weight/Cube goal			○		●
Fill rate goal			○		
Weapon System Data					
End-item criticality			●		○
End-item density			●	●	●
Indenture structure	A		●		○
Reliability Block Diagram			○		
End-item usage			○		○
Spares data					
NSN	S	●	●	●	●
Cost	S	●	●		
Weight/Cube			○		●
SM&R Code	S	●	●	○	○
CEC	S	●	●	●	●
Pipeline Data					
Demand	S	●	●	●	●
Failure rate			○		○
Order-ship time	S	●	●		
Repair rate/MTTR	M	●	○		
Washout rate	M	●	○		
Repair cycle time	M	●	●		○
Deployment Data					
Environment					○
Climate					○
Intensity rate					○

Table 1: Data requirements for demand- and availability-based inventory models. Data sources are SASSY (S), MIMMS (M), and Applications File (A). Elements listed with ● are required; elements with ○ could be used to enhance the models.

- Supported Activity Supply System (SASSY),
- Applications File in MCLB Albany, and
- Marine Corps Automated Readiness Evaluation System (MARES).

These will continue to be the primary databases for maintenance planning, in addition to the MAGTF-2 and MDSS databases, which are associated with deploying units specifically.

As Table 3 suggests, the Marine Corps currently has the capability to collect almost every data element necessary for future logistics planning models. The significant exception is failure rates.

To accurately specify the expected demand for an item, we must know three things: its tendency to fail, the number of items installed, and the level of use of the associated end-items. The Marine Corps' information systems record the aggregate measure of *demand*, which is really a combination of all three data elements.

Knowing failure rates is especially important for stocking deploying units, because the number of end-items may vary widely between deployments. As suggested in Ivancovich et al. [3], accurately recording failure rates is very difficult across a large population of end-items, because those end-items drop in and out of service often, and usage can be difficult to track. Deployed operations are different because the number of end-items is well-established, and usage can be easily estimated. This makes deployments an ideal domain in which the Marine Corps can develop operational failure rates for sparing models.

While the existence of relevant data elements is not a problem; the quality of that data is. Ivancovich et al. [2] identified several problems with current Marine Corps data:

No readiness or cost goals RBS methodologies require that the planner specify a readiness target or a budget available for sparing. Neither have been established for end-items in the Marine Corps. These data are important for maintenance planning, because a commander may desire a higher state of readiness for tanks than he does for HMMWV's.

Incomplete indenture structure Currently all Class IX items are associated with their appropriate end item(s) in the Applications File maintained at MCLB Albany, but only at the first indenture level; that is, an engine that supports a 5-ton truck is associated with that truck, and so is a pump that supports the engine. The fact that the pump supports the engine is not recorded. This type of data is necessary to manage and determine spares levels for repairable systems, and is specifically needed for high-quality availability-based solutions.

Missing or inaccurate criticality codes Interviews with Marine logisticians suggest that the criticality codes assigned to repair parts are not reliable and contain inconsistencies. For example, an alternator may be CEC-6 (highest importance) for an end item, but the mounting bracket required for the alternator is

CEC-2. A sparing methodology based on criticality may choose the alternator and not the bracket, when in fact the bracket is needed for the repair.

Missing or inaccurate supply and maintenance data Data elements in the MIMMS and SASSY databases are absent in some cases and of questionable reliability in others. Of particular concern to our proposed sparing model is the fact that volume for parts is often missing. Any sparing method that attempts to maximize effectiveness of a supply block for a limited volume needs cube data for individual items.

3.2 Satisficing, or "higher quality garbage"

Improving the logistics data situation in the Marine Corps will take many years and much money. In the short-term, models will have to make due with the data that are available, while making reasonable assumptions about its quality. For example, the current GenPak program, which generates supply blocks for deploying units, uses demand data to determine recommended quantities. Even though this data is not reliable in all cases, maintenance planners will continue to use it, at least until appropriate databases contain better information.

We contend that data quality should not impede the progress toward availability-based methods. Because the models themselves are superior to demand-based methods, even with poor input they will achieve better solutions that can be obtained currently.

For example, the Navy conducted a test of availability-based methodologies on the USS AMERICA's AVCAL, even though there was no indenture information. The results suggested that *America* could save $33 million in aviation repair parts inventory with essentially no degradation in readiness by using an availability-based model [1].

"Garbage in, garbage out" goes the modeling maxim. Availability-based methods do not improve the garbage going in, but we contend that a higher-quality garbage comes out.

3.3 Special requirements for deployments

Because deployed operations are different than regular in-garrison operations, we propose segregating that demand in order to develop tailored demand history for deploying units. The demand data need not be separately maintained, but rather a key must be maintained to access appropriate data.

For example, every requisition from a deploying unit has an associated unit code (called a *RUC*) that identifies the unit making the requisition. To access all requisitions from deployed units, we need only know the RUCs of those units. Demand data for those RUCs could be retrieved directly from the COMDAR.

We can further stratify demand data by recording the operating environment for the deployed unit. Table 2 lists the environment variables chosen by DCS Corporation during development of the Maintenance Deployment Commodity Planning Tool, a software planning tool begin developed for deploying Marine units.

Variable	Values
Environment	Ship, Shore, Both
Climate	Desert, Jungle, Temperate, Mountain, Cold, Frigid, Polar
Size of Unit/Event	MEU, CAX, MPS, JTF
Interval	Length of deployment
Type of deployment	Operation, Exercise, Training
Location	CONUS, OCONUS
Echelon	2^{nd}, Limited 3^{rd}, 3^{rd}, Limited 4^{th}, 4^{th}

Table 2: Data elements and suggested values for deployed operations

The intent behind the stratification scheme is to allow the planner of an upcoming operation to identify demand levels that came from environments similar to his anticipated environment. For example, if an upcoming *OCONUS Operation* is a *MEU* deploying to a *Jungle* climate, the planner could retrieve data from similar operations.

We suggest building in some retrieval flexibility at this point, in order to accommodate planning uncertainty. For example, suppose the planner knows only that he is deploying to a *Desert* environment and is unsure of all other parameters. Then we need only run an appropriate database query requiring demand from RUCs for all *Desert* operations, letting all other variables be free. In this way, the data used to develop the block can be as customized as the planner's knowledge of the operation. Another reason to accommodate ambiguity is that there may not be sufficient observations to generate reliable demand estimates for a given operating profile. This will clearly be the case when the database is beginning to be populated.

3.4 Dealing with common items

Tracking demand for NSNs that support multiple end items requires that we know the EDL for each RUC in the database. For example, suppose that an alternator can be used in three unique end-items. Data from past deployments would reflect total demand for the alternator across all three end-items, each of which may have been different in number for each deployment.

There are two ways to associate demand for an item to the mix of end-items in the EDL. The most precise, but most difficult, method requires that we track for each requisition the end-item associated with the demand. For example, if the alternator supporting three vehicles fails on a HMMWV, we must record one demand for a HMMWV-alternator pair. Current Marine Corps information systems do not have this capability.

A less precise, but easy-to-implement method is to estimate demand using multiple regression. Suppose that secondary item i supports multiple items. If we know the number n_j of each end-item for every demand observation (deployment), we can estimate demand for a future operation as

$$d = \beta_1 n_1 + \beta_2 n_2 + \beta_3 n_3 + \ldots,$$

where n_1 is the number of units of end-item 1 in the EDL, n_2 is the number of end-item 2, and so on, and the β's are multiple regression coefficients. Note that this method will not work for in-garrison operations because the number of each type of vehicle changes over time.

4 Conclusions

Much of the difficulty of operating an availability-based model for intermediate- and operational-level stocks is related to the current inability to measure failure rates [2]. The Marine Corps is unable to calculate failure rates from demand because there is no way to track the density and usage of end-items.

Deployed units provide an excellent opportunity to correct this systemic data problem on a local level. Because we know the exact number of end-items from the EDL, and we know how long the deployment was, we can establish fairly good estimates of failure rates over time. This should provide good input to the availability-based model we propose. More importantly, a small-scale implementation of availability-based models will ease the way for a wider implementation in the future; and as data quality improves, solutions to the models will improve.

Even without reasonable failure rates, an availability-based model should perform better than the GenPak because it optimizes the contents of the block with respect to the cube of individual items.

In summary, we recommend the following:

- The Marine Corps should establish appropriate databases to record information on deployed units and their supply blocks. Specifically, they should record the EDL, total cube, estimated intensity rate of operations, and environment data for all deployed operations.
- An availability-based model for supply blocks should be tested and implemented. Testing can be done easily with past data, with no effects on current operations.
- Cube data for all repair parts should be measured and recorded. This should become required data for provisioning any new weapon system.

References

[1] Anne J. Hale, *Analysis of* America*'s Readiness-Based Sparing Aviation Consolidated Allowance List*, CNA Research Memorandum 94-140, December 1994.

[2] John S. Ivancovich, Brian L. Butters, Barbara H. Measell, and William Williamson III, *Toward an Improved Marine Corps Class IX Requirements Process*, CNA Research Memorandum 98-84.09, May 1998.

[3] John S. Ivancovich, Brian L. Butters, Barbara H. Measell, and William Williamson III, *Developing an Operational Failure Indicator for Class IX*, CNA Research Memorandum 98-85.09, May 1998.

[4] Leonard Laforteza, Inventory Optimization of Class IX Supply Blocks for Deploying U. S. Marine Corps Combat Service Support Elements, Master's Thesis, Naval Postgraduate School, Monterey, CA, 1997.

[5] Craig C. Sherbrooke, *Optimal Inventory Modeling of Systems*, John Wiley & Sons, Inc., 1992.

[6] William Williamson III, John S. Ivancovich, Brian L. Butters, and Barbara H. Measell, *A Primer on Using Readiness-Based Sparing To Determine Marine Corps Class IX Requirements*, CNA Research Memorandum 98-86.09, May 1998.

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Kevin R. Gue **Code SM/Gk** **Naval Postgraduate School** **Monterey, CA 93944**	**5**