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MBA PROFESSIONAL REPORT

Improving Utility in the Marine Corps Depot Level Maintenance Program

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December 2004

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13. ABSTRACT ***)***

The Marine Corps operates a Depot Level Maintenance Program (DLMP) to support the continued operation of principal end items. Principal end items require periodic induction into the DLMP. This maintenance consists of major systems overhauls aimed at extending the life cycle of the principal end item. The frequency of these inductions is different for each end item. The number of systems requiring induction into Depot Level Maintenance in a given year is always greater than the funding available in that year resulting in a constraint. The Marine Corps has attempted to optimize the utility received from the DLMP through the use of a model that takes a number of variables into consideration resulting in a schedule for end-items to be inducted into the DLMP.. This model makes the most efficient use of available funding by creating the largest increase in readiness reporting possible given the constrained budget. The changing operational requirements in light of current conflicts and future operations tempo have made the current DLMP process problematic.

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IMPROVING UTILITY IN THE MARINE CORPS DEPOT LEVEL MAINTENANCE PROGRAM

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Submitted in partial fulfillment of the requirements for the degree of

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IMPROVING UTILITY IN THE MARINE CORPS DEPOT LEVEL MAINTENANCE PROGRAM

ABSTRACT

The Marine Corps operates a Depot Level Maintenance Program (DLMP) to support the continued operation of principal end items. Principal end items require periodic induction into the DLMP. This maintenance consists of major systems overhauls aimed at extending the life cycle of the principal end item. The frequency of these inductions is different for each end item. The number of systems requiring induction into Depot Level Maintenance in a given year is always greater than the funding available in that year resulting in a constraint. The Marine Corps has attempted to optimize the utility received from the DLMP through the use of a model that takes a number of variables into consideration resulting in a schedule for end-items to be inducted into the DLMP. This model makes the most efficient use of available funding by creating the largest increase in readiness reporting possible given the constrained budget. The changing operational requirements in light of current conflicts and future operations tempo have made the current DLMP process problematic. This project proposes to analyze the current process, to include the DERO model, the relationship between the DERO model and the DLMP, and the "human factor" decisions that go into the final implementation and execution of the DLMP. The expected product from this project is a recommendation to Marine Corps Systems Command and Marine Corps Logistics Command on a process that improves the DLMP over the long run, given the new operational environment faced as a result of the Global War On Terror.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAO	Approved Acquisition Objectives
ASEC	Analytical Systems Engineering Corporation
BOM	Bill of Materiel
DC, I&L	Deputy Commandant, Installations and Logistics
DC, P&R	Deputy Commandant, Programs and Resources
DERO	Dynamic Equipment Repair Optimization
DLH	Direct Labor Hours
DLMP	Depot Level Maintenance Program
DMFA	Depot Maintenance Float Allowance
DOD	Department of Defense
EAF	Equipment Allowance File
FYDP	Future Years Defense Plan
HQMC	Headquarters United States Marine Corps
ICCE	Individual Clothing and Combat Equipment
LMIS	Logistics Management Information System
MCCDC	Marine Corps Combat Development Command
MCDSS	Materiel Capability Decision Support System
MCGERR	Marine Corps Ground Equipment Readiness Reporting
MCLC	Marine Corps Logistics Command
MCO	Marine Corps Order
MCPC	Marine Corps Program Codes
MCSC	Marine Corps Systems Command
MPS	Maritime Prepositioning Ships
NALMEB	Norway Air Landed Marine Expeditionary Brigade
NGREA	National Guard and Reserve Equipment Appropriations
O&MMC	Operation and Maintenance Marine Corps
O&MMCR	Operation and Maintenance Marine Corps Reserve
PEI	Principal End Item
PEI STRAT	Principal End Item Stratification
PIP	Product Improvement Program
PM	Program Manager
PMC	Procurement Marine Corps
POM	Program Objectives Memorandum
PPBS	Planning, Programming and Budgeting System
R&E	Replacement and Evacuation
SCS	Stock Control System
SLEP	Service Life Extension Program
SOW	Statement Of Work
Supply Class VII	Principal End Items
Supply Class II	Individual Clothing and Combat Equipment
T/E	Table of Equipment
T/O	Table of Organization
WMR	War Materiel Requirements

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I. INTRODUCTION

The United States Marine Corps Depot Level Maintenance Program (DLMP) is a system of interconnected and dynamic processes which, when combined, are intended to maximize equipment readiness. The three essential functions of the DLMP include identifying and validating the maintenance work to be accomplished via a requirements determination process, identifying who can perform the maintenance on the requirements, and establishing a program execution framework in order to report status and identify cost, schedule, and performance metrics. Since the goal of this project is to improve one specific part of the DLMP system, we will not address several of the peripheral processes included in the overall DLMP. The aspect of the DLMP that this report will focus on is the DLMP requirements determination process.

The current DLMP requirements determination process was used for the first time in 1998 for Program Objectives Memorandum (POM) 2000. Prior to 1990, the Marine Corps maintained adequate rotational and out of service stocks of Principal End Items (PEI) to simultaneously satisfy the operational requirements of the operating forces and maintain depot skills and capability. However, due to diminishing financial resources and competing priorities, the depot maintenance program required increased scrutiny of requirements. Therefore, the DLMP requirements determination process was studied to develop alternatives, institutionalize and modify improvements, and examine other models and business case tools that would objectively quantify decisions and recommendations made to senior leadership both internal and external to the Marine Corps. This process of objective quantification by achieving shareholder consensus through the use of warfighting values and operational availability optimization in a constrained resource environment via the Dynamic Equipment Repair Optimization (DERO) model is a matter of much contention.

A. PURPOSE

The purpose of this project is to offer methods to increase the efficiency and level of stakeholder satisfaction in the current DLMP requirements determination process.

This project seeks to offer alternatives that may be implemented to improve the current DERO model based requirements determination process and alternatives to the DERO model based requirements determination process that are both more easily understood by the DLMP stakeholders and applicable to both the requirements determination and execution processes. Currently, the DERO based requirements determination system is a strategic method to support the Marine Corps' POM process (i.e. requirements determination). While one could argue that DERO accomplishes this objective, it does not translate well to DLMP execution. As the I Marine Expeditionary Force Maintenance Management Officer described using DERO during DLMP execution, "It's like using a strategic tool to solve a tactical problem."

B. REVIEW OF RELATED LITERATURE

Congressional Appropriations Committees' questioning of the credibility of the Services' forecast of depot maintenance requirements in conjunction with the Fiscal Year 1989 Budget resulted in the Defense Resources Board identifying the requirement for a detailed assessment of depot maintenance requirements and the relationship of funding levels to readiness and sustainability (O'Malley, T. J. and Bachman, Tovey C., 1990). An examination of several years of Air Force budgets in the late 1980s revealed that POM estimates of Air Force depot maintenance requirements were overstated when compared to actual obligations, that overstating requirements diminishes confidence in the requirements determination process, and that cuts in depot maintenance funding had little to no discernible effect on readiness rates. The authors explain the overstating of depot maintenance resource requirements by comparing the requirements provided in the POM submission with the resources provided by Congressional Appropriations and corresponding obligations. Between Fiscal Years 1980 through 1988, obligations exceeded POM submissions in five years and POM submissions exceeded obligations in four years. The given reasons for cuts in depot maintenance not having a discernible effect on readiness rates has to do with how the Air Force manages its parts inventory. Essentially, parts inventories are maintained in two channels. One channel supports actual peacetime training with parts maintained at one of five maintenance depots while the other channel supports predicted wartime requirements, or War Readiness Spares Kits

(WRSK). When peacetime training parts inventories were exhausted, material managers treated the WRSK as safety stock and inducted those parts into the depot maintenance process. This combining of the two parts inventories resulted in actual depot maintenance resource requirements being distorted and ultimately unpredictable. The lack of reliable predictions of peacetime depot maintenance resource requirements are due to a number of factors, the most obvious of which is changes in the flight hour program. The authors recommend a modification of the currently used Aircraft Availability Model to better capture depot level maintenance requirements and the associated and supporting resource requirements.

The U.S. Air Force uses a highly regimented flight hour program as a means to determine its depot maintenance resource requirements. Operational commands use the flight hour program to predict what services they will require from the Depot Maintenance Activity Group (DMAG). This prediction model requires strict adherence to specified flight hour programs (Air Force Materiel Command Instruction 21-128, 1997). As operational commands execute their flight hour programs, they use established average cost per flying hour metrics to predict how much of their annual budget they should apportion to the DMAG to support their aircraft readiness (Keating and Camm, 2002). The authors examine the continuous shortcomings that the Air Force Materiel Command encounters in providing the support and services to its operational customers. They report that Air Force Materiel Command's expenditures on its DMAGs are inconsistent with flying hours across different platforms. Keating and Camm hypothesize that DMAG expenditures are more complex than simply flying hours and can be broken down to two all encompassing representative groups, variable costs and fixed costs. Under their hypothesis, flight hour programs represent variable costs and represent an accurate predictor of only about forty-two percent of DMAG expenditures. DMAG fixed costs have many categories, all with a high degree of variance. The authors point out that programmed depot maintenance is scheduled in the POM years out from the current year and are therefore unrelated to current year operations. This leads to unscheduled maintenance costs in the year of execution being attributable to variations in flight hour programs and therefore causes a negative correlation between flight hours and depot maintenance requirements determination. Long lead times in spare parts procurement (sometimes causing demand or delivery to occur years after the obligation), overhead, and specifics of the government employed civilian labor force all contribute to DMAG fixed costs that are unrelated to flight hour programs. While the substance of this literature is solely the relationship of flight hours to DMAG resource determination, the suggestion that DMAG funding can be broken down into fixed and variable costs could contribute to a better understanding of the many, and often conflicting, depot level maintenance requirements determination aspects.

The General Accounting Office (GAO) reports that services are overstating their depot maintenance requirements (General Accounting Office, 1995). The report briefly describes the Air Force and Navy requirements determination process and contrasts their differences. Both models operate on a prediction methodology based on requirements drivers to determine depot maintenance resource requirements. In reporting that the services are overstating their depot maintenance requirements, the GAO uses demonstrable evidence to prove that obligations from the depot maintenance funding appropriations were significantly less than what was originally submitted in the POM. In budget years '93, '94, and '95, the services' stated depot maintenance backlog decreased by $288 million, $216 million, and $730 million respectively between the times that the budgets were submitted and the appropriations were signed. Between 1993 and 1995 the services received about $516 million more than requested for depot level maintenance. Service officials acknowledge that all funds received for depot maintenance are not necessarily used for that purpose. The report goes on to give valid explanations for the discrepancies. In general, depot maintenance backlogs, and corresponding requirements, tend to decrease during the year of budget execution. After the 1995 budget submission, an Army restructuring initiative was approved that resulted in the phasing out of older helicopters from the Army inventory. This resulted in a significant movement of assets from the unfunded to the funded category of depot maintenance requirements. At the beginning of fiscal year 1994, the Air Force's Air Combat Command depot maintenance backlog was $130 million. Throughout the year, the Air Force divested itself of numerous aging B-52s and F-111s, resulting in a depot maintenance backlog of only $60 million. This force reduction decreased the depot maintenance requirements for these aircraft and allowed other aircraft to move from the unfunded list to the funded list, decreasing the depot maintenance backload. It becomes clear that there is a distinct disconnect between depot maintenance requirements determination and depot maintenance execution. The report recommends several Congressional oversight controls to mitigate the effects caused by a lack of distinction between depot maintenance requirements determination and execution.

C. SUMMARY OF DIRECTIVE GUIDANCE AND BACKGROUND RESEARCH

The following section includes a brief synopsis of all directives and published information relative to the Marine Corps' DLMP and its requirements determination process. These synopses are included in order to provide the reader with a framework from which to understand the institutional goals and methodology of the Marine Corps' DLMP.

During 1997 the Analytical Systems Engineering Corporation (ASEC) was commissioned by the United States Marine Corps to execute a study of the DLMP (ASEC, 1998). Specifically, ASEC was commissioned to develop a process and methodology by which the unconstrained list of PEI's requiring depot repair can best be aligned to warfighting capability, evaluated using best business life cycle management principals, prioritized for depot level repair, and support a balanced and reasonable projection of the highest priority mission essential ground equipment needs that are adjusted for business and management considerations of the Marine Corps. While the scope of the ASEC study is much larger than the concentration of this MBA project, many topics and ideas are overlapping and interrelated. Recommendations and conclusions offered by the study specifically related to the DLMP requirements determination process include:

(1) That at the time of the study the DLMP process did not have sufficient formalized publications and directives.

(2) That Mission Areas be discontinued as the primary linkage between maintenance priorities and warfighting utility. Mission Areas correlate the

degree of use of equipment with where that equipment is assigned and the assigned unit's mission as stated in current operations plans.

(3) That Scenario Based Processes be automated, implemented and executed to link maintenance priorities and warfighting values with other variables such as pacing items, current operational posture, readiness and rotation programs. Scenario Based Processes correlate the degree of use of equipment with likely combat scenarios considering real world situations.

(4) That Marine Corps Combat Development Command (MCCDC) and Program Managers take a more active role in the DLMP process.

Marine Corps Order 4790.19, subject DEPOT MAINTENANCE POLICY, publishes the Marine Corps policy for depot maintenance. The mission of the Marine Corps depot maintenance policy is to provide depot maintenance support to the operating forces and to maintain an optimum state of contract, organic and interservice depot maintenance in support of the Marine Corps force structure and mobilization plans. Of particular note, this Order's concept of operations states that the Order does not prescribe total Marine Corps policy for depot maintenance; rather it contains only those policies essential to an integrated management system. As the reader should understand from this report, the operational level of the Marine Corps DLMP experiences policy conflict in determining to exactly what ends the integrated management system is intended to achieve. Said another way, in a constrained resource environment, conflict is created by the competing demands for limited resources intended to accomplish both operational availability of Marine Corps ground equipment and the support of capabilities and infrastructure of the maintenance depots.

Marine Corps Order 4400.193, subject MARINE CORPS STRATIFICATION OF PRINCIPAL END ITEM (PEI STRAT) PROCESS POLICY, establishes policy, responsibilities, and authority associated with the PEI Strat process. The PEI Strat process is used by DC, I&L to assess Marine Corps ground equipment asset posture against requirements as defined by the Commanding General, MCSC. A key element of the PEI Strat process is that it is used in the POM development process for DC, P&R. Generally, the difference between the logistics data (i.e. operational availability) contained in the PEI Strat process and the current and forecasted requirements placed on Marine Corps ground equipment assets is used to develop POM initiatives which, in turn, result in Legislation authorizing and appropriating programs such as the DLMP. Specifically, the PEI Strat process is used in support of:

(1) Allowance visibility

(2) Asset visibility

(3) Materiel capability (readiness / sustainment)

(4) Depot Level Maintenance Program

(5) POM development/budget execution

(6) Combat Development Process

(7) Force structure development and review

(8) Wargaming

(9) Modeling / "what if" scenarios

(10)Distribution of assets throughout the Marine Corps

All supply class VII (principal end items) and II (Individual Clothing and Combat Equipment (ICCE)) items required by the Marine Corps are included in the PEI Strat process.

Marine Corps Order 4400.194, subject MARINE CORPS CLASS VII STOCK ROTATION POLICY is a key reference in Marine Corps Order 4790.19, subject DEPOT MAINTENANCE POLICY. Complimenting the depot maintenance policy, the stock rotation policy is designed to enhance readiness, prolong service life, and achieve the full use of assets prior to disposal by helping commanders facilitate the rotation of selected principal end items while preserving the strategic capability of the prepositioning programs. The stock rotation policy model states that equipment in using units, such as operational units, that receives the most usage should be rotated with available equipment which receives considerably less usage (e.g. administrative storage/deadlines, prepositioned stocks, etc.). A centrally planned and coordinated stock rotation policy achieves its goal by rotating new or reconditioned equipment to replace worn equipment, and by spreading usage equally among all equipment. Properly executed, the stock rotation policy should serve as one way to optimize the DLMP by capitalizing on economies of scale as greater numbers of PEIs age concurrently and become candidates for depot level maintenance. The current DLMP requirements determination process accounts for principal end items subject to any rotation policy (e.g. the Replacement and Evacuation Program (R&E), Service Life Extension Program (SLEP), Midlife Rebuild Program, and the Product Improvement Program (PIP)).

D. DLMP REQUIREMENTS DETERMINATION PROCESS OVERVIEW

The DLMP process owner is the Supply Chain Management Center, Marine Corps Logistics Command. Stakeholders in the DLMP include: Deputy Commandant, Installations and Logistics (DC, I&L); Deputy Commandant, Programs and Resources (DC, P&R); Commander, Marine Corps Logistics Command (MCLC); Commander, Marine Corps Systems Command (MCSC); and the non-aviation operating forces.

The requirements determination process begins with a decision support system called the Materiel Capability Decision Support System (MCDSS). The MCDSS is a data warehouse which functions to capture several dynamic logistics metrics related to PEI operational availability and produce PEI Stratification sheets. PEI Stratification sheets provide a synopsis of equipment requirements balanced against on-hand assets and display the status, location, and operational availability posture of PEIs at a particular point in time in a prioritized sequence. The MCDSS draws its dynamic information from Marine Corps boss files. Boss files include various automated data sources such as:

(1) Logistics Management Information System (LMIS)

(2) Stock Control System (SCS)

(3) Marine Corps Ground Equipment Readiness Reporting (MCGERR)

Logistics metrics related to PEI operational availability included in the MCDSS include:

(1) Unserviceable PEIs held in depot stores

(2) PEI Stratification projection of future unserviceable items using nine quarters of unserviceable return history

(3) Program Manager (PM) established rotation programs

(4) PM scheduled rebuilds and mid-life overhauls

(5) Depot level Service Life Extension Programs (SLEP)

(6) Scheduled depot level maintenance

The PEI Stratification process begins the requirements determination process by relating PEI systems to requirements in a readiness (i.e. operational availability) prioritized sequence and depicting what, if any, depot maintenance action needs to be taken to support the PEI. Stratification includes only the current fiscal year's portion of the LMIS Equipment Allowance File (EAF) and includes planned allowances through the Future Years Defense Plan (FYDP). The PEI Stratification process also accounts for Approved Acquisition Objectives (AAO) for PEI systems that are being replaced at the end of their service life. The Depot Maintenance Float Allowance (DMFA) supports the DLMP. The DMFA is a quantity of mission essential, maintenance significant equipment that is available in depot storage, and included in the AAO, which allows for exchange with out of depot stores deadlined equipment without detracting from a unit's readiness condition and assigned mission capability.

Once the Marine Corps Logistics Command Supply Chain Management Center has completed the PEI Stratification sheets, they are delivered to the DLMP stakeholders previously listed. After the DLMP stakeholders have had an opportunity to review the PEI Stratification sheets produced by the MCDSS, they meet at a DLMP requirements conference for the purpose of reaching a consensus on the depot level maintenance requirements for each PEI. In addition to achieving a consensus on requirements for each PEI, Program Managers provide a Statement of Work (SOW) that can be used to calculate an initial rough order of magnitude of the Direct Labor Hours (DLH) to perform the required work and a Bill of Materiel (BOM) for the necessary materiel to complete the work. DLH and BOM costs are calculated to determine the total unit repair cost to be used in POM development.

The next step in the requirements determination process is to assign numerical warfighting values for all PEIs designated for depot level maintenance. This function is performed by DC, I&L. Since the establishment and designation of warfighting values is critical to the output of the next step in the requirements determination process, the DERO model itself, and serves as the basis for this report, we will cover this topic in greater detail later in the report.

Once warfighting values have been assigned to the PEIs listed on the PEI Stratification sheets, a warfighting capabilities list results. The warfighting capabilities list is simply the PEI Stratification sheets which include the warfighting values assigned to each group of PEIs. Commander, MCLC is charged with selecting items from the warfighting capabilities list to be funded with the limited amount of money that will eventually be made available to support the DLMP program. The selection is accomplished via the DERO optimization model and will be discussed in greater detail later in this report. The DERO model considers the following important input factors:

(1) Calculated equipment scores (i.e. from the warfighting capabilities list)

(2) Current rotation programs identified by the Commander, MCSC

(3) PEI Stratification

(4) Commander, MCSC's procurement initiatives and phase out plans

(5) Allowance data establishing the USMC War Material Requirement (WMR)

(6) Minimum PEI target operational availability percentages approved by Commander, MCLC

(7) Tentative annual program budgets provided by DC, P&R

Once the Commander, MCLC generates the DERO optimized list of PEIs selected for depot maintenance based on the above factors, particularly the constrained resource factor represented at factor (7), POM submissions are prepared for consideration by DC, P&R among competing resource interests and ultimately included in the Planning, Programming and Budgeting System (PPBS). At the commencement of each fiscal year when Congress passes budget execution authority to the Marine Corps, Operation and Maintenance Marine Corps (OMMC) and Operation and Maintenance Marine Corps Reserve (OMMCR) funds are allocated to the Marine Corps Program Codes (MCPC) which support the DLMP.

II. DLMP REQUIREMENTS DETERMINATION PROCESS

The authors were sponsored by Marine Corps Systems Command and Marine Corps Logistics Command to attend the Fiscal Year 2005 DLMP Requirements Determination Conference held at Marine Corps Logistics Base, Albany, Georgia during August, 2004. The following paragraphs relate the insight the authors gained by attending the conference relative to DERO model implementation, warfighting values and their associated sensitivity to DERO model output, the role that repair costs play in DERO model based requirements determination, process inputs, process outputs and their associated use, format, and flexibility, and stakeholder dissatisfaction with the current process. These insights give rise to our suggestions to improve the current DERO model based requirements determination process or use an alternate, utility based, requirements determination process.

A. REQUIREMENTS DETERMINATION PROCESS

The Fiscal Year 2005 Off-Cycle DLMP Requirements Determination Conference was convened on 17 August, 2004 by the Supply Chain Management Center, Marine Corps Logistics Command and concluded on 20 August, 2004. This DLMP cycle (i.e. the FY'05 Off Cycle) was convened specifically for the purpose of conducting DLMP requirements determination resulting from the $65.56 billion Congressional Defense Appropriation to support the Global War on Terrorism, of which $2.8 billion was specifically appropriated for Defense depot level maintenance. Normally, these conferences are held only during POM planning (i.e. odd numbered) years. Attendees at the conference included all DLMP stakeholders, specifically representatives from the following commands and activities:

1. Marine Corps Logistics Command Supply Chain Management Center
2. Marine Corps Logistics Command Studies and Analysis Department
3. Marine Corps Systems Command Acquisitions and Product Support
4. Marine Expeditionary Forces
5. Marine Forces Reserve

6. Deputy Commandant, Programs and Resources
7. Enhanced Equipment Allowance Pool, Marine Corps Air Ground Combat Center, Twentynine Palms, California
8. Program Groups responsible for life cycle management of like groups of principal end items
9. Blount Island Command

The first order of business was to provide attendees copies of the PEI Stratification sheets containing all PEIs under consideration. Each PEI was briefed within the context of its program group by the representative from the Supply Chain Management Center. As each PEI was briefed, any stakeholder could address information contained on the PEI stratification sheet for that PEI. The most common issues raised as the meeting progressed through the PEI list were unserviceable returns and warfighting values (i.e. inputs to the DERO model that are most easily manipulated by the stakeholders). It is important to note that stakeholders raised these issues in an attempt to assign important PEIs the weight required for the DERO model to pick them up as candidates for induction into depot level maintenance.

The beginnings of stakeholder dissatisfaction with the current process could be determined at this point. As the nature of the DERO model based requirements determination operates on the principle of maximizing Marine Corps wide readiness levels in a constrained resource (i.e. budget) environment, some stakeholders will get their desired PEIs into the DERO output at the expense of other stakeholders not getting their PEIs funded. This process naturally results in stakeholder conflict. Marine Expeditionary Force Maintenance Management Officers desire to see the PEIs they deem as most important to their current operations given the highest weights on the DERO input variable scales. Other activities, such as Blount Island Command (i.e. Maritime Prepositioning Forces) and the Enhanced Equipment Allowance Pool desire to see the same thing for their preferred PEIs. Yet other groups, such as the individual Program Groups whose livelihoods depend on receiving business from the DLMP, are at odds and in competition with all the other program groups. There are eight different program groups. Finally, all M1A-2 main battle tanks on the PEI stratification sheets were directly funded for depot level maintenance in a non-competitive nature by the program manager due to funding being specifically allocated to an Army maintenance depot which performs depot maintenance on the tanks.

On 19 August the discussion of the individual PEIs on the PEI stratification sheets concluded and the representatives from the Marine Corps Logistics Command Studies and Analysis Department who run the DERO model were brought into the discussion. Changes from the original PEI stratification sheets resulting from the discussions of each of the PEIs were briefed to them. They, in turn, took all the information from the previous three days of individual PEI discussions and began to input the data into the DERO model input variables. Throughout the evening of 19 August, the two DERO model operators attempted to run the DERO model. On thirteen separate occasions, the DERO model "crashed" and the operators had to recode portions of the program and/or data in an attempt to get the model to function properly.

On the morning of 20 August, the final day of the conference, the DERO output was to have been briefed to all the assembled stakeholders. When the model operators attempted to display the data on an overhead projector, no one in the room could interpret what they were seeing. Questions began to arise about what the output data represented. Challenges were made by some stakeholders about the results of the DERO run based on what weights they had assigned to the input variables of several of the PEIs. Discussions ensued between the conference hosts, Supply Chain Management Center, and the DERO operators, Studies and Analysis Department, regarding what input variables should and should not have gone into the DERO run and the manner in which the output was intended to be presented. At the end of this conference segment which concluded the conference, the conference hosts decided that they would work more closely with Studies and Analysis Department on another DERO run and that they would e-mail the results out to the conference attendees the following week. It was our sense that the DERO model had lost credibility. For example, one participant joked that he thought DERO stood for "Doesn't Ever Really Operate."

B. DERO MODEL

When the authors first arrived at Marine Corps Logistics Command, they spent several hours meeting with the DERO model operators and talking about the internal workings of the DERO model. With the exception of the five inputs discernible in the piecewise linear objective function, the DERO model requires forty-seven additional input variables including inputs from the rotations model. For a detailed list of these inputs, refer to the DLMP Handbook cite. When questioned by the authors about what some of the input variables meant, the operators replied that they had never used many of the variables and that in some cases they simply "zeroed out" inputs that they either did not receive information for or received information for that did not match the input variable requirements.

In a joint discussion with representatives from both the Supply Chain Management Center and Studies and Analysis Department about the DLMP Requirements Determination Conference, representatives from the Supply Chain Management Center asked the Studies and Analysis Department to make iterative DERO runs of the FY'05 Off Cycle data in twenty million dollar increments. The logic of this request is supported because Marine Corps resource managers frequently want to know what they could do if they were able to secure additional resources (e.g. "What should I send through DLMP if I had an additional $20 million?"). In an attempt to apply this logic and support the request, the DERO operators manipulated the budget function of the DERO model to reflect twenty million dollars. When the model ran, the output PEIs selected in the first twenty million dollar increment were removed from the PEI data set, and the DERO model was set to run again at twenty million dollars. This process was repeated until all PEIs on the stratification list were included in the DERO output and no PEIs were left to fund/repair. Six iterations at $20 million each were required to include all PEIs in the DERO output. What the Supply Chain Management Center representatives were attempting to do was to produce a prioritized list of which PEIs to send to depot level maintenance from most important to least important (i.e. first to last). The authors pointed out that because DERO is an optimization model, the results from three runs at $20 million each would not match the results of one run at $60 million, nor would the output results of any specific $20 million run be reflected in a prioritized manner. The representatives acknowledged these points to be true, yet still insisted that the output data be presented in this manner because that was what the stakeholders expected to see.

C. ISSUES WITH WARFIGHTING VALUES, REPAIR COST, AND OTHER INPUTS

Warfighting values from the current DERO model based requirements determination process are derived from the current edition of the Marine Corps Bulletin 3000 "Table of Marine Corps Ground Equipment Resource Reporting (MCGERR) Equipment." The warfighting values are 1, 2, 3, and 4 with 4 being the highest score (i.e. should influence DERO model output the most). Every PEI listed on the PEI stratification sheets is assigned a warfighting value from one to four based on that PEI's level of importance as reported in the Marine Corps Bulletin 3000. The intent in assigning warfighting values to PEIs as a DERO model input is to make some PEIs more or less competitive than others thereby influencing DERO model output. This is the reason that so much time was and is spent in DLMP requirements determination conferences assigning specific warfighting values to individual PEIs.

It should be noted that the present warfighting values of one through four are ordinal numbers. Ordinal numbers are used only for ranking (Keller and Warrack, 2003). These numbers do not imply that a ranking of four has twice the value of a ranking of two or four times the value of a ranking of one. The DERO model ignores this fact and includes the ordinal warfighting values as a real-value scalar in its objective function.

The ASEC study covered earlier (ASEC, 1998) included in its recommendations that varying quantitative warfighting capabilities be developed and that all PEIs be ranked by relative warfighting capabilities as a methodology to assign limited funding for depot level maintenance. This methodology relates warfighting capability to the relative utility of depot level maintenance funding based on the principle of marginal utility. The ASEC study recommends a system of three gradations to differentiate warfighting capabilities among all PEIs. The authors present a similar methodology for assigning quantitative warfighting capabilities but with a system of four gradations which will be explained in the next chapter. Both the ASEC study and the methodology proposed by the authors provide for a means to further stratify the differences between warfighting values and to increase their relative effects on the DLMP requirements determination process over the current process. Furthermore, the authors learned by attending the DLMP requirements determination conference and seeing the results that the present system of assigning warfighting values seems to have, in many cases, no bearing on DERO output. That is to say that changing a PEI's warfighting value from one to four may not necessarily alter the output of a specific DERO run when all other variables are held constant.

D. DEFERENCE TO REPAIR COST

The present DERO based requirements determination process optimizes readiness given a certain budget but with no consideration given to unit repair cost. This methodology fails to consider the economic concept of marginal utility because unit repair cost is not an input variable to the DERO model. Marginal cost and marginal benefit considerations could allow material managers to get a greater "bang for the buck" in readiness than the current DERO optimization model provides. In a hypothetical example, DERO would choose to repair low density items to an acceptable level of readiness at the expense of all other higher density items assuming that the low density items had a sufficiently high unit repair cost relative to the depot maintenance budget. While DERO does exactly what it is intended to do, maximize readiness independent of cost, the authors present an alternative model based on economic utility that considers the cost of achieving readiness increases across all PEIs.

E. INCONSISTENCY OF INPUTS

As mentioned above, there are a number of inconsistencies inherent in the current application of the DERO model based requirements determination process. Because the DERO operators either do not always have data for all DERO input variables or can not make the data they receive fit the DERO model input variables, several data input variables to the DERO model are normally "zeroed out." This would lead one to assume that the same DERO run would have different outputs depending on which input variables had been zeroed out. The idea of running the DERO model in twenty million dollar increments in an attempt to provide the stakeholders with a prioritized list of which PEIs to send to DLMP is simply not a correct application of the DERO model. While the stakeholders indeed desire to see a prioritized list, it is impossible for the current DERO model to provide one. Finally, because the DERO model is a POM support tool, it is run primarily during the POM development process during even numbered years. This means that the DERO output from the POM years should not be changed between POM years. However, as recent world events have proven, circumstances change vastly between POM years. All of this suggests that the DERO model may not be the best alternative to use for DLMP execution

F. DERO MODEL OUTPUT; ITS USE, FORMAT, AND FLEXIBILITY

As stated above, the representatives from the Supply Chain Management Center manipulated the DERO model input in an effort to present the DERO model output in a manner they thought stakeholders expected to see; that is in a prioritized sequence from most important to least important in the context of DLMP selection. It is impossible to present DERO model output in its present form in this manner since the DERO model simply optimizes readiness given a specific budget. The DERO model does not present output in any sort of prioritized sequence because output prioritization is not part of the DERO optimization model. For stakeholders, this format offers limited use and offers no flexibility. Stakeholders desire to have a prioritized list of DLMP candidate PEIs that they can pick and choose from based on changing resource and/or operational environments. In all other military contexts, operational (i.e. execution) planning is based on equally suitable yet differentiated courses of action that can be quickly selected based on dynamic situations. By contrast, the DERO model offers only a "take it or leave it" solution. If a resource manager wanted to change one input variable for one PEI in order to attempt to get that PEI included in the DERO model output, the entire DERO model output may change. The DERO model operators told the authors that there is no way to tell why a particular PEI was included in the DERO model output and why another one wasn't.

G. STAKEHOLDER DISSATISFACTION

Essentially, stakeholders are dissatisfied with the current DERO model based requirements determination process largely because it is too complex, it offers stakeholders little opportunity to influence DERO output based on changing resource or operational environments, and the DERO model does not adequately support DLMP execution. This widespread dissatisfaction with the current system has resulted in the Deputy Commandant for Installations and Logistics chartering a Best Value Equipment Sustainment Working Group. While the Best Value Equipment Sustainment Working Group is a topic separate from the scope of this project, it does recommend updating or replacing the current DERO model. A large part of the Working Group intent is to allow the DLMP to more effectively represent warfighter requirements. In the following sections, the authors offer methodologies to support this effort.

III. METHODOLOGY

A. WARFIGHTING VALUES

1. Introduction

The original goal of this project was to design a better system to develop and assign Warfighting Values (WFVs). That is, to find a more effective was to assign the variable that ultimately defines how important a piece of equipment is to the Marine Corps. Many of the stakeholders are not satisfied with the WFVs used in the current process and really do not have a clear understanding of how they are generated or what impact they have. Additionally, as a result of this study, it was discovered that the current WFV attribute does not significantly impact the current model. In other words, the current method being used to determine WFVs is not only unpopular with the stakeholders, but it is also not doing what it was intended to do (this was also documented in the meeting minutes for a DLMP Working Group in 2003). For this reason, it is imperative that WFVs be assigned in a manner that adds real value to the model.

2. Choosing Attributes

WFV is an attribute intended to capture the warfighting capability a Principal End Item (PEI) provides to the Marine Corps and the end user. In other words, the greater the WFV is for a PEI, the greater the value is to the warfighter. The current method used to develop WFVs, and the concerns associated with this process, was covered extensively in Chapter II. In this section, the focus will be on a new, more beneficial approach to developing WFVs that should add significant value to the DLMP.

Rather than assigning a WFV score from 1 to 4 to a PEI, it is more advantageous to define attributes that are important to the warfighter first. Once these attributes are defined, PEIs can then be compared to one another based on these attributes. Although there is still some subjectivity involved in choosing specific attributes, the overall result is a much more objective process. The process described by the authors will also allow the users to assign a WFV based on much more diverse criteria than the current process of assigning a score from 1 to 4. Although the authors have a combined total of 34 years of experience working with PEIs as managers and as end users, the most logical approach to defining what makes a PEI important to the warfighter was through personal interviews with key stakeholders in the DLMP. In July 2004, key players involved in the DLMP, to include the Maintenance Management Officers from each MEF, were interviewed at the DLMP conference in Albany, Georgia. These interviews, along with further research into the current process, and the use of the brainstorming tool in Criterium DecisionPlus (which will be discussed in depth later in this chapter) led to the following attributes being defined as the most important in defining quality WFVs: MCGERR Reportable, Lifecycle Indicator, Source of Requirement, and Combat Weapon System. These factors are described in more detail below.

While every effort was made to be systematic, more rigorous methods exist for the collection and assessment of the qualitative data obtained through unstructured interviews with key players involved with DLMP (see e.g., Denzin & Lincoln, 2000). More rigorous procedures also exist to develop measures to validate the factorial structure developed by the authors (construct validity and factor analysis: see e.g., Pedhazur & Schmelkin, 1991). The authors chose not to apply these methods in part because the focus in this study is on the development and application of a procedure to obtain WFVs given a set of factors: not on the development of authoritative, static and final set of factors to be applied to all PEIs.

a. MCGERR Reportable

MCGERR reportable equipment is identified in Marine Corps Bulletin 3000, *Table of Marine Corps Ground Equipment Resource Reporting (MCGERR) Equipment*. Equipment included in this bulletin must be a principal end item that is 85-percent fielded Marine Corps wide (including the Reserves), nominated by either the field commands or Headquarters, Marine Corps, and accepted for inclusion by the DC, I&L. These PEIs are mission essential equipment that that are required to be reported to higher headquarters. The Commandant of the Marine Corps (CMC) uses the equipment readiness reporting in MCGERR to measure each unit's capability to perform its assigned mission. Due to its significance to the end users and the Marine Corps as a whole, readiness for the PEIs identified as MCGERR Reportable is evaluated on a weekly basis.

Therefore, due to the importance placed upon this type of equipment, MCGERR Reportable has been identified as a key attribute in defining relevant WFVs.

b. Lifecycle Indicator

Lifecycle Indicator is an attribute that captures where a PEI is in its lifecycle. In other words, it is an indication that a PEI is either in the early stage of its lifecycle (also know as infant mortality), in the middle stage of its lifecycle (also known as normal life period), or at the end of its lifecycle (wear-out period). Figure 1 is a graphical representation of these lifecycle stages called the bathtub curve. This curve consists of the infant mortality period, normal or "useful life" period (which has a low, relatively constant failure rate), and the wear-out period (which has an increasing failure rate). Wear-out is inevitable due to fatigue or depletion of materials. In other words, in the long run, everything wears out.

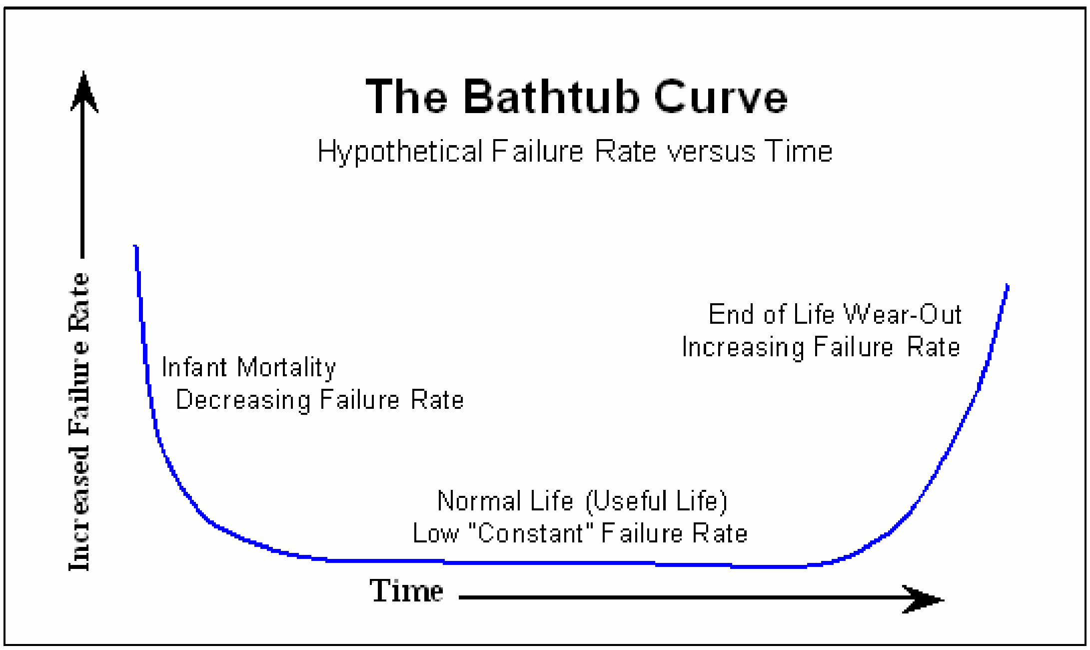

Figure 1. The Bathtub Curve

It is during this period, when reliability and operational availability are decreasing, that PEIs must be inducted into depot level maintenance. Quantity of WIRs/AAO is the equation that will be used as a lifecycle indicator. The greater the score for Quantity of WIRs/AAO, the more likely that a PEI is moving to the latter stages in its lifecycle. Simply stated, the higher the ratio of WIRs is to AAO, the more worn out the equipment is, and the more imperative depot level maintenance becomes to extend the equipment's lifecycle. It is important to note that combat WIRs may be an exception. Although a PEI with several combat-related WIRs may still be in the early stages of its lifecycle, a high Quantity of WIRs/AAO score is still a good indicator that it is in need of depot level maintenance to maintain operational availability. For this reason, Lifecycle Indicator has been chosen as a second WFV attribute.

c. Source of Requirement

Source of Requirement, also known as Waterfall Value, represents the unit that is requesting to induct equipment into depot level maintenance. More specifically, a Source of Requirement value will be applied to each PEI based upon the unit requesting service. Currently, waterfall value is a tool used for distributing PEIs as they come out of depot level maintenance. This is based on the theory that some units have priority over others due to their missions and operational tempo (e.g., a unit that is currently in a combat zone or real world scenario has a much higher priority than a Base unit in the States). Each unit is listed from most important to least important on a "waterfall" chart that is updated on an as needed basis. This distribution tool is a strong indicator of what equipment is important to induct into depot level maintenance. Therefore, due to the importance of the requesting unit, Source of Requirement was chosen as the most essential WFV attribute. It is important to note that although most PEIs have multiple sources; values for this attribute will be based on the highest priority source.

d. Combat Weapon Systems

For the purpose of this project, Combat Weapon System is any PEI that is actually used in combat (i.e., it is a PEI that actually fires live rounds at the enemy). Obviously, this is considered to be an important attribute due to the necessity of these PEIs being operationally available. Without these PEIs, missions cannot be accomplished. Therefore, Combat Weapon System was chosen as the final WFV factor.

It should be clear that, with the possible exception of Combat Weapon System, the factors that have been described by the authors are not static: MCGGER, Waterfall Values and lifecycle indicators may change from year to year for a given PEI.

Hence, a procedure is needed to systematically assign values to PEIs on each of these factors in an expedient manner, so that the procedure can be applied yearly. The authors describe such a procedure in the next section.

3. Criterium DecisionPlus

a. Overview

Once the desirable WFV attributes were selected, the next objective was to assign appropriate weights for each attribute in order to accurately reflect its importance to the warfighter. Once the weights have been established, the attributes could then be assigned to a sample of PEIs in order to measure their effectiveness in defining realistic WFVs. Rather than arbitrarily assigning numbers or weights to the attributes, the goal of this project was to be as objective as possible. Since this process involved several different criteria against which various alternatives were compared, tracking and rating the importance of those criteria presented a major challenge. Therefore, a decision management tool called Criterium DecisionPlus was chosen to assign value to the WFV attributes.

According to the Criterium DecisionPlus User's Guide, Criterium DecisionPlus implements the two primary decision-making methodologies currently being used by the government and commercial businesses alike; Analytical Hierarchy Process (AHP) and Multiattribute Utility Theory as implemented in the Simple Multiattribute Rating Technique (SMART). The main difference between the two is the rating techniques they use. SMART was the method of choice for this project. This technique breaks the decision problem down into attributes, and single attribute evaluations are constructed by means of value measurements. A value tree structure is created to assist in defining the problem, and values are determined for each attribute. Then, aggregation of the model results in facilitating comparison of the alternatives.

As the User's Guide states, the general approach most people use in decision making can be described as a process of logical activities. The first step is to define the problem. Not only must the goal be identified, the factors that are important or that can affect the decision must also be defined. Once the problem has been defined, brainstorming is a tool that can be used to identify all the issues that should be considered in the decision. Figure 2 illustrates the decision process that Criterium DecisionPlus supports. Criterium DecisionPlus's brainstorming capability assists in defining the problem and identifying the issues. In this step, the user starts with a clean canvas and finishes with the goal, important criteria, and alternatives identified.

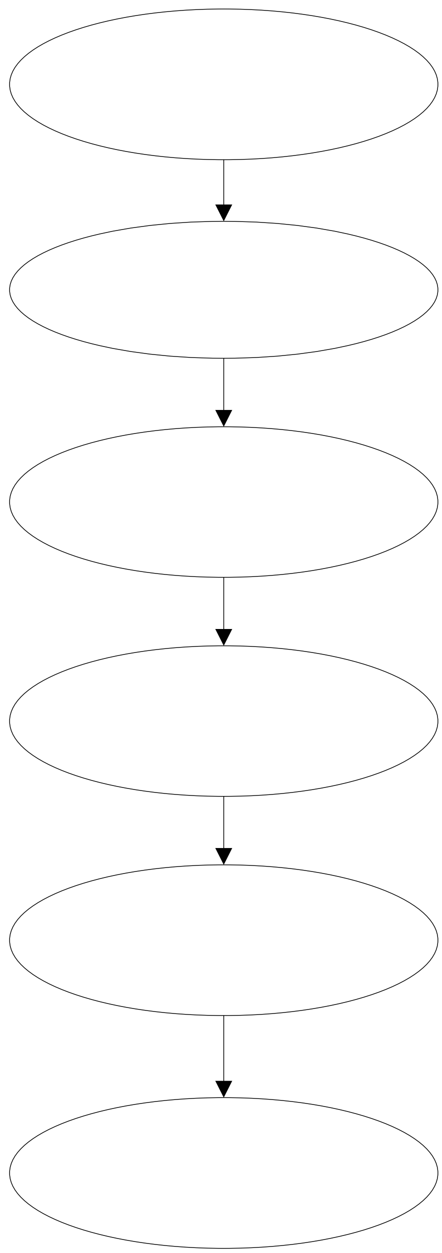

Figure 2. The Decision Process Diagram

The next step is to build the hierarchy, which can be generated by Criterium DecisionPlus automatically. It should be clear to the reader that Criterium DecisionPlus uses the term hierarchy because it allows for subfactors. The authors also refer to these subfactors as attributes or factors throughout the project. Rating the hierarchy, (i.e., judging or weighting the importance of the criteria and scoring the alternatives) is next. Weights can be entered and viewed in three ways; a numeric view, verbal view, or graphic view.

Full pairwise comparisons can be made by rating criteria against one another within its rating set or by using an abbreviated pairwise comparison that rates only subsets of all such pairs. The alternatives can then be rated against those criteria by assigning numeric, verbal, or graphic values. Using the SMART methodology, a function can be defined to determine the effective value of such ratings.

After the hierarchy has been rated, the results must be reviewed. Criterium DecisionPlus calculates in real time (i.e., it continually calculates results as the weights are entered so that if a value is changed, the results can be seen immediately). In Criterium DecisionPlus, the results can be viewed as discrete values (decision scores), which represent the preferences of alternatives, or as a screen that shows the contribution to each alternative preference based on the criteria at a given level in the hierarchy (contributions screen). This step also provides the opportunity to review the results from a common sense perspective. The user needs to ensure that the results make sense on a basic level.

The next step is to analyze the results. Criterium DecisionPlus determines how sensitive the decision is to changes in the relative importance assigned to criteria. It also prioritizes the list in order of most to least critical. This allows the user to focus on the criteria that can influence the decision the most. After the results have been analyzed using Criterium DecisionPlus, it should be evident that the preferred alternative, or final decision, is sound.

Finally, the decision must be documented in a manner that all interested parties can understand how and why the ultimate decision was reached. Not only will documentation provide insight into the decision making process, it also enables users to revisit the process if future events dictate change.

b. Methodology

This section is devoted to describing how the authors used Criterium DecisionPlus to assign weights to WFV attributes, which ultimately produces a ranked list of PEIs in order of WFV.

Since the overall goal was to assign weighted WFV attributes to each PEI, the first step was to set the goal in Criterium DecisionPlus's brainstorming session to "Assign WFV". The important criteria were identified as the four aforementioned attributes that were determined to be essential elements in determining the importance of each piece of gear; MCGERR Reportable, Lifecycle Indicator, Source of Requirement, and Combat Weapon System. A sample of 30 TAMCNs, or PEIs, was listed as the alternatives. This list was generated in a manner that would provide a fair distribution that would adequately represent the total population of PEIs that were eligible for depot level maintenance (e.g., combat weapon systems and non combat weapon systems, MCGERR Reportable and non MCGERR Reportable, current WFVs from 1 to 4, PEIs belonging to different units, etc.). A full list of the selected PEIs is listed in Table 1.

TAMCN	Nomenclature
A0966	Mobile EW Support System PIP
A1260	Navigation Set, Satellite Signals PLGR
A1440	Radar Set, Firefinder
A1503	Radar Set, 3D, Long Range
A2306	Sensor System Monitor, Mobile
A2505	Switchboard, Telephone, Automatic
A2635	Telephone Set
B0589	Excavator, Combat
B1291	Decontamination System, Ltwt
B1139	Hose Reel System (HRS)
B1580	Pump Module, Fuel (SIXCON)
B2086	Storage Tank Module, Water (SixCon)
B2460	Tractor, Full Tr (T5)
D0235	Semi-Trlr, Lowbed, 40T
D0080	Chassis, Trlr, GP, 3 1/2T, 2 Whl
D0877	Trlr, Powered, Wrecker/Recovery, 4X5
D0879	Trlr, Powered, 30T, Cargo, Dropside
D1092	Trk, Maint, Telephone
D1160	Interim Fast Attack Vehicle
E0150	Armored Vehicle, Launcher, Bridge
E0277	Display Group, Data
E0856	AAV, Recovery
E0930	Launch Simulator, Stinger
E0942	LAV, Anti-Tank
E0947	LAV, Light Assault, 25mm
E0960	Machine Gun, Lt, Squad, Auto Wpn
E0989	Machine Gun, Medium, 7.62mm
E1356	Recharging Unit, Coolant, Trng
E1888	Tank, Combat, FT, 120mm Gun
E3191	Trainer, Handling GM Launch (Stinger)

Table 1. List of PEIs used for this project

After the goal, important criteria, and alternatives were identified in the brainstorming session, the hierarchy could be generated. An example of the hierarchy is illustrated in Figure 3.

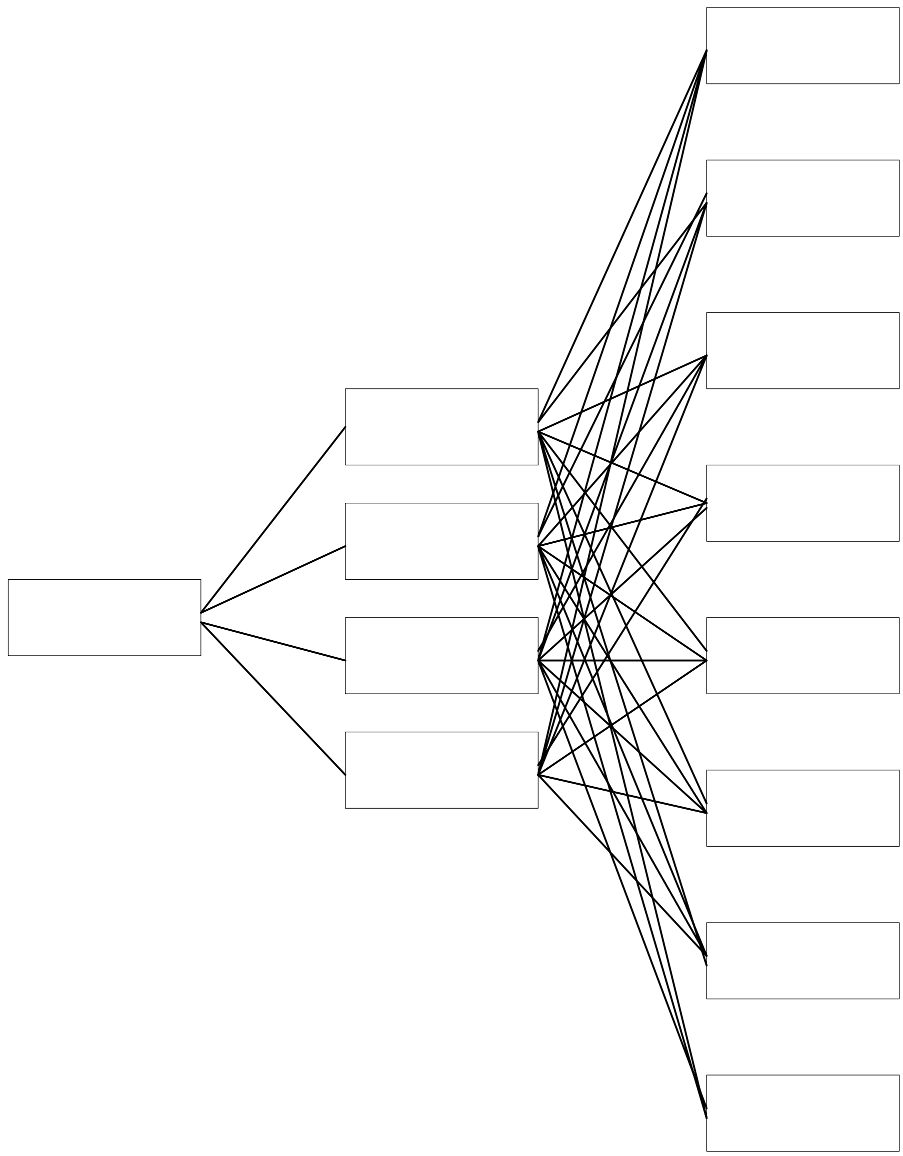

Figure 3. Example of the Hierarchy Produced by Criterium DecisionPlus

Once the hierarchy was built, it needed to be rated. The first step in this process was to choose the goal (Assign WFV Attributes) and rate the criteria (WFV Attributes) accordingly. More specifically, a weight from 1 to 100 had to be assigned to each of the four attributes based on its importance relative to the goal. Based on the interviews with key players in the DLMP and further research into the DLMP process, Source of Requirement was determined to be the most important attribute in assigning meaningful WFVs. As such, it received an overall weight of 100. Lifecycle Indicator and Combat Weapon System were selected as the next most important WFV attributes and received a weight of 90 each. Finally, the MCGERR Reportable attribute received a weight of 80.

Once all the weights were established for the four major attributes (criteria), scores had to be assigned for each PEI (alternatives) to reflect how each was impacted by the criteria. For the MCGERR Reportable attribute, a PEI either received a rating of 0 if it was not in the Marine Corps Bulletin 3000 or 100 if it was listed in the Bulletin. Additionally, TAMCNs received a score ranging between 10 and 100 for the Lifecycle Indicator attribute. Once the Quantity of WIRs/AAO calculation was complete for each PEI, this value was rated by percentage, then grouped and given a score depending on which group the TAMCN fell into. Table 2 illustrates these groups by percentages.

Lifecycle Indicator Scores

Value	Score
.1 or >	100
.08 - .09	90
.06 - .07	80
.04 - .05	70
.02 - .03	60
.009 - .01	50
.007-.008	40
.005 - .006	30
.003 - .004	20
.001 - .002	10
0	0

* **Note:** Numbers will be rounded up and given the appropriate score.
For example, if the value is .075, that TAMCN will receive a score of 90.

Table 2. Lifecycle Indicator Scores Based on WIR/AAO Calculations

Using the most current waterfall chart, Source of Requirement was also broken down into ratings ranging between 10 and 100. For example, a TAMCN that was needed by the operating forces, (e.g., II MEF) would be weighed more heavily than a TAMCN that was requested by the equipment stores in Norway. Table 3 illustrates the weights that were assigned to each unit for Source of Requirement.

Weights Assigned for Waterfall Value

Unit	Weight
I MEF/Special Mission	100
MPS	90
II & III MEF	80
29 Palms EEAP	70
Res T/A	60
Reserve Stores	50
DMFA	40
Norway	30
Gen. Supt. (Bases, etc.)	20
Net WRMR	10

Table 3. Weights Assigned for Waterfall Value (Source of Requirement) by Unit

Finally, the Combat Weapon System attribute was scored in a manner similar to the MCGERR Reportable attribute. If a PEI was a weapon that fired live rounds in actual combat, it received a rating of 100. If a PEI was not used in actual combat, it received a rating of 0.

To summarize the hierarchy rating process, each PEI was rated once by each of the four attributes (which were rated between 80 and 100 in the first step). For example, the TAMCN A1260 received a rating of 0 for MCGERR Reportable (because it was not in the Marine Corps Bulletin 3000), a rating of 60 for Lifecycle Indicator (because it received a score of .0227), a rating of 0 for Combat Weapon System (because it is not involved in direct combat), and a rating of 100 for Source of Requirement (because it was requested by I MEF). Each TAMCN was rated in a similar manner in order to obtain the final results. The scores for each PEI that were used as input into Criterium DecisionPlus are shown in Table 4 below.

TAMCN	Nomenclature	MCGERR Reportable Score	Lifecycle Indicator Score	Source of Reqt. Score	Weapon System Score
A0966	Mobile EW Support System PIP	100	80	80	0
A1260	Navigation Set, Satellite Signals PLGR	0	60	100	0
A1440	Radar Set, Firefinder	100	100	80	0
A1503	Radar Set, 3D, Long Range	100	0	80	0
A2306	Sensor System Monitor, Mobile	100	90	80	0
A2505	Switchboard, Telephone, Automatic	100	40	80	0
A2635	Telephone Set	0	50	80	0
B0589	Excavator, Combat	100	40	80	0
B1291	Decontamination System, Ltwt	100	10	80	0
B1139	Hose Reel System (HRS)	0	0	80	0
B1580	Pump Module, Fuel (SIXCON)	100	60	80	0
B2086	Storage Tank Module, Water (SixCon)	0	90	80	0
B2460	Tractor, Full Tr (T5)	100	50	80	0
D0235	Semi-Trlr, Lowbed, 40T	100	20	40	0
D0080	Chassis, Trlr, GP, 3 1/2T, 2 Whl	0	40	10	0
D0877	Trlr, Powered, Wrecker/Recovery, 4X5	100	50	80	0
D0879	Trlr, Powered, 30T, Cargo, Dropside	100	10	80	0
D1092	Trk, Maint, Telephone	0	0	80	0
D1160	Interim Fast Attack Vehicle	100	50	80	0
E0150	Armored Vehicle, Launcher, Bridge	100	0	80	0
E0277	Display Group, Data	100	0	10	0
E0856	AAV, Recovery	100	0	80	0
E0930	Launch Simulator, Stinger	0	0	40	0
E0942	LAV, Anti-Tank	100	100	80	100
E0947	LAV, Light Assault, 25mm	100	70	80	100
E0960	Machine Gun, Lt, Squad, Auto Wpn	0	60	100	100
E0989	Machine Gun, Medium, 7.62mm	100	60	80	100
E1356	Recharging Unit, Coolant, Trng	0	0	50	0
E1888	Tank, Combat, FT, 120mm Gun	100	80	90	100
E3191	Trainer, Handling GM Launch (Stinger)	0	0	60	0

Table 4. Summary of Input Used for Criterium DecisionPlus for Each PEI

c. Results

After all the alternatives (PEIs) received all four ratings, Criterium DecisionPlus generated the final scores. If the criteria have been weighted accurately and the alternatives have been rated in a logical manner, the PEIs receiving the highest scores should be those that belong to units within I MEF or units performing special missions, are MCGERR Reportable, have a high ratio of WIRs, and are directly involved in actual combat. In the scores and reports section, the five PEIs receiving the highest scores and the five PEIs receiving the lowest scores will be discussed in depth.

(1) Scores and Reports. The full list of scores ranked from highest score to lowest score is illustrated in Figure 4.

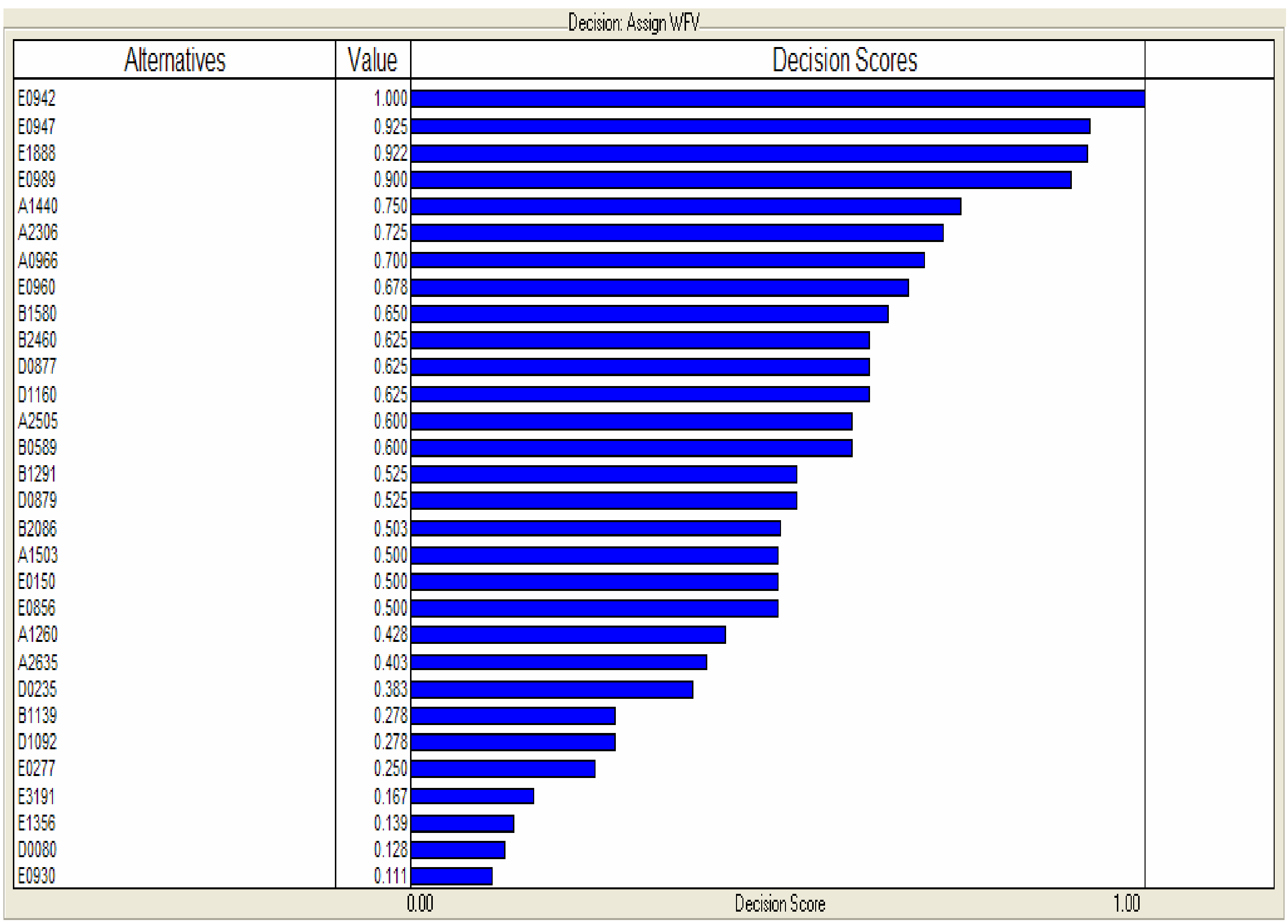

Figure 4. The Decision Score Report Produced in Criterium DecisionPlus

The PEI receiving the highest score was TAMCN E0942, LAV, Anti-Tank. This PEI is used in direct combat, is MCGERR Reportable, had a very high number of WIRs compared to AAO, and was nominated for induction by I MEF. Therefore, it received the highest possible score for each attribute, which gave it a final score of 1.000 (on a scale from 0 to 1). The second highest score, with a value of .925, belonged to E0947, LAV, Light Assault, 25mm. Obviously, this PEI is involved in direct combat as well, so it received a score of 100 for Combat Weapon System. It also received perfect scores for MCGERR Reportable and Source of Requirement (it belonged to I MEF). The main difference between the first and second PEI was the Lifecycle Indicator attribute (E0947 received a 70). E1888, Tank, Combat, 120mm Gun, was the third highest scoring PEI with a value of .922. In addition to receiving the maximum rating for the Combat Weapon System attribute, it received a 100 for MCGERR Reportable, a 90 for Source of Requirement (it belonged to MPS), and an 80 for Lifecycle Indicator. The PEI with the fourth highest score of .900 was E0989, Machine Gun, Medium, 7.62mm. Although this PEI received the highest possible ratings for the MCGERR Reportable, Source of Requirement, and Combat Weapon System attributes, it only received a 60 for Lifecycle Indicator. Rounding out the top five, was A1440, Radar Set, Firefinder. Although this PEI is not a system that fires live rounds in combat (it received a Combat Weapon System rating of 0), it received the highest possible values for the remaining three attributes. A value of 100 for Source of Requirement, which is the most heavily weighted attribute, is a key reason this PEI is in the top five.

The situation is much different for the five lowest scoring PEIs. The PEI that ranked fifth from the bottom was E0277, Display Group, Data, with an overall value of .250. This PEI received a 100 for the MCGERR Reportable attribute, but only received a 10 for Source of Requirement (which indicates that for this specific DLMP cycle, it is being inducted by a unit that is very low on the waterfall chart). Furthermore, E0277 received a score of 0 for both the Lifecycle Indicator and Combat Weapon System attributes. E3191, Trainer, Handling GM Launch (Stinger) was ranked fourth from last with a score of .167. It received a 60 for the Source of Requirement attribute, but rated a score of 0 for the MCGERR Reportable, Lifecycle Indicator, and

Combat Weapon System attributes. Ranked third from last was E1356, Recharging Unit, Coolant, Training, with a total value of .139. This PEI received a 50 for Source of Requirement and a score of 0 for each of the remaining three attributes. With an overall value of .126, D0080, Chassis, Trailer, GP, 3&1/2T, 2 Whl, was the second from last PEI. It did receive a 40 for Lifecycle Indicator, but only scored a 10 for the Source of Requirement Attribute. Once again, this PEI received a 0 for the remaining attributes. Finally, E0930, Launch Simulator, Stinger, was ranked as the last PEI with a total value of .111. It received a score of 40 for Source of Requirement, but rated a 0 for the MCGERR Reportable, Lifecycle Indicator, and Combat Weapon System attributes.

(2) Analysis**.** At first glance, the results definitely pass the sanity check (or common sense) test. The most heavily weighted attribute, Source of Requirement, obviously impacted the scores as expected. The PEIs also seem to be ranked in a logical manner. Criterium DecisionPlus is equipped with tools that enable users to analyze results on an even deeper level. The Contribution by Criteria report is one such tool. It is expected that the criteria with the highest accumulated weight to contribute more toward the results than the others. However, if all the alternatives score low on those criteria, those criteria's contribution to the overall decision score of the alternatives may be less than expected. Through Criterium DecisionPlus's contribution by criteria analysis, the criteria that actually made the largest contribution and the least contribution can be easily seen. The result is a good indication whether the decision is a reasonable one or not, and if the weights are sensible or not.

Figure 5 illustrate the contribution by criteria for each of the top five PEIs. The pie charts illustrate the accumulated values of the five alternatives at a target criterion (the goal), broken down by the contribution from each of the criterion.

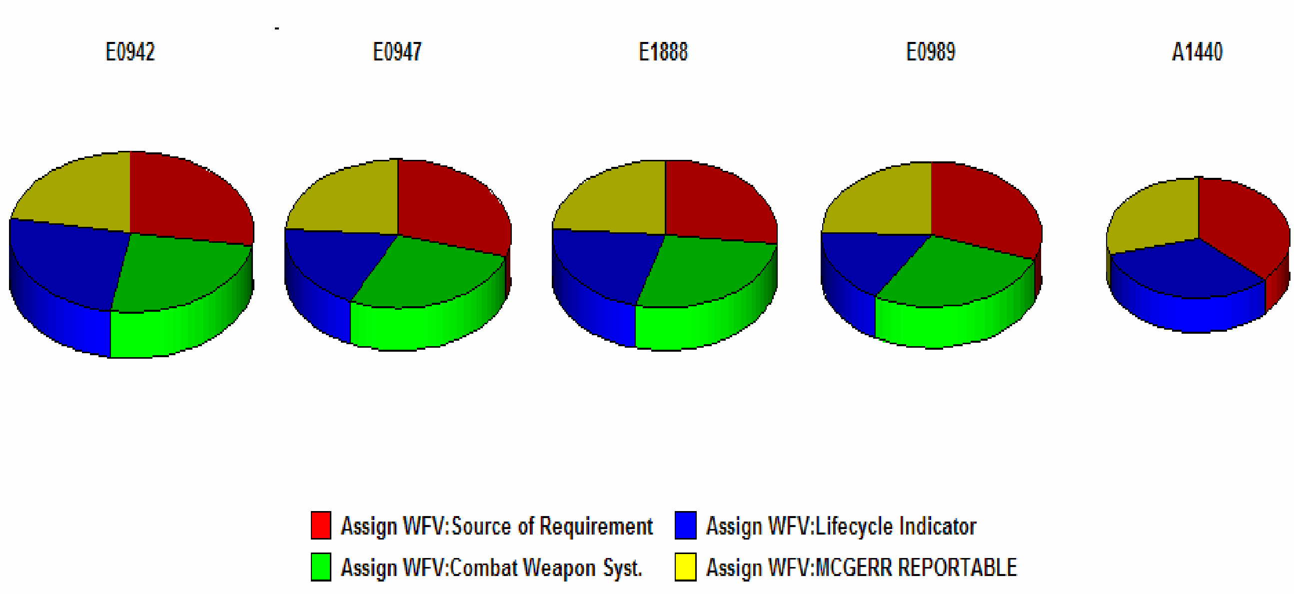

Figure 5. Contributions for Criteria for the Top Five PEIs

These figures illustrate that the Source of Requirement attribute did indeed make the largest contribution to the decision. Furthermore, it is evident the Lifecycle Indicator and Combat Weapon System attributes made the next most significant contribution. For example, although E0989 and A1440 scored higher than E1888 for Source of Requirement, E1888's higher scores for Combat Weapon System and Lifecycle Indicator pushed it ahead into the third position.

Figure 6 illustrates the same information for each criterion for the last five PEIs. Obviously, the contribution by criteria graph looks much different for the five lowest PEIs than it did for the top five.

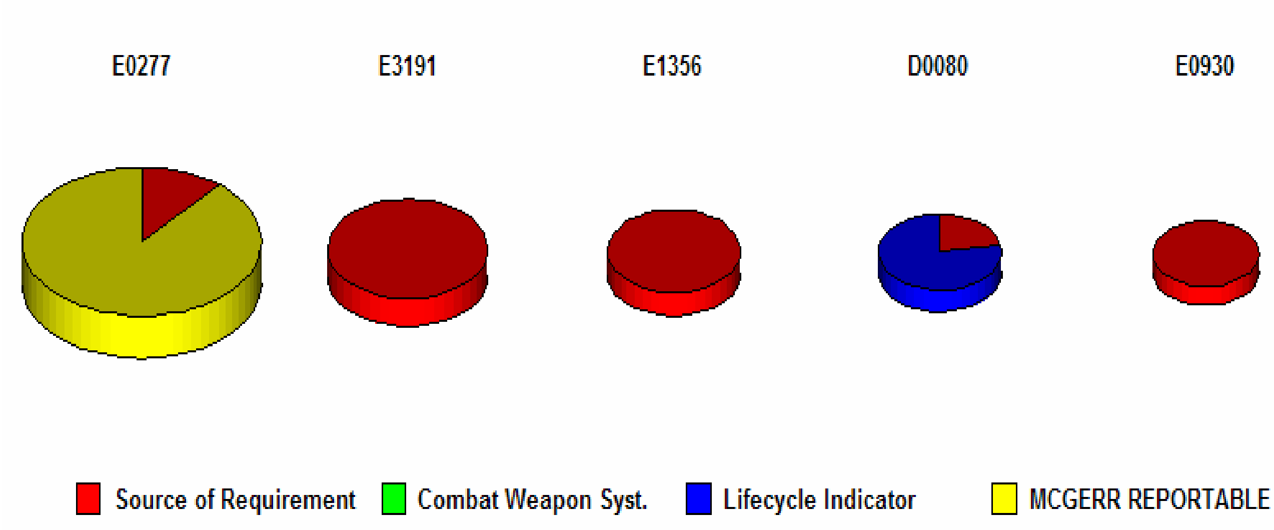

Figure 6. Contributions by Criteria for the Bottom Five PEIs

Again it is evident that although Source of Requirement has the most significant impact, if a PEI does not have an exceptionally high value for this attribute and scores low in the other attributes as well, it will finish more toward the bottom of the list. These charts illustrate the way one factor/attribute can compensate for another, which explains the sensitivity of the solution to the weights given to these factors/attributes.

Another tool offered by Criterium DecisionPlus is its Sensitivity Analysis feature. Through Sensitivity Analysis, the user can determine how sensitive the decision is to changes in the relative importance to the criteria. When Sensitivity Analysis is initiated, Criterium DecisionPlus shows a list of weights of sub criteria, with respect to their parent criteria, with a metric that measures the sensitivity of the result when the value of that weight is changed. Criterium DecisionPlus prioritizes the list from most critical to least critical so the user can focus on the criteria that can influence the decision the most. When weights are assigned to sub criterion with respect to a parent criterion, the decision model has the capability to discriminate between the alternatives. If the ordering of the leading alternatives changes with the smallest change in a particular weight, the decision model can be described as "sensitive" to that weight. It is important to understand if the model is overly sensitive to such weights, and Criterium DecisionPlus enables the user to test just how sensitive the results are to changes in weights. In Figures 7 and 8, the sensitivity plots can be seen for the Lifecycle Indicator and Combat Weapon System attributes (note that E0942 runs horizontally at the top of the graph).

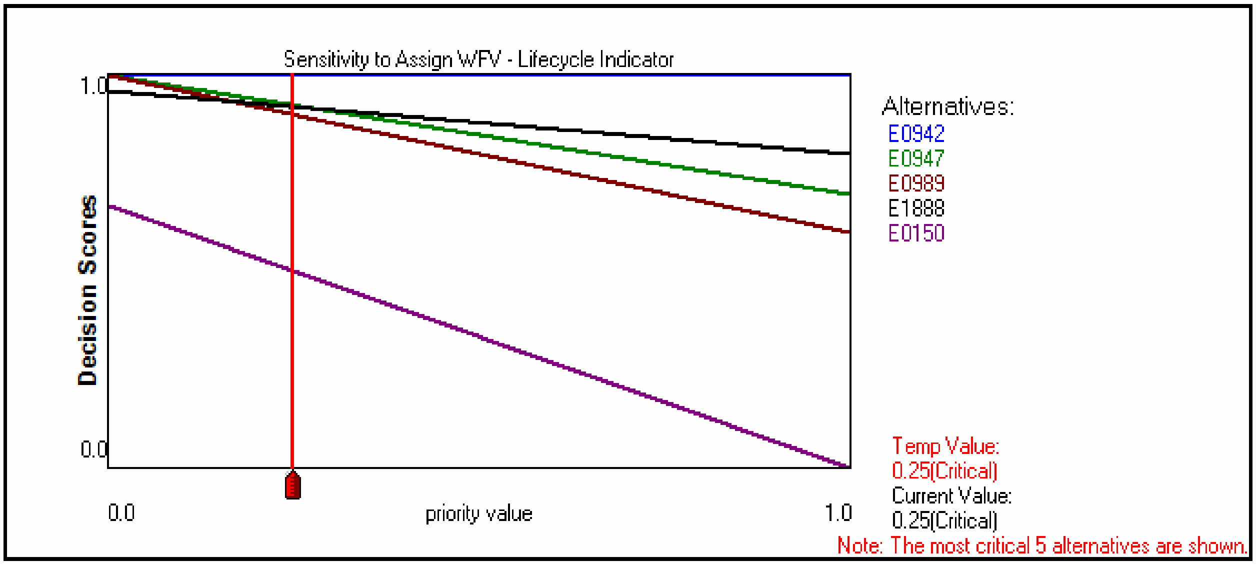

Figure 7. Sensitivity by Lifecycle Indicator

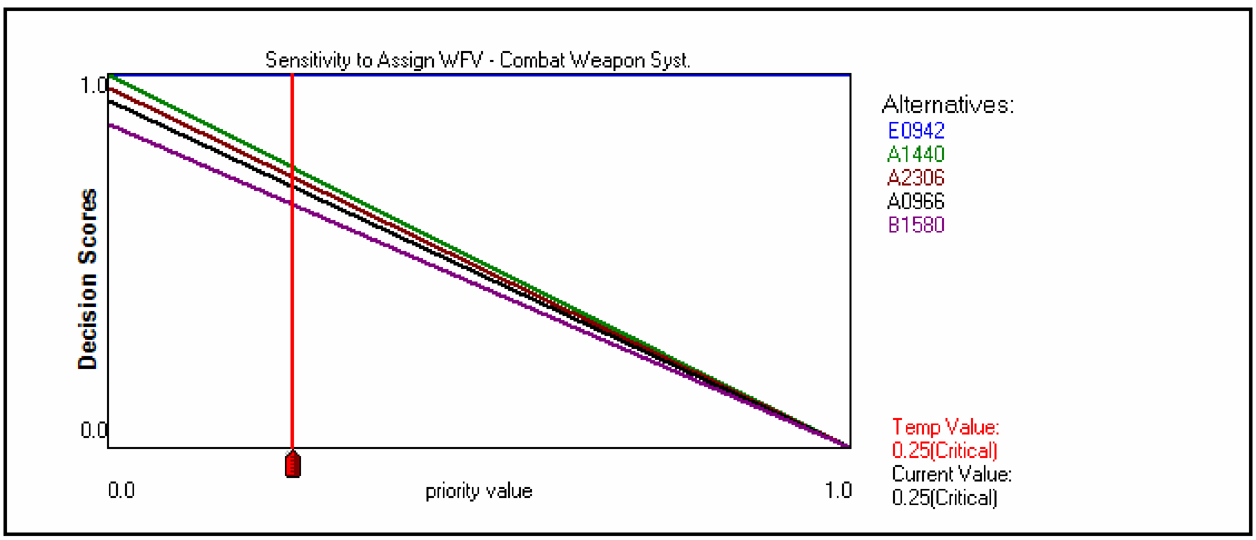

Figure 8. Sensitivity by Combat Weapon System

In the Sensitivity Plot figures, each weight is identified by the sub criterion whose weight it is (i.e., Lifecycle Indicator and Combat Weapon System), and the parent criterion (i.e., Assign WFV) with respect to which its value is assigned. The horizontal axis illustrates the priority of that weight (from 0 to 1) the model uses in calculating decision scores. The vertical axis shows the decision score for each alternative. The plot shows how changing the priority value of the current weight would affect the decision scores if it is varied over all possible values when all the other weights remain fixed. The decision scores change linearly and each alternative is represented by a color-coded straight line. The vertical red line is at the current value. In other words, it illustrates the priority corresponding to the value of the weight that was entered in the criterion rating window. The value of this weight is shown in verbal format in the parenthesis to the right of the graph. The height of the intersection of the vertical red line and the alternatives' lines provides the decision score that is current for each alternative. The plot shows only lines for five of these alternatives.

A useful way to understand the significance of the sensitivity analysis is to measure how much the current value of the priority can change before the model's preferred alternative (E0942) is superseded by a different alternative. At this value, the lines corresponding to the top alternative and the second alternative intersect on the sensitivity plot. This is called a crossover point, and there may be several or none in the plot for a given weight. Measuring the change in priority values from the current value to the closest crossover point provides a useful measure of how important that weight is to the outcome of the model. The plots in the figures above are for the weights with the most critical priority in the model. If the model is stable (meaning the current preference will not change with small changes in the value of that priority) with respect to the most critical priority, then the model is said to be stable to changes in all other priorities in the model. In simpler terms, when the percentage crossover number is greater than 5%, the current preference is stable to changes in every other priority throughout the entire model. The lowest percentage crossover number in this decision model was 25%. Therefore, E0942 is stable to changes in all other priorities.

In Figure 7, which represents the sensitivity by Lifecycle Indicator, the vertical red line (i.e., the current value) is very close to the nearest crossover point. This indicates that a relatively small change in priority for Lifecycle Indicator will affect the alternatives. For example, by moving the line slightly to the left (decreasing its priority value) will cause E0947 to switch places (crossover) with E1888. Moving the red line further to the left will result in another crossover between E1888 and E0989. Simply stated, if the weight for Lifecycle Indicator was reduced for these PEIs, they would be ranked differently in the final results. In comparison, Figure 8, the sensitivity plot for the Combat Weapon System factor, is much different. The red line could be moved far to the right without hitting any crossover points. This indicates that these PEIs are much less sensitive to a change in the priority value for the Combat Weapon System attribute.

4. Conclusion

The authors chose this methodology in an effort to design a better system to develop and assign WFV attributes. Using experience, interviews with key stakeholders, and the brainstorming tool in Criterium DecisionPlus, four attributes were chosen that were considered to be the most important in defining quality WFVs: MCGERR Reportable, Lifecycle Indicator, Source of Requirement, and Combat Weapon System. MCGERR Reportable equipment is identified in the Marine Corps Bulletin 3000 as being important enough to the Marine Corps that its readiness must be reported on a weekly basis. The Lifecycle Indicator attribute captures where a PEI is in its lifecycle (beginning, middle, or end), and is determined by dividing the quantity of WIRs for a PEI by its AAO. Source of Requirement is also known as the Waterfall Value. This attribute represents the unit that is requesting to induct equipment into depot level maintenance, and was chosen as the most essential WFV attribute. Finally, the Combat Weapon System attribute was assigned to any PEI that is used in direct combat. Using Criterium decision plus, these four attributes were weighted, and then used to score the Alternatives (PEIs). The final results were reviewed, analyzed and documented using this decision management tool.

Criterium DecisionPlus proved to be a very valuable tool in generating the final list of WFVs. In addition to being instrumental in defining and identifying the WFV attributes, Criterium DecisionPlus provided additional benefits. It provided much deeper insight into all the factors that affected the final results. It also instilled confidence that all factors were considered within the decision framework. In short, it took a process that can be described as very time consuming and subjective, and turned it into a more efficient and objective process.

It is imperative to remember that Criterium DecisionPlus can be applied in many different scenarios and is relatively user friendly. Changes can be made instantaneously, and because Criterium DecisionPlus continually calculates results as weights are entered, if the user changes a value, the results can be seen immediately. For example, if the environment changes drastically in a year, different WFV attributes may be identified. Moreover, weights may be assigned much differently to the criteria. Criterium DecisionPlus makes it very easy to address these changes and produce meaningful results in a timely manner. Therefore, the PEI that is currently at the bottom of the list could be one of the top five PEIs a year later.

Presently, the final results can actually be used in a couple of different ways. First of all, the final list can be used to assign readiness targets for each of the PEIs. For example, the first PEI in the final list (E0942) would receive a much higher readiness target than the last PEI on the list (E0930). Target Readiness will be discussed in greater detail in section C of this chapter. Second, if necessary, the final results could be used as a stand alone product. In other words, if time is a major constraint, Criterium DecisionPlus could be used to quickly generate a ranked list of PEIs that could be screened for submittal into depot maintenance. Regardless of how Criterium DecisionPlus is implemented, it is a tool that provides many advantages to the end user and the Marine Corps as a whole. For the purpose of this project, it provided a more advantageous approach to developing WFV attributes that will hopefully add significant value to the DLMP.

B. UTILITY

Utility is defined as the satisfaction or benefit that is received from consuming a good or service (Lieberman and Hall, 2000 p84). In the context of the DLMP, there are two types of relevant utility; economic utility and warfighter utility

1. Economic Utility

Economic utility is a measure of the return that the Marine Corps is getting for the investment that it is making in the Depot Maintenance process. Specifically, economic utility is a measure of the increase in the readiness of assets that the Marine Corps achieves from the DLMP given the money that is allocated. Economic utility is captured in the following term: ΔR/URC, the change in readiness received by repairing a quantity of (1) of a given PEI divided by the unit repair cost of that PEI. As it applies to a specific PEI, the result of this term is the percentage increase in readiness received per dollar spent repairing that PEI. Simply put, this term shows the "bang for the buck".

To illustrate this aspect, PEIs with varying densities and unit repair costs can be compared with respect to economic utility. The following table contains 4 PEIs. A1503 has a low density and high URC, D1092 has a low density and moderate URC, A1260 has a high density and low URC, and E0947 has a moderate density and a high URC.

TAMCN	NOMENCLATURE	URC	AAO	ΔR	ΔR/URC
A1503	Radar Set, 3D, Long Range	$ 7,429,900.00	13	0.07692	0.001035
D1092	Trk, Maint, Telephone	$ 143,000.00	22	0.04545	0.031786
A1260	Navigation Set, Satellite Signals PLGR	$ 348.00	5015	0.00020	0.057299
E0947	LAV, Light Assault, 25mm	$ 405,326.00	379	0.00264	0.000651

Table 5. Economic Utility

In this table the "ΔR" column is the change in readiness that is realized by repairing one unit of that PEI. The "ΔR/URC" column is the change in readiness realized from repairing one unit of a PEI divided by the cost of doing so. The results of this column have been multiplied by a factor of 100,000 for ease of comparing the numbers. It should be noted that the actual numbers in this column (.001…, .031…, etc) are not meaningful numbers. This is true because we cannot spend just one dollar on repairing these items. In order to repair a PEI at the depot we must incur the entire unit repair cost. The use of these numbers is a method of comparing the relative value (utility) of repairing a PEI given its density and cost.

The PEI with the highest economic utility of these four is the PLGR, A1260. This says that the Marine Corps receives the most economic value for its money by spending dollars to repair PLGRs (keep in mind that economic utility is only one piece of the equation, warfighter utility will have a significant effect on the final prioritization of PEIs). The PLGR is a very high density item with an AAO of 5015. This high density makes the change in readiness associated with repairing one PLGR very low (.0002). However, the unit repair cost of the PLGR is extremely low (at $348 it is one of the lowest unit repair costs across all PEI's). This low URC offsets the low change in readiness per unit to the point where it is actually very economical to repair PLGRs. The Marine Corps can repair a large number of PLGRs (eventually reaching a significant increase in readiness of PLGRs) for a small cost when compared to other assets. The 3D Long Range Radar Set (Radar) is a very low density item with an AAO of 13. This low density makes the change in readiness associated with repairing one Radar very high (.0769). The unit repair cost of this radar (nearly $7.5 million) is one of the highest URCs across all PEIs. This high URC is combined with the high change in readiness to create an economic utility that is relatively low when compared to other PEIs.

2. Warfighter Utility

Warfighter utility is an attempt to capture the value that a given PEI has to the warfighter relative to all other PEIs. The methods used to derive a warfighting value have been described in detail in Chapter III-A.

Unlike a commercial, profit maximizing organization, the Marine Corps must consider factors other than economic utility. Utilizing the principals of economic utility alone would result in the least expensive, lowest density items being repaired first, while expensive and high density items would not compete well for limited Depot funds. As would be expected, many of these very expensive, moderate density items are essential to mission accomplishment on the battlefield. It is this competition for limited funds that requires trade offs to ensure that the Marine Corps is using best business practices to spend its depot maintenance dollars while operating in the best interest of the warfighter. It is for this reason that consistent, measured tradeoffs must be made between economic utility ($\Delta R/URC$), and warfighter utility.

C. TARGET READINESS

Target readiness is the readiness rating that the DERO model attempts to achieve for each PEI. In a situation with unlimited resources, DERO would strive to achieve a target readiness of 100% for all assets. However, given fiscal constraints, it is understood that not all assets (in most cases no assets) will be restored to 100% readiness by the DLMP. The DERO model does allow input for target readiness for each PEI. Under the current practice, and as a matter of policy, target readiness has been designated as 85% for all PEIs. However utilizing a common target readiness for all PEIs misses an opportunity for the DERO model to adequately discriminate between PEIs based on the principals of diminishing marginal returns and utility.

1. Diminishing Marginal Returns

Diminishing marginal returns is described as the decrease in satisfaction received from the nth unit of something, relative to the satisfaction received from the (nth-1) unit of the same. In a military context, consider the following example. Consider a tank commander who has 100 tanks in his command and is currently at a readiness rate of 65%. In order to be mission capable, this commander must have a readiness rate of 80%. However, though he is not technically mission capable until 80%, he is capable of performing limited missions at 75% readiness. In this example, the utility received by the commander from repairing the first 10 tanks is very high (moving him from 65% to 75%, illustrated in red on the graph below). The utility received from repairing the next 5 tanks (75% to 80%, shown in green) is still high, but not as high as the first 10. Furthermore, the utility received from repairing additional tanks above 80% (shown in blue) may still be high for the commander, but is less than the 1^{st} through 15^{th} tanks repaired.

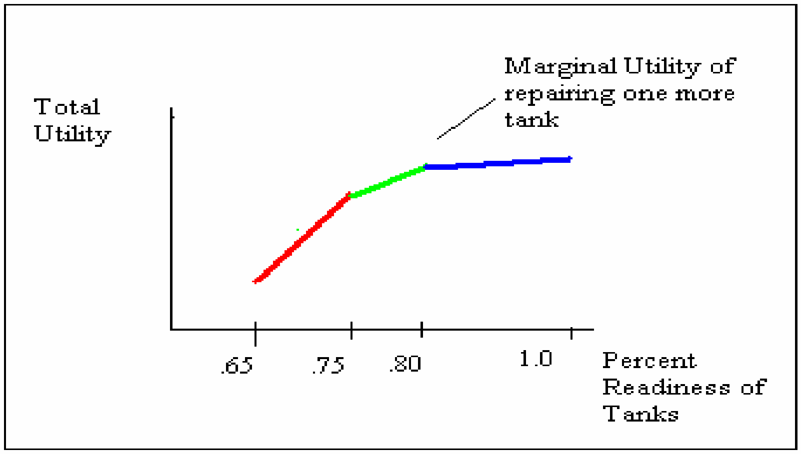

Figure 9. Diminishing Marginal Utility Example

To better illustrate this principal, consider a situation with limited resources where a task force commander has two assets (tanks and LAVs), both at a current readiness of 50%. This particular commander places a higher value on tanks than he does LAVs, and therefore begins to repair tanks with his limited resources. As the repairs commence, the commander is happy to see his readiness of tanks increase while LAVs remain at 50%. Being a task force commander, the commander has a need to utilize both tanks and LAVs. At some point in the repair process this commander will reach a point where repairing one LAV (bringing LAV readiness to 51%) provides him with a greater marginal utility than repairing one more tank (bringing him perhaps to 81% readiness). In other words, fixing the 31st tank is less important to the commander than fixing the 1st LAV.

This demonstrates that the marginal utility received by fixing tanks (and presumably any PEI) diminishes as readiness grows higher and higher. At some point, it becomes more important to leave tanks where they are and fix a PEI that is at a lower readiness rate. This principal says that in general, given limited resources, it is better to repair a PEI with a lower readiness rating before repairing another PEI with a higher readiness rating. However, as illustrated in the last example (tanks and LAVs), some

PEIs are more valuable to the warfighter than others. It is this discrepancy in value that leads the authors to recommend tying warfighting values to target readiness.

2. Target Readiness as a Measure of Warfighter Utility

The current practice of setting the target readiness of every PEI to 85% does not reflect the discrepancy in value to the warfighter across the spectrum of PEIs. Under this system, a tank with a current readiness of 70% will receive the same treatment by the model as a PLGR (all other things being equal). However, assume that the target readiness of the tank was 95%, and the target readiness of the PLGR was 80%. And now suppose that the diminishing marginal returns experienced by the warfighter were reflected in the model by the distance (or difference) from the target readiness to the current readiness. In this situation, the tank has a difference of 25% (95%-70%), while the PLGR has a difference of 10% (80%-70%). Based on the principal of diminishing marginal returns, it is clear that under these circumstances the model should give preference to repairing the tank over the PLGR (all other things being equal). The application of the readiness differential will be discussed in more detail in Chapter IV.

How does one assign a target readiness to a PEI? The authors recommendation is to convert the warfighting values discussed in Chapter III-A to a target readiness for each PEI. This process is both subjective and objective; however, if applied uniformly across all PEIs the subjectivity with respect to any given PEI will be negligible. Additionally, just as the warfighting values are dynamic and will change from year to year for a given PEI to reflect current priorities and an ever changing global threat, so will target readiness. The intent of this system is to assign PEIs with the highest warfighting values a correspondingly high target readiness. PEIs with a high target readiness will receive preferential treatment over PEIs with a lower target readiness (all other things being equal).

As detailed in Chapter III-A WFVs are represented by a ranking value that is derived from the weighting of four attributes. The result is a ranking value between 0 and 1. The following scatter plot shows the range of WFVs for the sample population.

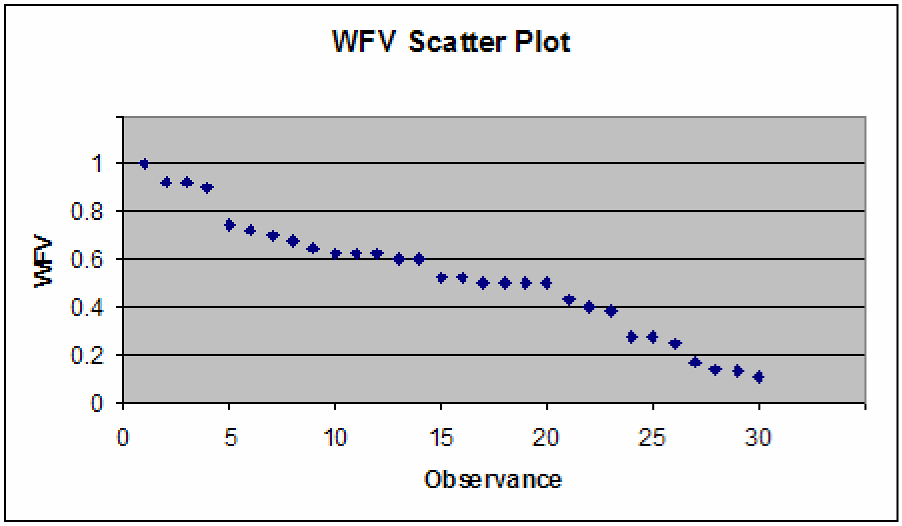

Figure 10. Scatter Plot of WFVs From the Sample Population

The intent in this case is to group PEIs with similar WFVs together and assign them a target readiness. There are a number of academic references that discuss detailed methods of cluster analysis. One such method utilizes a clustering algorithm to partition similar observances together. This method utilizes dissimilarities, which are non-negative numbers that are close to zero when two points are near each other, and are large when two points are very different (Kaufman and Rousseeuw, 1990 p16). Under this methodology, the dissimilarities between points within a cluster are minimized while the distance between clusters is maximized (Kaufman and Rousseeuw, 1990, p40). The result of this process is partitioned clusters containing the points with the most similar characteristics. Given these like clusters of WFVs, one can assign a target readiness to each cluster.

Another method of transferring these WFVs to target readiness is to use a linear model. Doing so requires a decision of an upper and lower limit for the range of target readiness. The ranges of target readiness are a policy decision that must consider acceptable levels of readiness, specifically on the low end. The details of this decision are outside the scope of this project. The authors have chosen a range of 100%-75% for the purpose of illustrating the method. This methodology creates a 4:1 ratio between WFV and target readiness. The chart below shows this ratio across the range of WFVs and target readiness.

WFV	Target Readiness		WFV	Target Readiness
1.00-.98	100%		.50-.46	87%
.98-.94	99%		.46-.42	86%
.94-.90	98%		.42-.38	85%
.90-.86	97%		.38-.34	84%
.86-.82	96%		.34-.30	83%
.82-.78	95%		.30-.26	82%
.78-.74	94%		.26-.22	81%
.74-.70	93%		.22-.18	80%
.70-.66	92%		.18-.14	79%
.66-.62	91%		.14-.10	78%
.62-.58	90%		.10-.06	77%
.58-.54	89%		.06-02	76%
.54-.50	88%		.02-.00	75%

Table 6. Linear Conversion of WFVs to Target Readiness

The PEIs with the highest value to the warfighter have the highest target readiness, and therefore receive a higher priority for depot repairs (again, all other things being equal). In effect, the warfighting value is now present in the form of target readiness.

The WFV and corresponding target readiness of the 30 sample PEIs used in this project are shown below.

TAMCN	Nomenclature	WFV	Target Readiness
A0966	Mobile EW Support System PIP	0.7	93%
A1260	Navigation Set, Satellite Signals PLGR	0.428	86%
A1440	Radar Set, Firefinder	0.75	94%
A1503	Radar Set, 3D, Long Range	0.5	88%
A2306	Sensor System Monitor, Mobile	0.725	93%
A2505	Switchboard, Telephone, Automatic	0.6	90%
A2635	Telephone Set	0.403	85%
B0589	Excavator, Combat	0.6	90%
B1291	Decontamination System, Ltwt	0.525	88%
B1139	Hose Reel System (HRS)	0.278	82%
B1580	Pump Module, Fuel (SIXCON)	0.65	91%
B2086	Storage Tank Module, Water (SixCon)	0.503	88%
B2460	Tractor, Full Tr (T5)	0.625	91%
D0235	Semi-Trlr, Lowbed, 40T	0.383	85%
D0080	Chassis, Trlr, GP, 3 1/2T, 2 Whl	0.128	78%
D0877	Trlr, Powered, Wrecker/Recovery, 4X5	0.625	91%
D0879	Trlr, Powered, 30T, Cargo, Dropside	0.525	88%
D1092	Trk, Maint, Telephone	0.278	82%
D1160	Interim Fast Attack Vehicle	0.625	91%
E0150	Armored Vehicle, Launcher, Bridge	0.5	88%
E0277	Display Group, Data	0.25	81%
E0856	AAV, Recovery	0.5	88%
E0930	Launch Simulator, Stinger	0.111	78%
E0942	LAV, Anti-Tank	1	100%
E0947	LAV, Light Assault, 25mm	0.925	98%
E0960	Machine Gun, Lt, Squad, Auto Wpn	0.678	92%
E0989	Machine Gun, Medium, 7.62mm	0.9	98%
E1356	Recharging Unit, Coolant, Trng	0.139	78%
E1888	Tank, Combat, FT, 120mm Gun	0.922	98%
E3191	Trainer, Handling GM Launch (Stinger)	0.167	79%

Table 7. Target Readiness Conversion for the Sample Set

3. Piece-Wise Linear Coefficient

The current DERO model captures the principal of diminishing marginal returns as shown in the following graph.

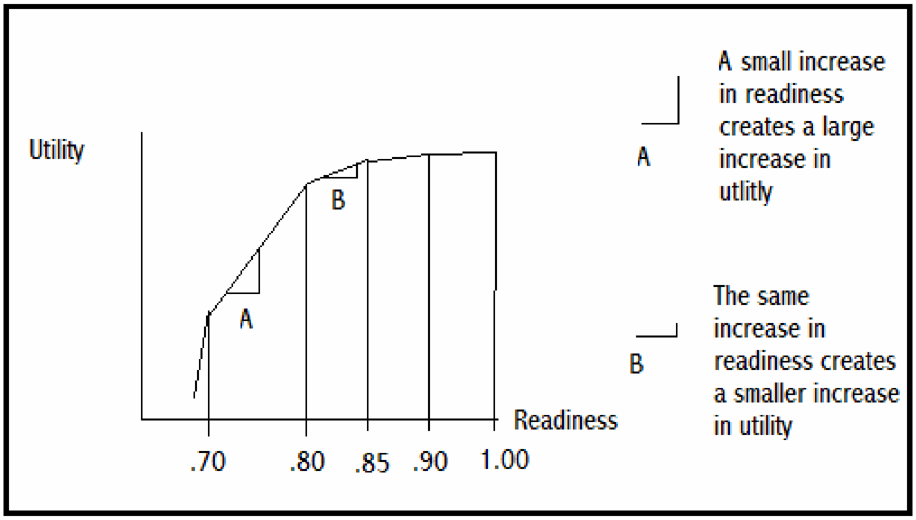

Figure 11. Diminishing Returns DERO Model

The diminishing marginal returns are captured in a piece-wise linear function. The key aspect of this function is the slopes of each of the line segments. The slopes of these segments (14, 7, 3, 2, 5 –as utilized in the DERO model) result in a greater increase in utility for PEIs with a lower readiness (and therefore larger slope) for each unit increase in readiness, compared to PEIs with a higher readiness (and smaller slope). At point A on the graph, a 3% increase in readiness (the horizontal change at point A) results in an increase in utility equal to the vertical change shown at point A. At point B, the same 3% increase in readiness results in an increase of utility equal to the vertical change shown at point B. The same change in readiness results in a much greater increase in utility at point A than at point B.

While maintaining the same principals of this piece-wise function, the authors have modified the way in which it is applied to utilize the target readiness less current readiness procedure described previously. Specifically, the X axis has been changed from readiness to target readiness less current readiness. The new graph is shown below.

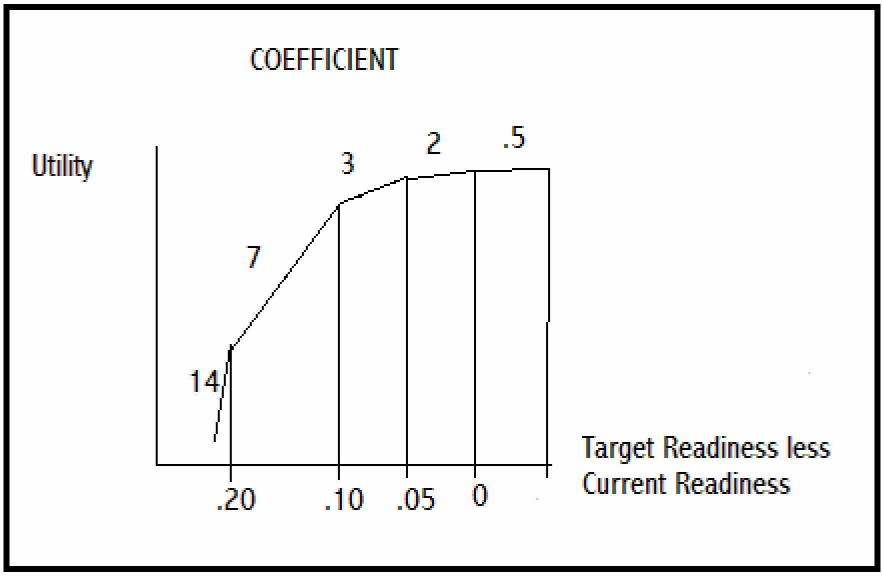

Figure 12. Diminishing Returns Utilizing the Readiness Differential

A PEI's target readiness less its current readiness equals the readiness differential for that PEI, and determines where that PEI falls out on the piece-wise linear curve. The target readiness has been determined by capturing the warfighters utility of that PEI. Using this methodology, a PEI with a readiness differential on the left portion of the graph will receive preferential treatment over a PEI with a readiness differential on the right portion of the graph.

The coefficient for a given PEI is determined by the slope of the piece-wise linear curve which contains the readiness differential for that PEI. For example, a PEI with a target readiness of 90% and a current readiness of 68% has a readiness differential of 22%. This PEI falls on the portion of the graph where the slope of the line is 14, therefore the coefficient of this PEI is 14. Another PEI that has a target readiness of 90% and a current readiness of 83% has a readiness differential of 7%. This PEI falls on the portion of the graph where the slope of the line is 3, therefore the coefficient of this PEI is 3.

At the point where the readiness differential becomes negative the coefficient is 0.5. At this point a PEI enters into the DLMP with a current readiness that is greater than its target readiness. In this situation it is more beneficial to the warfighter for the process to repair PEIs with a positive readiness differential than those with a negative differential. The coefficient of 0.5 will act to penalize a PEI with a negative readiness differential. This concept will be discussed in detail in Chapter IV.

The coefficient (as a representation of WFV via target readiness) portrays warfighter utility. The term (ΔR/URC) portrays economic utility. The interaction between economic and warfighter utility is the basis for the model that is recommended by the authors and is the subject of Chapter IV.

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IV. UTILITY ALGORITHM

A. ALGORITHM

Utilizing the methodologies of warfighting values, utility and target readiness discussed in Chapter III, the following algorithm is presented as an alternative to the DERO model.

$$(\Delta R/URC)*Cn = \text{Ranking Value}$$

As previously discussed, the ΔR/URC portion of this equation accounts for economic utility. The coefficient variable (Cn) represents the slope of the piece-wise linear curve which contains the readiness differential (target readiness less current readiness). Each PEI's target readiness is directly correlated to the WFV of that PEI. Therefore, the warfighter's utility is represented in this model by the coefficient. The result of the algorithm when applied across all PEIs is a prioritized list of PEIs to be funded for depot maintenance in order to account for economic and warfighter utility.

A portion of the output is provided below to illustrate the inputs of the utility algorithm.

TAMCN	NOMENCLATURE	URC	AAO	USR	Tgt R	Curr R	ΔR	ΔR/URC	R Diff	Cn
E0150	Armored Vehicle, Launcher, Bridge	232,515	27	1	.88	0.5900	0.0370	0.0159	.29	14
A0966	Mobile EW Support System	307,613	13	1	.93	0.7692	0.0769	0.0250	.161	7
D1160	Interim Fast Attack Vehicle	50,000	80	9	.91	0.5700	0.0125	0.0250	.34	14

Table 8. Utility Algorithm Inputs

The URC is the cost of repairing a single unit of a PEI at the depot. The ΔR is the increase in readiness for a PEI when a single unit is repaired (ΔR is 1/AAO). ΔR/URC is the increase in readiness per dollar spent, or the economic utility of repairing a PEI. This utility is a fixed characteristic of a PEI and will not change as the model is executed (the only change to this value would occur if either the unit repair cost itself changes, or if the AAO changes. These changes are considered to be external to this process, and their effect on the model will not be discussed). USR is the quantity of unserviceable returns that are available for turn in to the depot. Tgt R is the readiness rate that is desired for a given PEI, given a constrained budget, and is derived from the PEI's WFV. Curr R is the current readiness of each PEI. R Diff is the readiness differential, or target readiness less current readiness. Cn is the coefficient of the PEI.

B. MODEL DRIVERS

There are four primary elements that drive the outcome of this model; the combination of density and cost, WFVs in the form of a target readiness, current readiness, and unserviceable returns.

It has been demonstrated that the ratio of density and cost (ΔR/URC) provide a measure of the "bang for the buck" or economic utility. In general, a low density and low URC will create the highest economic utility and therefore have a positive effect on the final ranking value. Conversely, a high density and high URC will create a low economic value having a negative effect on the final ranking value. In reality, most PEIs fall in the mid range of density and URC. At the extremes very low density items are typically very expensive to repair creating a tradeoff within this term of the equation. The low density provides a high change in readiness for each unit repaired, however the high URC makes it very expensive to repair that one unit. The ratio of these variables results in an economic utility value that competes with the rest of the PEIs. This term interacts with target readiness (in the form of the coefficient) to create the final ranking value.

The second driver of the model is target readiness. Target readiness itself is derived from the WFV assigned to a PEI, and through the use of the readiness differential (target readiness less current readiness) the WFV determines the coefficient. Assuming two PEIs with the same level of current readiness, their target readiness will impact how they are prioritized by the model. The PEI with a higher target readiness will have a greater readiness differential and therefore a higher coefficient. Given two PEIs with the same economic utility, the PEI with the higher coefficient will be prioritized ahead of the lower coefficient. However, when PEIs differ in economic utility, the interaction between economic utility and the coefficient determine where a PEI is prioritized by the model. These interactions create another tradeoff. A PEI with a high economic utility and high Cn (via a high target readiness and WFV), will have the highest final ranking value. At the other extreme, a PEI with a low economic utility and low Cn will have the lowest final ranking value. Most PEIs have some combination of economic utility and Cn that fall between these extremes. The interaction of these variables uses economic utility and warfighter utility to objectively prioritize all PEIs.

The third driver is current readiness. Current readiness is a condition that is present at the time that the input data is collected. Given a target readiness derived from the WFV, a lower current readiness will create a larger readiness differential resulting in a higher coefficient and a higher ranking value. Based on the theory of diminishing marginal returns there is more utility in fixing PEIs with a lower current readiness than those with a higher current readiness, all other things being equal. The piecewise linear curve utilized in this model was adopted from the original DERO model (DLMP Handbook, Marine Corps Logistics Command, p25).

The fourth driver of the model is unserviceable returns. The only impact USR has directly on the model is the formation of readiness bands (readiness bands are discussed in detail in the next section). Once these bands are calculated, USRs no longer have any interaction with the utility algorithm. However, USRs are a limiting factor for the simple fact that no matter how high the economic utility, nor how great the warfighter utility, a PEI cannot be selected for repair at the depot if it is not identified as available for turn in.

C. READINESS BANDS

Some further discussion is required to explain how quantities of a PEI are selected and prioritized by the model. Shown below is the same coefficient chart that was discussed in Chapter III.

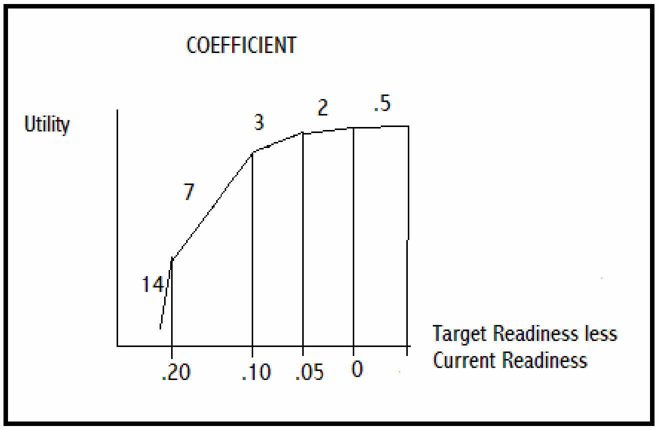

Figure 13. Coefficient Piece-Wise Linear Curve

Upon initial consideration by the model, a PEI falls on this curve based on its readiness differential, and is therefore assigned a corresponding coefficient (equal to the slope of that portion of the curve). With coefficient 'Cn', once a PEI is selected by the model, that is once the PEI's ranking value (ΔR/URC)*Cn is greater than that of all other PEIs, it will remain greater until the readiness differential decreases (moving right on the curve to the next line segment) and the coefficient decreases. In other words, once a PEI is selected by the model, the model will select a quantity of that PEI that creates an increase in readiness sufficient to move the readiness differential to the next line segment on the curve. Once this occurs, the ranking value of the PEI decreases (as the coefficient in the calculation has now changed), and any further quantities of that PEI must compete against all other PEIs before being selected again.

For example, if E0150 has an initial readiness differential of .29 (.88-.59), its corresponding initial coefficient is 14. The ΔR/URC for this PEI is .0159 and will remain constant throughout the calculation. The ranking value (using the utility algorithm (ΔR/URC)*Cn) of this PEI is .223. Once this PEI is selected by the model, the entire first readiness band of three is selected. Once these three are repaired the new current readiness is .701 (the initial current readiness of .59 plus the increase of (3*.037) .111 realized by repairing the first three units of this PEI). With a new current readiness of

.701, the PEI's readiness differential has decreased to .179 (.88-.701) placing it on a different segment (to the right) of the piece-wise curve. After the first band of this PEI is selected and prioritized for repair, the next readiness band to be considered must now be calculated with a coefficient of 7 vice 14. While the ΔR/URC remains constant at .0159, putting 7 into the equation as this PEI's coefficient results in a new ranking value of .112. The next band of E0150 will not be selected for repair by the model until all other PEIs with a ranking value greater than .112 have been selected first. To carry this example one step further, once E0150 is selected by the model again, it will select a quantity of three. This is the case because it will take an increase in readiness of three units (3*.037 = .111) to move the readiness differential (.88-(.701+.111) = .068) across the next line segment of the piece-wise curve, once again changing the coefficient from 7 to 3, and further reducing the ranking value.

This grouping of quantities based on the piece-wise segment creates what the authors have termed readiness bands. Readiness bands are groups of quantities of a PEI that will be selected for repair at the same time. In other words, once the first unit is chosen, the entire readiness band will be chosen before the coefficient of the PEI is reduced requiring a recalculation of the ranking value. The chart below shows a PEI with a large number of unserviceable returns available for repair at the Depot. The quantity of USRs for this PEI creates readiness bands that stretch across all five of the possible coefficient values.

TAMCN	NOMEN	URC	AAO	USR	Tgt R	Curr R	ΔR	R Diff	Cn	Value
D0235	Semi-Trlr			100						
D0235	Semi-Trlr	30,593	301	16	0.85	0.5980	0.0033	0.252	14	.152
D0235	Semi-Trlr	30,593	301	30	0.85	0.6512	0.0033	0.199	7	.076
D0235	Semi-Trlr	30,593	301	15	0.85	0.7508	0.0033	0.099	3	.033
D0235	Semi-Trlr	30,593	301	15	0.85	0.8007	0.0033	0.049	2	.022
D0236	Semi-Trlr	30,593	301	24	0.85	0.8505	0.0033	-0.001	0.5	.005

Table 9. Example of Readiness Bands

The total number of USRs for this PEI is 100. With an initial readiness differential of .252, it takes a quantity of 16 to move the readiness differential from a coefficient of 14 to a coefficient of 7. This quantity of 1 is the first readiness band for this PEI. Once the ranking value of .152 becomes the highest value available across all PEIs the utility algorithm will select the first readiness band. When the coefficient is reduced to 7, the ranking value is reduced to .076. The next readiness band for this PEI will not be selected until all PEIs above .076 are selected. When this band is selected, the entire quantity of 30 is selected together. The number of readiness bands that exist for each PEI will be dependant on the number of USRs and the ΔR for that PEI. High density PEIs like the PLGR may have a quantity of many hundreds in a single readiness band due to the small increase in readiness for repairing each unit. Conversely, low density items like the radar discussed previously may only have a quantity of one or two in a readiness band due to the high change in readiness realized for repairing each unit.

D. RESULTS

Using the 30 PEIs selected in Chapter III, the utility algorithm has been run in spreadsheet format to demonstrate the output. When observing final ranking values and priorities it must be remembered that this output is only significant given the exact input of these 30 sample PEIs. Different WFVs (and therefore different target readiness), current readiness, and unserviceable returns will result in a different ranking. Sensitivity to changes in input will be discussed in the next section. The intent of this example is to illustrate the format and flexibility of the output. For this example, the target readiness used in this model has been derived from the WFVs of the 30 sample TAMCNs using the linear method discussed in Chapter III. Current readiness figures were pulled from MERIT, and the quantities of unserviceable returns for each PEI are fictional, chosen to show a wide range of potential readiness bands.

TAMCN	NOMENCLATURE	URC	AAO	USR	Tgt R	Curr R	ΔR	ΔR/ URC	R Diff	Cn	Value	Cumulative Total Cost
D1160	Interim Fast Attack Vehicle	$50,000	80	12	0.91	0.5700	0.01250	0.0250	0.340	14	0.350	$600,000
E3191	Trainer, Handling Launch (Stinger)	$4,483	171	4	0.79	0.7700	0.00585	0.1304	0.020	2	0.261	$617,932
E0150	Armored Vehicle, Launcher, Bridge	$232,515	27	3	0.88	0.5900	0.03704	0.0159	0.290	14	0.223	$1,315,477
A2635	Telephone Set	$612	5383	38	0.85	0.7431	0.00019	0.0304	0.107	7	0.212	$1,338,735
E0930	Launch Simulator, Stinger	$25,906	55	1	0.78	0.7273	0.01818	0.0702	0.053	3	0.211	$1,364,641
A1440	Radar Set, Firefinder	$420,767	19	1	0.94	0.7368	0.05263	0.0125	0.203	14	0.175	$1,785,408
A0966	Mobile EW Support System	$307,613	13	1	0.93	0.7692	0.07692	0.0250	0.161	7	0.175	$2,093,021
D1160	Interim Fast Attack Vehicle	$50,000	80	7	0.91	0.7200	0.01250	0.0250	0.190	7	0.175	$2,443,021
D0235	Semi-Trlr, Lowbed, 40T	$30,593	301	16	0.85	0.5980	0.00332	0.0109	0.252	14	0.152	$2,932,509
E0930	Launch Simulator, Stinger	$25,906	55	2	0.78	0.7455	0.01818	0.0702	0.035	2	0.140	$2,984,321
E0150	Armored Vehicle, Launcher, Bridge	$232,515	27	3	0.88	0.7011	0.03704	0.0159	0.179	7	0.112	$3,681,866
A2635	Telephone Set	$612	5383	82	0.85	0.7502	0.00019	0.0304	0.100	3	0.091	$3,732,055
A1440	Radar Set, Firefinder	$420,767	19	1	0.94	0.7895	0.05263	0.0125	0.151	7	0.088	$4,152,822
B2460	Tractor, Full Tr (T5)	$45,275	190	12	0.91	0.7368	0.00526	0.0116	0.173	7	0.081	$4,696,122
D0235	Semi-Trlr, Lowbed, 40T	$30,593	301	30	0.85	0.6512	0.00332	0.0109	0.199	7	0.076	$5,613,912
A0966	Mobile EW Support System	$307,613	13	1	0.93	0.8462	0.07692	0.0250	0.084	3	0.075	$5,921,525
E1356	Recharging Unit, Coolant, Trng	$50,000	80	3	0.78	0.7000	0.01250	0.0250	0.080	3	0.075	$6,071,525
E3191	Trainer, Handling Launch (Stinger)	$4,483	171	15	0.79	0.7934	0.00585	0.1304	-0.003	0.5	0.065	$6,138,770
D0877	Trlr, Powered, Wrecker/Recovery	$215,369	115	4	0.91	0.6800	0.00870	0.0040	0.230	14	0.057	$7,000,246
E1356	Recharging Unit, Coolant, Trng	$50,000	80	2	0.78	0.7375	0.01250	0.0250	0.043	2	0.050	$7,100,246
E0150	Armored Vehicle, Launcher, Bridge	$232,515	27	1	0.88	0.8122	0.03704	0.0159	0.068	3	0.048	$7,332,761
A2505	Switchboard, Telephone, Auto	$16,042	396	17	0.90	0.8081	0.00253	0.0157	0.092	3	0.047	$7,605,475
B2086	Storage Tank Mod Water (SixCon)	$8,401	2016	173	0.88	0.6944	0.00050	0.0059	0.186	7	0.041	$9,058,848
A1441	Radar Set, Firefinder	$420,767	19	1	0.94	0.8421	0.05263	0.0125	0.098	3	0.038	$9,479,615
E0930	Launch Simulator, Stinger	$25,906	55	9	0.78	0.7818	0.01818	0.0702	-0.002	0.5	0.035	$9,712,769
E0942	LAV, Anti-Tank	$408,179	98	7	1.00	0.6100	0.01020	0.0025	0.390	14	0.035	$12,570,022
D0235	Semi-Trlr, Lowbed, 40T	$30,593	301	15	0.85	0.7508	0.00332	0.0109	0.099	3	0.033	$13,028,917
A2505	Switchboard, Telephone, Auto	$16,042	396	20	0.90	0.8510	0.00253	0.0157	0.049	2	0.031	$13,349,757
A1260	Navigation Set, Satellite PLGR	$348	5015	400	0.86	0.9200	0.00020	0.0573	-0.060	0.5	0.029	$13,488,957
A2306	Sensor System Monitor, Mobile	$482,469	22	1	0.93	0.8636	0.04545	0.0094	0.066	3	0.028	$13,971,426
D0877	Trlr, Powered, Wrecker/Recovery	$215,369	115	11	0.91	0.7148	0.00870	0.0040	0.195	7	0.028	$16,340,485
B1139	Hose Reel System (HRS)	$184,637	47	1	0.82	0.8085	0.02128	0.0115	0.012	2	0.023	$16,525,122

D0235	Semi-Trlr, Lowbed, 40T	$30,593	301	15	0.85	0.8007	0.00332	0.0109	0.049	2	0.022	$16,984,017
B1291	Decontamination System, Ltwt	$27,448	1224	55	0.88	0.7353	0.00082	0.0030	0.145	7	0.021	$18,493,657
E0960	Machine Gun, Lt, Squad, Auto Wpn	$1,909	8066	83	0.92	0.8600	0.00012	0.0065	0.060	3	0.019	$18,652,104
B2086	Storage Tank Mod, Water (SixCon)	$8,401	2016	101	0.88	0.7802	0.00050	0.0059	0.100	3	0.018	$19,500,605
E0277	Display Group, Data	$6,293	453	52	0.81	0.8600	0.00221	0.0351	-0.050	0.5	0.018	$19,827,841
D1092	Trk, Maint, Telephone	$143,000	22	3	0.82	0.8200	0.04545	0.0318	0.000	0.5	0.016	$20,256,841
B1580	Pump Module, Fuel (SIXCON)	$20,983	631	25	0.91	0.8716	0.00158	0.0076	0.038	2	0.015	$20,781,416
D0879	Trlr, Powered, 30T, Cargo, Drop	$160,023	326	10	0.88	0.7500	0.00307	0.0019	0.130	7	0.013	$22,381,646
E0960	Machine Gun, Lt, Squad, Auto Wpn	$1,909	8066	416	0.92	0.8703	0.00012	0.0065	0.050	2	0.013	$23,175,790
E0989	Machine Gun, Medium, 7.62mm	$3,031	5249	150	0.98	0.9400	0.00019	0.0063	0.040	2	0.013	$23,630,442
D0877	Trlr, Powered, Wrecker/Recovery,	$215,369	115	6	0.91	0.8104	0.00870	0.0040	0.100	3	0.012	$24,922,656
B2086	Storage Tank Mod, Water (SixCon)	$8,401	2016	96	0.88	0.8303	0.00050	0.0059	0.050	2	0.012	$25,729,152
B0589	Excavator, Combat	$226,756	130	6	0.90	0.8077	0.00769	0.0034	0.092	3	0.010	$27,089,688
E0947	LAV, Light Assault, 25mm	$405,326	379	28	0.98	0.6600	0.00264	0.0007	0.320	14	0.009	$38,438,816
B1291	Decontamination System, Ltwt	$27,448	1224	61	0.88	0.7802	0.00082	0.0030	0.100	3	0.009	$40,113,144
E0856	AAV, Recovery	$611,041	60	3	0.88	0.7900	0.01667	0.0027	0.090	3	0.008	$41,946,267
A2505	Switchboard, Telephone, Auto	$16,042	396	13	0.90	0.9015	0.00253	0.0157	-0.002	0.5	0.008	$42,154,813
A1503	Radar Set, 3D, Long Range	$7,429,900	13	2	0.88	0.6923	0.07692	0.0010	0.188	7	0.007	$57,014,613
B0589	Excavator, Combat	$226,756	130	4	0.90	0.8538	0.00769	0.0034	0.046	2	0.007	$57,921,637
B1291	Decontamination System, Ltwt	$27,448	1224	62	0.88	0.8301	0.00082	0.0030	0.050	2	0.006	$59,623,413
B1139	Hose Reel System (HRS)	$184,637	47	6	0.82	0.8298	0.02128	0.0115	-0.010	0.5	0.006	$60,731,235
D0879	Trlr, Powered, 30T, Cargo, Drop	$160,023	326	17	0.88	0.7807	0.00307	0.0019	0.099	3	0.006	$63,451,626
E0856	AAV, Recovery	$611,041	60	3	0.88	0.8400	0.01667	0.0027	0.040	2	0.005	$65,284,749
D0235	Semi-Trlr, Lowbed, 40T	$30,593	301	24	0.85	0.8505	0.00332	0.0109	0.000	0.5	0.005	$66,018,981
E1888	Tank, Combat, FT, 120mm Gun	$828,083	403	25	0.98	0.7200	0.00248	0.0003	0.260	14	0.004	$86,721,056
D0879	Trlr, Powered, 30T, Cargo, Drop	$160,023	326	5	0.88	0.8328	0.00307	0.0019	0.047	2	0.004	$87,521,171
B1580	Pump Module, Fuel (SIXCON)	$20,983	631	28	0.91	0.9112	0.00158	0.0076	-0.001	0.5	0.004	$88,108,695
E0960	Machine Gun, Lt, Squad, Auto Wpn	$1,909	8066	101	0.92	0.9219	0.00012	0.0065	-0.002	0.5	0.003	$88,301,504
D0080	Chassis, Trlr, GP, 3 1/2T, 2 Whl	$8,697	2314	222	0.78	0.8000	0.00043	0.0050	-0.020	0.5	0.002	$90,232,238
E1888	Tank, Combat, FT, 120mm Gun	$828,083	403	1	0.98	0.7820	0.00248	0.0003	0.198	7	0.002	$91,060,321
B1291	Decontamination System, Ltwt	$27,448	1224	22	0.88	0.8807	0.00082	0.0030	-0.001	0.5	0.001	$91,664,177
E0856	AAV, Recovery	$611,041	60	4	0.88	0.8900	0.01667	0.0027	-0.010	0.5	0.001	$94,108,341

Table 10. Utility Algorithm Results

As seen in Table 10, the output of this model is displayed as a prioritized list of PEIs to be inducted into the depot. The output of the model has been sorted by the final ranking value from highest to lowest. A particular PEI may appear on this list as many as five times, depending on the number of readiness bands for that PEI.

Given a constrained budget, a budget line can be drawn on this output, utilizing the cumulative total cost column. All PEIs falling above the budget line are funded, all below are unfunded. In the case that the budget falls within a readiness band (which will nearly always be the case), that band will be funded to the extent of the budget. Any remaining money will be spent on the next highest priority that has a URC within the remaining budget.

The assumption that ranking values alone should determine the priority for equipment induction, regardless of the size of the readiness band, is a heuristic that allows the priority list to be developed before the budget number is known with certainty; a useful characteristic. Once a budget number is known, it is proposed that the ranking be used in a myopic fashion to determine which PEIs should be inducted for maintenance. Myopic procedures work in a linear fashion, considering only the next item in a list – in this case, PEIs will be inducted in a myopic fashion, taking the next item in the list without any consideration of items further down on the list, until the budget is exhausted. For any given budget amount however, a myopic procedure is heuristic, not optimal. For example, assume a budget of $60 million on the sample output provided in Table 10. This budget falls in the middle of a readiness band for B1139. Funding a quantity of 2 (of the 6 USRs available) brings the total expenditure to $59,892,687. There is not enough money left to fund another unit of B1139. Furthermore, there is not enough money to fund either of the next two PEIs on the prioritized list; D0879 with a URC of $160,023, and E0856 with a URC of $611,041. This myopic procedure moves to the next prioritized readiness band affordable within the remaining budget. In this case, D0235 is partially funded, virtually using the entire remaining budget.

To prevent this problem, a linear program could be developed that would take the cost of each readiness band into consideration. Such a linear program could be run against the ranked list after the budget numbers were announced. This procedure has not been included, first because it is outside the scope of this project, and second, because in practice the myopic nature of the proposed procedure will cause few problems.

While heuristic, this output allows decision makers to see exactly what equipment will be dropped from the depots schedule in the event of a budget cut. Conversely, planners can see exactly what assets to fund with budget plus ups. Additionally, in the year of execution, as PEIs become unavailable for return to the depot (which occurs every year), decision makers are able to move down the prioritized list to determine what is the next best alternative.

In order to interpret the results of this model, four PEIs have been selected from different portions of the list to examine why they were ranked as they were.

TAMCN	NOMENCLATURE	URC	AAO	USR	Tgt R	Curr R	ΔR	ΔR/ URC	R Diff	Cn	Value
D1160	Interim Fast Attack Vehicle	$50,000	80	12	0.91	0.57	0.0125	0.025	0.34	14	.350
D1160	Interim Fast Attack Vehicle	$50,000	80	7	0.91	0.72	0.0125	0.025	0.19	7	.175

Table 11. Explanation of Rankings; IFAV

D1160 has been chosen because its first readiness band ranked first among all PEIs. This PEI has a high target readiness (.91) derived from its WFV of .625. The low current readiness (.57) caused a readiness differential of .34 which gives this readiness band a coefficient of 14. The coefficient (representing the warfighter's utility for this readiness band of this PEI) is then multiplied by the ΔR/URC (representing the economic utility to the Marine Corps of repairing this PEI). This PEI has a mid-range URC and is a low density item, meaning that repairing a single unit has a significant increase in readiness (1.25% in this case). This results in a relatively high economic utility, multiplied by the highest possible warfighter utility (for this readiness band), resulting in the highest final ranking value. After selecting this readiness band, the readiness differential changes to .190, moving the next readiness band to the next segment of the piece-wise linear curve. With a coefficient of 7, the final ranking value of the second readiness band of D1160 is significantly less, and is not selected by the model until six other readiness bands of different PEIs have first been selected.

This PEI demonstrates many of the properties of this model. Recall that the economic utility does not change throughout the process. The warfighter utility however, is reduced as readiness bands are selected and quantities of the PEI are repaired. As this occurs the readiness differential gets smaller and the coefficient decreases. As the coefficient decreases the final ranking value decreases, placing each subsequent readiness band of this PEI further down the prioritized list.

TAMCN	NOMENCLATURE	URC	AAO	USR	Tgt R	Curr R	ΔR	ΔR/ URC	R Diff	Cn	Value
A1503	Radar Set, 3D, Long Range	$7,429,900	13	2	0.88	0.6923	0.07692	0.0010	0.188	7	.007

Table 12. Explanation of Rankings; Long Range Radar

A1503 has the most expensive unit repair cost of the sample list. This PEI is also a low density item. Repairing a single radar increases readiness of the PEI by 7.7%. The economic utility of repairing this radar is a tradeoff between a large increase in readiness and a very high cost. Given the current readiness of 69%, the readiness differential for the first readiness band of this PEI is 18.8%. This places it on the portion of the piece-wise linear curve with a slope of 7, resulting in a coefficient of 7. In this case, the low economic utility combined with the relatively high warfighter utility places the first and only readiness band of this PEI 50th (of 64) on the prioritized list.

TAMCN	NOMENCLATURE	URC	AAO	USR	Tgt R	Curr R	ΔR	ΔR/ URC	R Diff	Cn	Value
A1260	Navigation Set, Satellite Signal PLGR	$348	5015	400	0.86	0.9200	0.00020	0.0573	-0.06	0.5	0.029

Table 13. Explanation of Rankings; PLGR

A1260 has the least expensive unit repair cost of the sample, but is one of the highest density items. Repairing a single unit of this PEI only increases the readiness by

.002%. This high density is offset by the low URC to create an economic utility that is relatively high. With a current readiness of 92%, this PEI is already above its target readiness of 86% as determined by its WFV. This negative readiness differential places the PEI on the farthest right portion of the piece-wise linear curve with a coefficient of .5. When multiplied by the economic utility value of .0573, this coefficient actually acts to penalize this PEI (multiplying by a fraction), which results in an even lower final ranking value. This is a desired effect of the model since the PEI is already above its target readiness. The combination of these factors places this readiness band (due to the high density, the entire 400 units fall into one readiness band) at 29th on the prioritized list.

TAMCN	NOMENCLATURE	URC	AAO	USR	Tgt R	Curr R	ΔR	ΔR/ URC	R Diff	Cn	Value
E0942	LAV, Anti-Tank	$408,179	98	7	1.00	0.6100	0.01020	0.0025	0.390	14	.035

Table 14. Explanation of Rankings; LAV-AT

E0942 has been chosen because it has a target readiness of 100% based on its WFV of 1. The economic utility of repairing this PEI is in the bottom half of the sample set. This is due to the relatively high URC, and a moderate density level. With a current readiness of 61% and a target readiness of 100%, the readiness differential of 39% falls on the portion of the piece-wise linear curve with a coefficient of 14. This PEI will maintain a coefficient of 14 until enough units have been repaired to make the readiness differential less than 20%. In this case, the readiness must reach 80% before the coefficient would drop to 7, lowering the final ranking value. With an increase in readiness per unit repaired of 1.02%, the first readiness band for this PEI would be a quantity of 29. However, there are only 7 LAV-ATs available to be turned in to the depot in this cycle. The entire value of 7 is selected 26th on the prioritized list.

The purpose of examining these four PEIs was to understand exactly why they were prioritized as they were given these specific inputs. The next section will examine some of the same PEIs to illustrate how their placement on this prioritized list could change given a change in their inputs.

E. SENSITIVITY

One of the primary criticisms of the DERO model is the lack of sensitivity to differences in WFVs. The following examples will show how the final ranking value is affected by changes to the inputs to the model.

TAMCN	NOMENCLATURE	URC	AAO	USR	Tgt R	Curr R	ΔR	ΔR/ URC	R Diff	Cn	Value
A1503	Radar Set, 3D, Long Range	$7,429,900	13	2	0.88	0.6923	0.07692	0.0010	0.188	7	.007
A1503	Radar Set, 3D, Long Range	$7,429,900	13	1	0.92	0.6923	0.07692	0.0010	0.228	14	.014
A1504	Radar Set, 3D, Long Range	$7,429,900	13	1	0.92	0.7692	0.07692	0.0010	0.151	7	.007
A1503	Radar Set, 3D, Long Range	$7,429,900	13	2	0.88	0.5400	0.07692	0.0010	0..34	14	.014

Table 15. Sensitivity Analysis; Long Range Radar

The first set of results shows the long range radar with the sample data entered in the model. With this data the first and only readiness band was ranked 50th among the sample PEIs. In the second set of results shown (highlighted in green), the target readiness has been changed from .88 to .92. This change could occur for a number of reasons. Chapter III discussed the attributes that are used to calculate a PEI's WFV. In this instance, if the WIRs for the radar increased, or if the unit requesting depot maintenance for this cycle was higher on the waterfall chart than in the past, the radar's WFV would increase. With a higher WFV, a corresponding increase in target readiness creates a larger readiness differential (given the same current readiness), resulting in a greater coefficient, in this case 14. The economic utility of this PEI has not changed, but the warfighter's utility has increased. The resulting ranking value for the first readiness band is now .014, moving it from 50th on the sample prioritization to 40th. This scenario would only select a quantity of one in the first readiness band. The second readiness band with a coefficient of 7 would remain 50th on the prioritized list.

In the third set of results highlighted in yellow, the WFV has returned to .88, however the current readiness has been lowered to .54. This example is meant to illustrate that a PEI with an extremely low current readiness will receive favorable treatment by the model. With this low readiness level, the readiness differential becomes large (.34). In this case, it is sufficiently large so that both of the unserviceable returns fall into the same readiness band and receive the highest coefficient of 14. The resulting ranking value means that a quantity of two radars will be selected 40th on the prioritized list.

TAMCN	NOMENCLATURE	URC	AAO	USR	Tgt R	Curr R	ΔR	ΔR/ URC	R Diff	Cn	Value
A1260	Navigation Set, Satellite Signals PLGR	$348	5015	400	0.86	0.9200	0.00020	0.0573	-0.06	0.5	0.029
A1261	Navigation Set, Satellite Signals PLGR	$348	5015	400	0.86	0.7800	0.00020	0.0573	0.08	3	0.172

Table 16. Sensitivity Analysis; PLGR

Once again due to its low URC, the PLGR has a high economic utility. Also recall that because its current readiness was already higher than its target readiness, the coefficient was .5. The result was a ranking value placing the PLGR 29th on the prioritized list. In the second row, (highlighted in blue) the target readiness remains the same, but the current readiness has been decreased. The result is a readiness differential that corresponds to a coefficient of 3. Applying the algorithm, the PLGRs improved ranking value now places it 9th on the prioritized list. A higher target readiness or a lower current readiness may increase the coefficient, raising the PEI even higher on the prioritized list.

F. CONCLUSION

This chapter has covered the utility algorithm, its inputs, outputs, and sensitivity to changes in inputs. The four driving factors of this model interact to produce a prioritized list of PEIs that account for both economic and warfighter utility. Utilizing this method ensures that the Marine Corps is receiving a better return on its investment in the DLMP, driven by the needs of the warfighter.

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V. PROPOSED SOLUTIONS

The premise of this project was to examine the DLMP process and make recommendations to address the dissatisfactions being voiced by the stakeholders. The authors' research revealed that the bulk of this dissatisfaction came from an optimization model that most stakeholders do not trust, nor do they believe it adequately reflects priorities that stakeholders value. Specifically, the process of assigning warfighting values to PEIs, and the effect those warfighting values have on the model's output are thought to be inadequate. In addition, the proprietary software used to run the DERO model (which is not licensed on NMCI) and the inflexibility of the output produced by the model complicate the process beyond reason.

Utilizing stakeholder interviews, best business practices, and academic research, the authors present the following three proposed solutions to improve the process. Each recommendation builds on its predecessor with the first being the least intrusive to the current process, and the third being a completely different model.

1. Utilize the multivariable approach defined in Chapter III to develop warfighting values that are significantly differentiated, relevant to the needs of the warfighter, and are capable of changing with the current situation and the evolving needs of the Corps.
2. Based on these warfighting values, implement the method defined in Chapter III to create a target readiness for each PEI, rather than the common target readiness for all PEIs that is currently used.
3. In place of the DERO model, utilize the utility algorithm described in Chapter IV to prioritize PEIs based on the combination of economic and warfighter utility.

The pros and cons of each of these proposals are discussed below.

A. WARFIGHTING VALUES

The first proposal is to continue using the DERO model; however, it is recommended to assign WFVs using the method described in Chapter III. Using the prescribed approach to developing WFVs has a number of advantages over the current process. The first advantage is the scale. The proposed method has a continuous range from .00 to 1.00 while the current method is limited to the discrete set {1,2,3,4}. The large range under the proposed method allows for greater differentiation between PEIs. This differentiation has the potential to have a much greater effect on the output of the DERO model. The scale of the WFVs proposed in this report requires further analysis to determine their effect on the DERO model. The second advantage is the increased exposure to factors such as the life cycle stage of the PEI and the needs of deployed or high priority units. Utilizing four diverse attributes creates a more relevant WFV than the current practice of using four similar characterizations. Related to the diversity of the attributes used to determine WFVs is the fact that two of the four attributes have the potential to change every cycle making the WFVs dynamic and allowing them to best support current and near term priorities.

A disadvantage of the proposed method of assigning WFVs is the increased labor required to gather data and recalculate the WFVs each cycle. Under the current system the WFVs do not change therefore no time is spent on this part of the process. Under the proposed system, each PEI will require a calculation to obtain the ratio of the quantity of WIRs to AAO. An additional adjustment is necessary based on which unit is providing the USR, and where the unit is prioritized in the waterfall chart during that cycle. However, in the authors' opinion, the recalculation of the factors related to WFVs in each cycle is also a strength of the proposed procedure; it merely recognizes the fact that WFVs are dynamic, and does depend on the current environment. Failure to recalculate the WFV may save time, but it will also produce a result that fails to use the best available information to adequately account for the warfighter's utility. Another disadvantage is that this recommendation does not address the DERO models disregard for economic considerations such as the cost of repairing PEIs. Finally, this approach does not address the current policy of maintaining an 85% target readiness across all PEIs.

B. TARGET READINESS

The second proposal is to continue utilizing the DERO model utilizing the WFVs in proposal one to create a range of target readiness. The current process assigns a target readiness of 85% to every PEI. The proposed method links target readiness to WFVs where the PEIs with the highest WFVs are assigned the highest target readiness. Assigning a target readiness between 75% and 100% is another way of differentiating between PEIs within the model to ensure that limited depot dollars are spent in the best interest of the warfighter. Setting the target readiness of every PEI to 85% implies that the utility of all PEIs is equal.

A disadvantage to this proposal is that in addition to recalculating WFVs each cycle, target readiness must be recalibrated to coincide with the new WFVs. This process will require additional time in preparation for the DLMP requirements conference. Again, however, this additional labor is required to adequately reflect changes in priorities that occur between cycles. Simply stating a blanket 85% readiness target may save time, but it does not reflect current priorities.

Moreover, the procedure outlined, while systematic, is heuristic. The heuristic nature of this process can be seen in the somewhat arbitrary way that WFVs are partitioned to create target readiness levels.

As a potential solution to this concern, citations to procedures that can guarantee an improvement in the target readiness partitions have been provided. Developing such a code, though it might save time by automating target readiness determination, would further complicate the process. Development of this partitioning code has not been included, both because it was determined to be outside the scope of this project, but also because the partitioning heuristic utilized provides an adequate and less complex solution.

Another disadvantage is that neither this second proposal nor the first addresses the issue of economic utility. Given a limited budget, the Marine Corps would be missing an opportunity to ensure that it gets the greatest return on investment from depot level maintenance if it did not adopt a method that considers economic utility.

C. UTILITY ALGORITHM

The third proposal calls for the most dramatic change to the current process. This proposal recommends that the DERO model be replaced by the utility algorithm presented in Chapter IV.

The utility algorithm utilizes inputs that are easily understood, both in their origin and their effect on the model. The biggest fundamental difference between the DERO model and the utility algorithm is the consideration of repair cost when deciding what PEIs to fund with a limited budget. The DERO model strives to achieve the fastest increase in readiness given a budget. That is, it selects PEIs with the lowest levels of readiness and chooses them to be funded until it runs out of money. There is no consideration of what less expensive opportunities are being forgone by repairing expensive PEIs. The utility algorithm strives to achieve the largest increase in readiness per budget dollar spent. That is, the algorithm searches for the most efficient increases in readiness, and then combines them with the needs of the warfighter to produce the prioritized funded list.

One of the biggest advantages of the utility algorithm is the format and flexibility of its output. The utility algorithm places banded quantities of each PEI in a prioritized list from first to last. This format allows decision makers to see exactly what equipment will be funded at any level of budget appropriation. Requests for supplemental funding can easily be justified with the prioritized list of PEIs, showing exactly what will be repaired with the additional funds. Additionally changes in asset availability at the time of execution can be dealt with quickly and efficiently by moving to the next item on the prioritized list.

Finally the use of Microsoft Excel to run the model allows this process to occur on NMCI supported computers. Results can easily be displayed so that stakeholders can see the contribution of economic utility and warfighter utility to the final ranking value, and have a genuine understanding of the results that they are presented with.

A disadvantage of the utility algorithm is that it is a significant departure from the current process. The change will likely meet resistance from stakeholders ingrained in the current process.

Another disadvantage of this model is the potentially prohibitive effect of extreme unit repair costs. PEIs with high AAOs and extremely high URCs do not receive a favorable ranking in this model. Specifically, tanks (AAO 403, URC $828,083) do not compete well due to the very low economic utility of repairing these assets. The authors believe that these objective rankings accurately reflect the economic and warfighting utility of these assets. However, if stakeholders feel that the procedure is biased against high-dollar-value URC items, this effect can be easily negated by adjusting the (unit) weight of the ΔR/URC in the model to reduce the importance of economic utility, or by incorporating another sub factor into the WFV to give more weight to such PEIs.

D. CONCLUSION

In conclusion is a brief discussion on how the proposed solutions have addressed the problems identified with the DLMP.

First a new method for calculating Warfighting Values has been proposed. This method gives stakeholders the opportunity to use a variety of attributes to ensure that the final WFV reflects the needs of the warfighter. Stakeholders are able to understand why a PEI has a particular WFV, and most importantly, know that the WFV has an impact on the output of the model. Second, the output of the Utility Algorithm is presented in a manner that is easily interpreted by those on the outside of the process, and easily executed by those who work within the process. Finally, the combination of warfighter's utility, economic utility, and diminishing marginal returns utilized in the Utility Algorithm provide the Marine Corps with an improved return on investment, and the warfighter with a more significant impact on the depot maintenance process.

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APPENDIX A

Ranking of Economic Utility for the Sample Set

TAMCN	NOMENCLATURE	ΔR/URC*
E3191	Trainer, Handling GM Launch (Stinger)	0.1304
E0930	Launch Simulator, Stinger	0.0702
A1260	Navigation Set, Satellite Signals PLGR	0.0573
E0277	Display Group, Data	0.0351
D1092	Trk, Maint, Telephone	0.0318
A2635	Telephone Set	0.0304
A0966	Mobile EW Support System PIP	0.0250
D1160	Interim Fast Attack Vehicle	0.0250
E1356	Recharging Unit, Coolant, Trng	0.0250
E0150	Armored Vehicle, Launcher, Bridge	0.0159
A2505	Switchboard, Telephone, Automatic	0.0157
A1440	Radar Set, Firefinder	0.0125
B2460	Tractor, Full Tr (T5)	0.0116
B1139	Hose Reel System (HRS)	0.0115
D0235	Semi-Trlr, Lowbed, 40T	0.0109
A2306	Sensor System Monitor, Mobile	0.0094
B1580	Pump Module, Fuel (SIXCON)	0.0076
E0960	Machine Gun, Lt, Squad, Auto Wpn	0.0065
E0989	Machine Gun, Medium, 7.62mm	0.0063
B2086	Storage Tank Module, Water (SixCon)	0.0059
D0080	Chassis, Trlr, GP, 3 1/2T, 2 Whl	0.0050
D0877	Trlr, Powered, Wrecker/Recovery, 4X5	0.0040
B0589	Excavator, Combat	0.0034
B1291	Decontamination System, Ltwt	0.0030
E0856	AAV, Recovery	0.0027
E0942	LAV, Anti-Tank	0.0025
D0879	Trlr, Powered, 30T, Cargo, Dropside	0.0019
A1503	Radar Set, 3D, Long Range	0.0010
E0947	LAV, Light Assault, 25mm	0.0007
E1888	Tank, Combat, FT, 120mm Gun	0.0003

* The ΔR/URC column is multiplied by 100,000 for the ease of visually comparing the numbers.

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APPENDIX B

Utility Algorithm Formulas

	A	B	C	D	E	F	G	H	I	J	K	L
1	TAMCN	NOMEN	URC	AAO	USR	Tgt R	Curr R	ΔR	ΔR/ URC	R Diff	Cn	Value
2	A0966	MEWSS	307,613	13	1	0.93	0.7692	1/D2	(H2/(C2))* 100000	F2-G2	IF(J2>=0.2,"14",IF(J2>=0.1, "7",IF(J2>=0.05,"3",IF(J2>0,"2",".5"))))	(I2*K2)
3	A0966	MEWSS	307,613	13	1	0.93	G2+ (E2*H3)	1/D3	(H3/(C3))* 100000	F3-G3	IF(J3>=0.2,"14",IF(J3>=0.1, "7",IF(J3>=0.05,"3",IF(J3>0,"2",".5"))))	(I3*K3)

This table shows the formulas that are entered in the Utility Algorithm spreadsheet. The following is a description of the cells that contain a formula.

G3. Cell G3 is the current readiness of the second readiness band for this PEI. The formula takes the initial current readiness plus the increase in readiness realized when the first readiness band is repaired.

H2. Cell H2 is the change in readiness realized by repairing a single unit of this PEI. The increase in readiness is 1/AAO.

I2. Cell I2 is the change in readiness divided by the unit repair cost, also known as the economic utility.

J2. Cell J2 is the readiness differential, which is the target readiness minus the current readiness.

K2. Cell K2 is the coefficient. This formula is a series of "IF, THEN" statements that determine the coefficient based on the readiness differential in cell J2.

L2. Cell L2 is the final ranking value. This value is the product of the economic utility and the coefficient.

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