NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

JOINT APPLIED PROJECT REPORT

AFFORDABILITY DECISION-MAKING MODEL

September 2020

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** September 2020	**3. REPORT TYPE AND DATES COVERED** Joint Applied Project Report	
4. TITLE AND SUBTITLE AFFORDABILITY DECISION-MAKING MODEL			**5. FUNDING NUMBERS**
6. AUTHOR(S) Thomas M. Miller and Eric D. Murphy			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.			**12b. DISTRIBUTION CODE** A

13. ABSTRACT (maximum 200 words)

Department of Defense (DOD) senior leaders are chartered to make decisions on proceeding or canceling programs based on cost data. Affordability is one of the biggest reasons for the DOD to cancel programs. When making affordability decisions, DOD leaders weigh the life cycle costs from research and development, technology maturation, system testing, procurement and operations, and support. The authors developed an affordability decision model to be used to make affordability decisions for Acquisition Category I vehicle programs. While developing the model the following questions were answered:

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14. SUBJECT TERMS affordability, decision, model, affordable, life cycle, programs, program, life cycle cost, Department of Defense, DOD, High Mobility Multipurpose Wheeled Vehicle, HMMWV, Joint Light Tactical Vehicle, JLTV, Mine Resistant Ambush Protected All-Terrain Vehicle, M-ATV			**15. NUMBER OF PAGES** 77
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500 | Standard Form 298 (Rev. 2-89) Prescribed by ANSI Std. 239-18

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AFFORDABILITY DECISION-MAKING MODEL

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN PROGRAM MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
September 2020

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LIST OF ACRONYMS AND ABBREVIATIONS

AAO	Army's Acquisition Objective
ACAT	Acquisition Category
ADM	Acquisition Decision Memorandum
APS	Army's Preposition Stock
AT&L	Acquisition, Technology and Logistics
BBP	Better Buying Power
CAE	Component Acquisition Executive
CLS	Contract Logistics Support
CONUS	Continental United States
CPD	Capabilities Production Document
DAE	Defense Acquisition Executive
DLA	Defense Logistics Agency
DOD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DPAS	Defense Property Accountability System
EDA	Excess Defense Articles
EFP	Explosively Formed Penetrator
ETMs	electronic technical manuals
FMS	Foreign Military Sales
FoV	Family of Vehicles
FSR	Field Service Representatives
FY	Fiscal Year
FYDP	Future Year Defense Program
GCSS-A	Global Combat Support System-Army
HMMWV	High Mobility Multipurpose Wheeled Vehicle
IAW	in accordance with
IDA	Institute for Defense Analysis

IDIQ	Indefinite Delivery Indefinite Quantity
IED	Improvised Explosive Devices
IETMs	interactive technical manuals
JCIDS	Joint Capabilities Integration and Development System
JLTV	Joint Light Tactical Vehicle
KPP	Key Performance Parameter
KSA	Key System Attributes
LCCE	Life Cycle Cost Estimate
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MILCON	Military Construction
MIL-STD	Military Standard
MOD	Military Occupation Series
M-ATV	Mine Resistant Ambush Protected All-Terrain Vehicle
M&S	Modeling and Simulation
OCONUS	Outside the Continental United States
OEM	Original equipment manufacturers
OPTEMPO	Operational Tempo
O&M	Operation and Maintenance
O&S	Operation and Sustainment
PBUSE	Property Book Unit Supply Enhanced
PICA	Primary Inventory Contract Activity
PM	Program Manager
PORTOPT	Port Optimization
RDT&E	Research, Development, Test and Evaluation
RPG	Rocket Propelled Grenades
R&S	Reliability and Sustainability
SAMS-E	Standard Army Maintenance System-Enhanced
SECDEF	Secretary of Defense
STAMIS	Standard Army Management Information System

TPE	Theater Provided Equipment
UIK	Underbody Improvement Kit
USD	Under Secretary of Defense
USD(ATL)	Under Secretary of Defense (Acquisition, Technology and Logistics)

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ACKNOWLEDGMENTS

We would like to thank our families for their support and encouragement in completing this Joint Applied Project. Without their support and encouragement, we would not have been able to dedicate the time and the drive to complete this.

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I. INTRODUCTION

Affordability is the backbone of Department of Defense (DOD) program success, which was reiterated by former Secretary of Defense James Mattis, on January 19, 2018, when commenting on the National Defense Strategy. Mattis stated, “To keep pace with our times, the department will transition to a culture of performance and affordability that operates at the speed of relevance” (2018, para 50). Prior to programs beginning development or production, and depending on the acquisition milestone phase, an affordability analysis is required for approval by the milestone decision authority (MDA) (Department of Defense [DOD], 2015). Many times, however, as programs move through the acquisition life cycle, program costs can increase and decrease for a number of reasons. As a result of these changes, programs are reviewed by senior leaders and decisions are made, based on the affordability of the program, to either proceed with the program or cancel it. In an effort to make better informed decisions in the future, this project will provide an affordability decision model for acquisition category (ACAT) I programs based on the analysis of prior defense programs.

Our research was based upon the historical cost data of the High Mobility Multipurpose Wheeled Vehicle (HMMWV) and the Mine Resistant Ambush Protected All-Terrain Vehicle (M-ATV). The historical cost data that we looked at includes research, development, test and evaluation (RDT&E), procurement (unit cost, initial spares and support equipment) and operation and sustainment (O&S) (Military Personnel, Military Construction (MILCON), repair parts and fuel usage). We used the historical cost data and our own experience to develop the cost inputs for the model. This model is for senior leaders/MDAs to use when making proceed or cancel decisions in the future for ACAT I vehicle programs. The model accounts for wartime and surge requirements as well as acquisition outcomes. After developing the model, we verified it by using data from the HWMMV and M-ATV programs. Any issues in the model we noted and provided recommendations for if the model should be changed in the future for use on other ACAT I vehicle programs specifically the Joint Light Tactical Vehicle (JLTV) program.

A. BACKGROUND

Affordability analyses are required for all DOD ACAT-level programs and are required to be updated as programs prepare for all milestone decisions. According to the DOD "Affordability analyses are not intended to produce rigid, long-range plans; their purpose is to inform current decisions about the reasonableness of embarking on long-term capital investments at specific capability levels" (2015, p. 20). The overall goal of the analysis is to avoid starting or continuing programs that cannot be produced or be supported within a reasonable expectation of future budgets. The affordability analysis is based off of the life cycle cost estimate (LCCE), which consists of RDT&E costs, investment costs, O&S costs, and disposal costs over the entire life cycle. Table 1 provides the definition of ACAT I programs (DOD, 2015, p. 47).

Table 1. ACAT Description

ACAT	**Reason for ACAT Designation**	**Decision Authority**

ACAT I	• MDAP (10 U.S.C. 2430 (Reference (g)))
	  • Dollar value for all increments of the program: estimated by the DAE to require an eventual total expenditure for research, development, and test and evaluation (RDT&E) of more than $480 million in Fiscal Year (FY) 2014 constant dollars or, for procurement, of more than $2.79 billion in FY 2014 constant dollars
	  • MDA designation
	• MDA designation as special interest1
		ACAT ID: DAE or as delegated
		ACAT IC: Head of the DOD Component or, if delegated, the CAE (not further delegable)

MDAs use the information in the affordability analysis to determine if programs should proceed or be canceled; therefore, the information has to be as accurate as possible. Oftentimes these decisions are made without the total affordability of the program leading to incorrect decisions being made. The purpose of this project is to develop an affordability decision model to be used by MDAs when making affordability decisions for future programs.

B. PROBLEM STATEMENT

ACAT I programs proceed or are terminated based on affordability, assuming that information is accurate. Without accurate information, programs that may be affordable could be canceled and those programs that were viewed as affordable may result in severe cost overruns in the future. As programs become more complex and larger in value, the DOD has to do a better job accurately estimating future program costs.

C. RESEARCH OBJECTIVES

The research objective of this project is to develop an affordability model, based on historical cost data and our own experience that can be used by MDAs in the future on ACAT I vehicle programs. The goal is to avoid starting or continuing programs that cannot be produced or supported within the reasonable expectation of future budgets.

D. RESEARCH QUESTIONS

1. Primary Research Question

- What are the primary elements to address in an affordability decision model for a "proceed or cancel" decision?

2. Secondary Research Question

- Are there any external parameters that need to be considered prior to using the affordability decision model?

E. PURPOSE/BENEFIT

The purpose of the project is to provide a model that can be used by MDAs to make a "proceed or cancel" decision for ACAT I vehicle programs. The model will be based upon the review of historical cost data for the HMMWV and M-ATV programs, which will include the life cycle cost in relation to the acquisition approach, type for system, and how long the system will be utilized by the warfighter. With this model, MDAs will be able to review the facts that are presented in a program’s affordability analysis to make, proceed or cancel decisions with higher confidence in their decision.

F. SCOPE

For this project, we chose to review the cost data associated with the HMMWV and M-ATV programs to develop an affordability model that can be used for future ACAT I vehicle program decisions specifically the JLTV. We chose these programs because of their similar mission requirements. The M-ATV was the replacement for the HMMWV in Iraq and Afghanistan due to the HMMWVs limited off-road capabilities and lack of armor protection. Whereas the JLTV is the new permanent replacement for the HMMWV moving forward which provides greater survivability. It also meets the airlift capability of the CH-47F helicopter and meets the air assault mission requirements with the B-kit armor removed. Due to the commonality of these programs the historical cost data of the HMMWV and M-ATV programs provides an account of the cost elements required for an affordability decision model that is then extended and applied to an affordability determination for the JLTV program.

By developing an affordability model based on historical cost data for the predecessors of the JLTV this model can be used to make better affordability decisions for the JLTV program in the future. The model is first used with cost data from the HWMMV and M-ATV programs. The model results will then be analyzed to show the effects of the elements of the model and its impact if used on other programs specifically the JLTV program.

G. METHODOLOGY

For the model, we developed a list of cost elements based on a review of the HMMWV and M-ATV cost data and personal experience. The cost data included RDT&E, Procurement, O&S historical cost data along with other unique factors. The unique factors such as urgency, accelerated schedules, and surges to support wartime activities were assessed on a program basis. The model was developed with a series of cost inputs that are common across all programs such as shipping, fielding and sustainment. In addition to the common cost inputs, the model also has program-specific cost elements such as RDT&E,

additional testing and vehicle costs. After completing the model, we then ran the model for both the HMMWV and M-ATV programs to verify it. We then compared the results of the model against the actual costs for both programs to determine if the model was accurate in capturing program costs. Once we reviewed the model against the cost data, we determined if changes to the model were required in order for the model to be used on future ACAT I vehicle programs to include the JLTV. We compared each line of the model to the corresponding actual cost data to determine if the cost was estimated accurately or if a change was required.

Table 2 shows the model and its cost elements, the fields highlighted in green are those that are to be filled in for each program. The table is color coded by funding type. Red is for RDT&E cost elements. Blue is for procurement cost elements. Orange is for O&S cost elements. We developed the model based on our experience and from the HMMWV and M-ATV cost data. Chapter IV provides a detailed explanation of the model and its specific inputs.

Table 2. Affordability Model

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Initial RDT&E	0	$500,000,000	0	$0	$0	Initial RDT&E unit cost based on program requirements.
Does the current requirement require additional testing than the current system? (Each Additional KPP)	0	$50,000	0	$0	$0	How many additional test required
Are there additional testing for survivablity requirements (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Are there additional reliablity requirements (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Are there additional enhancements required by the user (KSA) (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Are there additional performances test required (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Is there any other RDT&E needed after initial testing	0	$1,000,000	0	$0	$0	Is there any additional RDT&E funding needed
Is the unit cost greater than the current system (Qty of Systems X Unit Cost) (Yes or No) Yes # of systems and answer next question, No use # of systems	0	$0	0	$0	$0	Plug in number specific to system.
Is the unit cost greater than the current system (Yes) (Qty of Systems X Unit Cost)	0	$0	0	$0	$0	Plug in number specific to system.
Is the QTY greater than the current system (Cost Current System)	0	$0	0	$0	$0	QTY greater
Is the QTY greater than the current system (Cost of current and additional cost)	0	$0	0	$0	$0	QTY greater
How many fieldings are required (CONUS)	0	$25,000	0	$0	$0	Estimated number of fielding's
How many fieldings are required (OCONUS)	0	$50,000	0	$0	$0	Estimated number of fielding's
Is there new support equipment required	0	$20,000	0	$0	$0	New Support Euipment
Are new special tools required (1:25)	0	$10,000	0	$0	$0	1:25 ratio
Is there spare parts packages required (1:25)	0	$250,000	0	$0	$0	1:25 ratio
Does DLA need to be primed for initial spares on the shelf	0	$20,000,000	0	$0	$0	Does DLA require funding
Is there transporation requirements for shipping vehicles from the OEM	0	$10,000	0	$0	$0	Number of shipments CONUS
Will additional transporation be required for the system (OCONUS)	0	$10,000	0	$0	$0	Number of shipments OCONUS
Are there technical manuals required (ETM)	0	$5,000,000	0	$0	$0	Does the system require an ETM
Are there technical manuals required (IETM)	0	$10,000,000	0	$0	$0	Does the system require an IETM
Is there a new Military Occupational Series (MOS) Required (Additional Operator or Maintainer)	0	$150,000	0	$0	$0	Does the system need new operators or maintainers
Will there be Contract Logistics Support (CLS) (CONUS)	0	$150,000	0	$0	$0	Does the system require contract Field Service Representatives CONUS and for how long
Will there be Contract Logistics Support (CLS) (OCONUS)	0	$360,000	0	$0	$0	Does the system require contract Field Service Representatives OCONUS and for how long
Is there any new construction needed to support the new system	0	$1,000,000	0	$0	$0	Does the system require new facilities
Will there be sustainment cost for facilities (# of Fielding Sites)	0	$10,000	0	$0	$0	Is there any additional funding required for sustainment of new facillites
Estimated OPTEMPO increase from the current system (10% as a baseline or known number) times average cost times number of years	0	$5,000	0	$0	$0	Will the system see an increase of OPTEMPO use and how many vehicles
Total						**Total Procurement Cost**
Average Cost Per System						**Average of Vehicle Cost**
Possible reduction in O&S cost from additional testing that can be a cost benefit						
Overall cost benefit to the system	**Procurement Cost X (10% of Fleet)**	**1 Test (1%)**	**2 Tests (2%)**	**3 Tests (3%)**	**≥ 4 Tests (5%)**	**Cost Benefit**
Survivability and Enhanceability (Is the CB comparable to the enhancement and survivability of the system) or Enhance ability (Can it be upgraded and does the cost benefit the upgrade)	Procurement Cost Times 10% of fleet	10% of fleet procurement cost times 1% Cost Benefit	10% of fleet procurement cost times 2% Cost Benefit	10% of fleet procurement cost times 3% Cost Benefit	10% of fleet procurement cost times 5% Cost Benefit	Is the additional testing a cost benefit or not
Overall benefit to the system	**Readiness**	**1 Test (>90%) > 1 Year**	**2 Tests (>90%) >2 Years**	**3 Tests (>90%) > 3 Years**	**≥ 4 Tests (>90%) ≥ 4 Years**	**Cost Benefit**
Reliability and Maintainability (RAM) and Performance (Does the CB correlate to readiness, better performance or being maintainable and reliable)	> 90%					Is the additional testing a cost benefit or not

H. REPORT ORGANIZATION

Chapter I provides an introduction to the project. In Chapter II we provide a background of the programs used in the project. Chapter III is a literature review of the Institute for Defense Analysis (IDA) model for the affordability of Defense Acquisition Programs. In Chapter IV we discuss the data compiled in support of this project. Chapter V provides an analysis of the data. Lastly, Chapter VI provides our conclusion and recommendation.

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II. BACKGROUND

Affordability became a key focus of DOD programs as a result of DOD Directive 5000.01. The directive specifically related affordability to overall program cost and program stability. It stated that "all participants in the acquisition system shall recognize the reality of fiscal constraints. They shall view cost as an independent variable, and the DOD Components shall plan programs based on realistic projections of the dollars and manpower likely to be available in future years" (Department of Defense [DOD], 2003, p. 5). Following the 2007 update, Dr. Ashton Carter, Under Secretary of Defense (Acquisition Technology and Logistics (USD[ATL]), introduced a series of initiatives called Better Buying Power (BBP) 1.0. Carter's BBP Memo 1.0 talked about affordability, as it stated "restore affordability to our programs and activates" (2010, p.1). Based on these directives, affordability became a requirement of DOD programs via the Joint Capabilities Integration and Development System (JCIDS). Affordability determinations are made by senior leaders based upon the results of the affordability analysis and the LCCE prepared for programs. As stated earlier, an affordability determination is required at milestones A and B.

However, this was not the first time that program affordability has been brought to the forefront of DOD acquisition. Two members of Congress, Senator Sam Nunn and Representative David McCurdy, introduced the Nunn-McCurdy Act, which was signed into law by President Ronald Regan in 1982 (Schwartz, 2010). The act did not specifically use the term "affordability," but the act was intended to control cost growth. The act was in response to a number of ACAT I Programs that had recently experienced significant cost overruns.

The act requires that programs report to Congress when they exceed certain cost growth increases. The thought at the time of the act was that having to publicly state that a program had excessive cost growth would increase the desire for the DOD to control costs on their own. These cost growth increases are called breaches and there are two types significant and critical.

> A “significant” breach is when the Program Acquisition Unit Cost (the total cost of development, procurement, and construction divided by the number of units procured) or the Procurement Unit Cost (the total procurement cost divided by the number of units to be procured) increases 15% or more over the current baseline estimate or 30% or more over the original baseline estimate. A “critical” breach occurs when the program acquisition or the procurement unit cost increases 25% or more over the current baseline estimate or 50% or more over the original baseline estimate (Schwartz, 2010, p. 2).

Originally, the critical and significant breaches only applied to the most recent baseline estimate. In 2006, Congress also applied cost growth thresholds to the original baseline estimate to prevent programs from simply being re-baselined in order to prevent having to report a breach. In an effort to further entice the DOD to control costs, Congress added a requirement in 2009 that any program that reports a critical breach is to be considered terminated unless the Secretary of Defense approves the program to continue (Schwartz, 2010).

More recently, program affordability has been brought to the forefront of DOD acquisition through the BBP initiatives. At the direction of Secretary of Defense (SECDEF) Robert Gates, in June 2010, (USD(ATL)) Carter issued a memo to the DOD acquisition community about BBP. In his memo, Carter spoke of the increased DOD budgets that had been ongoing since 11 September 2001 and that the DOD has to start implementing changes moving forward to control costs, to improve the way it does business especially as budgets were starting to be reduced. As this was Carter’s first time speaking to the DOD about this he provided two high level points for this initiative. Below is a portion of his memo stating the two high level points:

> First, the savings we are seeking will not be found overnight. It has taken years for excessive costs and unproductive overhead to creep into our business processes, and it will take years to work them out. We will be concentrating on new contracts as they are awarded in coming years, to ensure that they reflect new efficiencies. Some of the targets and objectives we decide to pursue will only be able to be achieved on a timeline of several years. On the other hand, Secretary Gates has explained clearly why we need to embark now. And the earlier we embark, the easier it will be to succeed.

> Second, we in the Department cannot succeed at this task alone. We need the input and involvement of industry, and I will be actively seeking their support and ideas. We do not have an arsenal system in the United States: the Department does not make most of our weapons or provide many non-governmental services essential to warfighting—these are provided by private industry. Our industry partners are patriots as well as businessmen. This initiative should contribute to the continuing vitality and financial viability of the defense industry in the era ahead by aligning the direction and incentives of the Department and industry. It is intended to enhance and incentivize efficiency and total factor productivity. Most of the rest of the economy exhibits productivity growth, meaning that every year the buyer gets more for the same amount of money. So it should be in the defense economy. Increased productivity is good for both industry and government. So also is avoiding budget turbulence and getting more programs into stable production.
>
> We also need the help of Congress. Members of Congress observe with dismay as they are asked to approve ever-increasing funding for the very same product or service. We will need their input and support to make necessary adjustments that will in some cases be difficult. (Carter, 2010a, p.2)

In addition to the high-level guidance, Carter also provided a list of objectives; one of which was to "restore affordability to our programs and activities" (p. 1). This was the first time since the Nunn-McCurdy Act that program affordability was brought to the forefront of DOD acquisition programs. In September 2010 Carter provided additional guidance and direction for DOD regarding BBP. This memo again stressed affordability as the memo contained a section called Target Affordability and Control Cost Growth with a subheading of Mandate affordability as a requirement:

> Affordability means conducting a program at a cost constrained by the maximum resources the Department can allocate for that capability. Many of our programs flunk this basic test from their inception. Specifically, at Milestone A, my Acquisition Decision Memorandum (ADM) approving formal commencement of the program will contain an affordability target to be treated by the program manager (PM) like a Key Performance Parameter (KPP) such as speed, power, or data rate- i.e., a design parameter not to be sacrificed or compromised without my specific authority. At Milestone B, when a system's detailed design is begun, I will require presentation of a systems engineering tradeoff analysis showing how cost varies as the major design parameters and time to complete are varied. This analysis would allow decisions to be made about how the system could be made less expensive without loss of important capability. This analysis

> would then form the basis of the 'Affordability Requirement' that would be part of the ADM decision. I will be issuing a directive in the near future to implement this guidance that will apply to both elements of a program's life cycle cost - the acquisition cost (typically 30 percent) and the operating and support cost (typically 70 percent). For smaller programs, the CAEs will be directed to do the same at their level of approval. I recognize that we need to improve the Department's capability to perform this kind of engineering tradeoff analysis, but the ability to understand and control future costs from a program's inception is critical to achieving affordability requirements. (Carter, 2010b, p. 2)

Based on Carter's guidance, affordability not only is required to be discussed at each major milestone decisions but must also be considered as a KPP. With affordability now being treated as a KPP, PMs not only had to start understanding program affordability but also tracking it throughout the life cycle of the program as KPPs have to be met. This was a change in how affordability was viewed in the DOD previously.

Through the implementation of BBP, like with any type of implementation, there were lessons learned and refinements that took place. In order to refine and improve BBP, BBP 2.0 was issued in 2012 by Frank Kendall, the then-USD (AT&L). BBP 2.0 is made up of 36 initiatives that are organized into seven key areas. However, as Kendall stated "the basic goal of BBP, however, remains unchanged: deliver better value to the taxpayer" (p. 1).

As with the original BBP, BBP 2.0 reiterated the importance of affordability as it was still one of the key areas called Achieve Affordable Programs. His BPP 2.0 Memo stated three main points to Achieve Affordable Programs, which, are listed as follows:

- Mandate affordability as a requirement
- Institute a system of investment planning to derive affordability caps
- Enforce affordability caps (Kendall, 2012, p.2)

The most recent iteration, BBP 3.0, was released in April 2015 by Kendall. This iteration focused more on increasing and maintaining our technological advantage over our adversaries. However, it still had affordability as one of the key areas stating the "continued needs to set and enforce affordability caps" (Kendall, 2015, p. 2). Between BBP 2.0 and

3.0 the DOD Instruction (DoDI) I 5000.02 was updated to include policy requirements for affordability caps. As a result of this inclusion, affordability is now required to be reviewed at all milestone decisions (DOD, 2015).

Affordability has been a concern in DOD acquisition since 1982 with the Nunn-McCurdy Act and through all the BBP Initiatives. With the Nunn-McCurdy Act incorporated into the United States Code and the affordability requirements incorporated into Department of Defense Directive (DoDD) 5000.01 and DoDI 5000.02, both Congress and DOD leadership have implemented affordability requirements that clearly display the overall importance of this topic. Since Congress appropriates funding and DOD leadership is responsible for the execution/spending of the appropriated funds, both understand that programs can no longer be fixed by simply throwing more money at the problem. They also understand the importance of obtaining the best value for the government and being good stewards of the taxpayers' dollars, especially in non-conflict times. With this understanding of affordability and how it is related to DOD programs, we collected actual cost data on the HMMWV and M-ATV programs.

We used information to develop our affordability decision model from the HMMWV and M-ATV programs. The next few pages provide background on both of these programs. For both programs, a high-level program background is provided along with information on program costs and vehicle quantities to show the size of the programs. In addition, the evolution of the Army going from the HMMWV to the M-ATV and finally to JLTV is described.

According to the Olive-Drab, the HMMWV was a replacement for the M-151 Jeep and the light-duty trucks produced by General Motors and Dodge. The first HMMWV contract was awarded to AM General in 1983. This five-year contract had an estimated value of $1.2 billion, which allowed the government to procure up to 55,000 vehicles in 15 different configurations. 1983 was the biggest multi-year contract awarded for light tactical trucks in history. Due to the higher demand for HMMWVs the Army ordered an additional 15,000 as an option increasing the total value of the contract from $1.2B to $1.6B (Olive Drab, 2011).

The HMMWV has had multiple iterations and upgrades since 1983. Total production, which is scheduled to conclude in fiscal year (FY) 2020, is estimated to be approximately 240,000 by AM General. Approximately 133,000 remaining HMMWVs are for Foreign Military Sales (FMS) and to be issued as Excess Defense Articles (EDA). The existing HMMWV fleet will remain in the Army inventory system and will be gradually phased out through attrition with the replacement of the JLTV (Olive Drab, 2011).

The M-ATV was the last MRAP variant that was an urgent requirement in support of military operations in Iraq and Afghanistan. The M-ATV was a joint Service program with the Army designated as the Primary Inventory Contract Activity (PICA). The PICA is "the single manager responsible for cataloging, procuring, disposing and identifying depot-level maintenance assignment. A PICA serves as the principal supply control activity responsible for establishing stockage objectives, controlling stockage objectives and maintaining item accountability for an item of supply; formerly called the wholesale inventory manager" (Defense Acquisition University, n.d.). However, each Service had its own requirements for the M-ATV to meet its mission needs. The HMMWV's up armor and the off road capability were limited which created a capabilities gap in Iraq and Afghanistan. Due to the increased weight of the HMMWV and less powerful powertrain, there was a critical need to fill the capabilities gap that the HMMWV could not meet to meet the urgency of the fight in Afghanistan. The M-ATV had the same type of independent suspension system as the HMMWV's but its increased ground clearance made it more effective off road.

In addition to the increased ground clearance, the M-ATV had increased power to accommodate the heavier duty suspension system to support up to 37,000 pounds (Army Project Office Mine Resistant Ambush Protected [APO MRAP] Operations Cell, PowerPoint slides, July 10, 2012). These capabilities met the Afghanistan off-road requirements for protected ground mobility, improved explosive device (IED) protection and small arms fire. Additional survivability upgrades consisted of explosively formed penetrator (EFP) armor kits to defeat EFP threats and rocket propelled grenades (RPG) netting to defeat RPGs.

In November 2008, Indefinite Delivery Indefinite Quantity (IDIQ) contracts, for up to 10,000 M-ATVs, were awarded to five original equipment manufacturers (OEM). Each OEM was awarded a delivery order for three M-ATVs, meeting the IDIQ minimum quantity requirement, which were used for testing. In June 2009 the Oshkosh Defense, LLC (Oshkosh) M-ATV, one of the five OEMs, was awarded production deliver orders as they were determined to be the best value for the government and ended in October 2012. A total of 8,722 M-ATVs were delivered to the United States Army, Marine Corps, Navy, Air Force and Special Operations Command (SOCOM) (T. Miller personal communication March 19, 2019). During the wars in Iraq and Afghanistan, the Army conducted an MRAP study and in August 2014 decided on 5,651 M-ATVs as their enduring fleet (APO MRAP Operations Cell, PowerPoint slides, July 10, 2012).

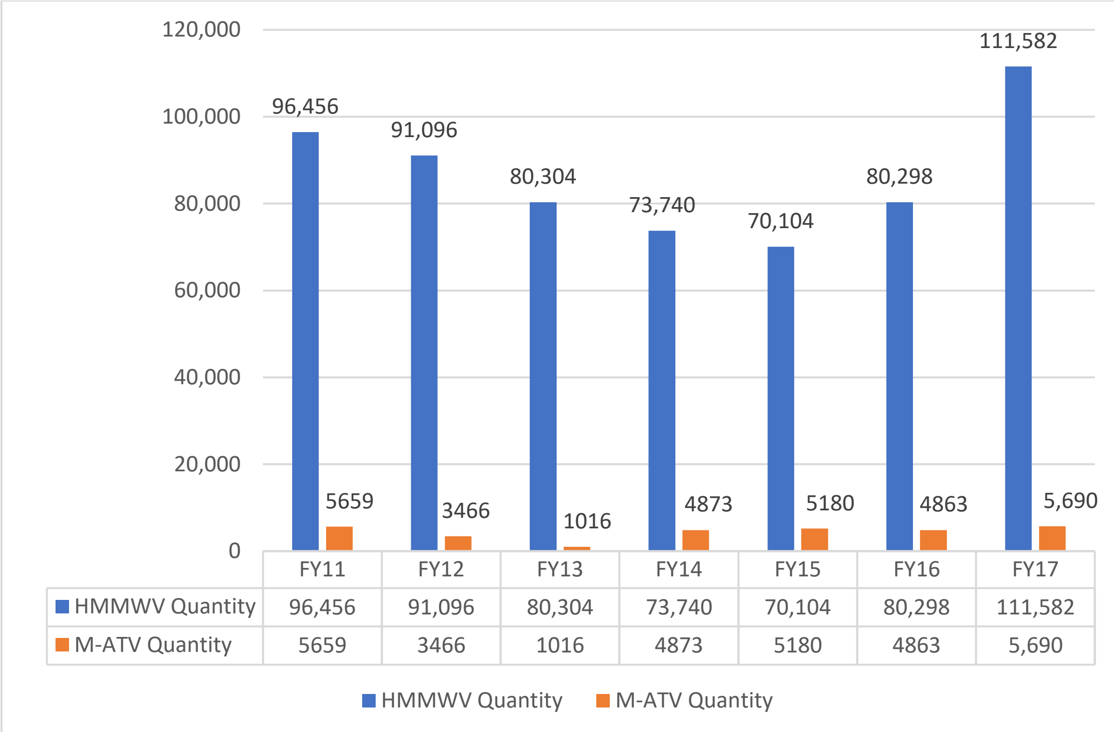
The M-ATV was an interim solution to the HMMWV due to the operating environment and the requirement for a more survivable vehicle. The M-ATV is still being used in overseas contingency operations due to threat environments in Iraq and Afghanistan.

The JLTV is planned to be used as the HMMWV replacement and it is a joint Service lead program with the Army as the PICA like the M-ATV. Each Service has its own requirements for the JLTV to meet their mission needs. In August 2015, a firm fixed price option year contract for an estimated 17,000 JLTVs was valued at $6.7B and awarded to Oshkosh Defense.

> The primary mission of the JLTV is to provide protected, sustained and networked light tactical mobility to the Joint forces capable of worldwide deployment across the full spectrum of military operations and mission profiles under all weather and terrain conditions. It will provide mobility to reconnaissance units and sustain direct fire in support of combat maneuver with substantial payload for personnel, equipment and supplies. The JLTV will support command, control and communication in both stationary and on-the-move modes, enabling interoperability with Joint and coalition forces in decentralized operations over extended ranges in complex and dynamic operational environments (T. Miller, personal communication, March 12, 2018).

Figure 1 compares the quantities reported for the HMMWV and M-ATV in the current Standard Army Management Information System (STAMIS) (T. Miller, personal communication, July 19, 2018). The comparison shows the total quantity of HMMWVs to M-ATVs reported from FY11 to FY17. From FY11–FY15 HMMWV quantities continued to decrease due to the drawdown operations in Iraq and Afghanistan and units in the United States not using the vehicles. However, in FY16-FY17 the HMMWV quantities increased. The M-ATV quantities also declined through FY13 and then began increasing in FY14. After FY14, the M-ATV quantities remained somewhat consistent where the HMMWV numbers increased dramatically.

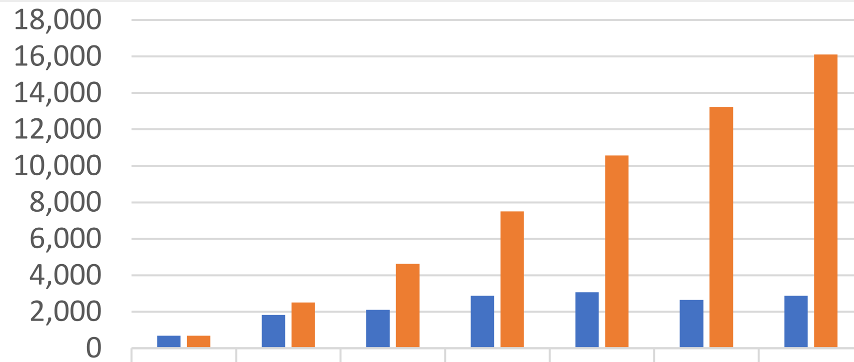
During this reporting period, the government did not dispose of vehicles and then buy new ones, as the figure may seem to indicate. The reasons for the decline and increase in quantities were due to vehicles being retrograded from Iraq and Afghanistan and being sent to the depots for RESET during FY13-FY14. In addition, during this time the Army switched accountability systems. The Army wholesale side switched from Property Book Unit Supply Enhanced (PBUSE) to Defense Property Accountability System (DPAS) and the Army retail side switched from Standard Army Maintenance System-Enhanced (SAMS-E) to Global Combat Support System-Army (GCSS-A). It was not until FY16 when the new databases began reporting actual quantities that the quantities began to increase. The quantities continued to be updated after this, as there was a lag in reporting. This lag was due to retrograde vehicles not being accounted for as they were in transit or vehicles were being double counted. Vehicles could have been double counted with the same vehicle being counted by an individual unit and then as Army's Preposition Stock (APS) with theater provided equipment.



	FY11	FY12	FY13	FY14	FY15	FY16	FY17
HMMWV Quantity	96,456	91,096	80,304	73,740	70,104	80,298	111,582
M-ATV Quantity	5659	3466	1016	4873	5180	4863	5,690

Figure 1. HMMWV and M-ATV STAMIS Reporting FY11–FY17

The JLTV program office is estimating a little over 16,000 JLTVs to be procured from FY16 to FY22 and the overall Army's Acquisition Objective (AAO) will be about 55,000 vehicles. The Services decide what variant they require each year the program office executes this with the OEM. Due to the complexity of the systems and different configurations, the OEM must ensure the supply base is on contract to meet their production schedule to the Army. The Figure 2below outlines the number of JLTVs to be procured each year and a total number by the end of each FY. JLTV procurements will be about five times the amount of M-ATVs and half the procurement of the HMMWVs.



	FY16	FY17	FY18	FY19	FY20	FY21	FY22
JLTV Procurements	686	1,828	2,110	2,881	3,067	2,656	2,877
Total Procured	686	2,514	4,624	7,505	10,572	13,228	16,105

Figure 2. JLTV Procurement

III. LITERATURE REVIEW

As stated earlier, in 2010 the DOD rolled out the BBP initiative to correct many well-documented problems with defense acquisition management. Affordability was the focus of the initiative, and the USD (AT&L) asked the Institute for Defense Analyses (IDA) to conduct a study that would help inform decisions by DOD acquisition executives regarding affordability. The IDA study, called the Affordability of Defense Acquisition Programs, provided a detailed insight of Service budgets and captured not just the Army, but all Services. The study stated the following on affordability:

> Affordability cannot be effectively addressed by the Defense and Component Acquisition Executives in the acquisition milestone review processes alone—it must also be addressed within the context of the overall DOD fiscal and force programs (i.e., the *Program Review* phase of the DOD planning, programming, and budgeting system (PPBS)). In the absence of that context, DOD acquisition executives cannot make well-informed decisions about affordability at acquisition milestone reviews (Porter et al., 2015).

In addition, the study stated that even though certain programs may be needed shortly afterwards, the DOD's long-term planning does not account for programs that are not listed in the Future Year Defense Program (FYPD). As reported in AcqNotes, "the Future Years Defense Program (FYDP) (10 USC § 221) summarizes forces, resources and equipment associated with all DOD programs. The FYDP displays total DOD resources and force structure information for 6 years; current 2 budgeted years and 4 additional years" (AcqNotes, 2018). In addition, the study explained that the DOD also needs to do a better job of estimating future costs primarily relating to procurement and O&S. The study did not provide a specific model on improving the estimating for overall program costs to support affordability decisions. However, they did make reference to their "Port Optimization" (PortOpt) model, "This model estimates the likely procurement costs of MDAPs under alternative production schedules, and optimizes those schedules simultaneously for multiple programs" (Porter et al., 2015).

The PortOpt model is based on projections, as opposed to from similar past programs. The inputs are described, but the actual model is not provided in the paper. There are different ways to perform analysis to provide recommendations to leadership for decisions. It may not always be the information they are used to; however, it gives them points to weigh when a decision is needed. There are two great advantages of the PortOpt model. First, it can optimize multiple programs and roll them up for each Service. Second, it can be used to "reduce peaks in the annual procurement funding required by a portfolio of programs by rescheduling production when production rates become efficient" (Porter et al, 2015).

One of the bullet points in the paper stated that the "O&S costs for acquisition programs are more difficult to estimate with accuracy than investment costs because of the unknown in new acquisition programs" (Porter et al., 2015). That is a true statement especially for procurement, where there are multiple new subsystems being integrated into one complete system. The OEM should have a projected cost based on mean times of repair and repair costs of subsystems. The OEM should also be able to provide actual reliability and sustainability (R&S) cost by either running reliability testing with system components or they could estimate by using modeling and simulations (M&S) tests.

PMs are chartered to ensure that what the Army needs fits within their budgets and meets the capabilities defined by the user. If the PMs are replacing current systems due to obsolescence, end of life, or because a new capability is needed, they can use previous system cost data when available. They can compare with the highest cost driver known by O&S cost systems to help make decisions if the new systems will be affordable or not. The IDA model did focus on O&S cost but tended to break out the Military Personal and Operation and Maintenance (O&M) cost separately. These costs are combined when conducting O&S cost data mining.

Our research investigated the O&S costs of two systems, which is different from the IDA study. For our project, we continued to address affordability at the program level. The IDA study recommended that affordability should be determined at the component level covering multiple programs. However, after reading the IDA study it helped frame the thinking for what different data should be researched and to develop inputs to help frame the output of our model. There were two recommendations from the study that helped frame the thinking of our research for RDT&E and Procurement cost: "Research and further analysis should be done to develop better methods to determine and isolate O&S cost elements for system design, reliability, and survivability testing and support strategy concepts” and “O&S cost estimates should support acquisition milestone reviews and be examined with the same as investment costs” (Porter et al., 2015).

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IV. MODEL

The data inputs researched for the development of this model consisted of RDT&E, Procurement, and O&S costs for both the HMWWV and M-ATV. In addition to reviewing the costs inputs, we also used standard cost estimating inputs for programs to develop the model. The model applies different inputs for the number of testing events to support the following: KPPs, Key System Attributes (KSAs), survivability requirements (if applicable), cost and quantity of vehicles, number of fielding sites both Continental United States (CONUS) and Outside the Continental United States (OCONUS), support equipment, special tools and test equipment, spare packages, technical documentation, transportation costs, new military occupation series (MOS), field service representatives (FSR) for contractor logistics support (CLS), new construction of facilities and operational tempo (OPTEMPO).

The model contains a series of cost inputs that are common across all programs such as shipping, fielding and sustainment. In addition to the common cost inputs, the model also has program specific cost elements such as RDT&E, additional testing and vehicle costs. Each input provides a cost, which is accumulated throughout the model to determine a total cost for the program. We built the model in Microsoft Excel, which allows the model to be very easy to use and simple to adjust as required by individual programs. All fields that require costs or quantities to be inputted into the model are highlighted in green.

Table 3 has the model's cost inputs for initial RDT&E, additional testing, survivability, reliability, other KSAs and performance enhancements. For the initial RDT&E event unit cost, this is program specific. This input will come from the program's initial cost estimate. The unit cost for current requirement requires additional testing than the current system is fixed is for any new requirement that was not on the prior system. For example, if the M-ATV had additional requirements over the HMMWV these requirements would be captures here for additional test costs. If this is a new requirement that is not replacing a current system the quantity would remain at zero, as the testing costs would be captured in the initial RDT&E.

Additional tests related to survivability, reliability, enhancements and performance will only have quantities entered if the system is replacing a current system; otherwise, the costs for these tests will be included in the original cost test cost estimate. If the system is replacing a current system, then these are calculated in addition to the overall additional testing. For example, if you have five additional requirements to test, you could input that in the additional testing row, then if two of the five were for survivability, you would put a two in the additional survivability row. The additional survivability row would then be calculated by taking the quantity of two, which would then be multiplied by the individual testing cost of $50,000 and then taking 25% of that total. Therefore, for this example, the total survivability test cost would equal $25,000 ((2X$50,000) X 0.25). If initial testing is complete and new testing is required, the event unit cost is fixed at $1,000,000.

Table 3. RDT&E Requirements

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Initial RDT&E	0	$0	0	$0	$0	Initial RDT&E unit cost based on program requirements.
Does the current requirement require additional testing than the current system? (Each Additional KPP)	0	$50,000	0	$0	$0	How many additional test required
Are there additional testing for survivability requirements (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Are there additional reliability requirements (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Are there additional enhancements required by the user (KSA) (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Are there additional performances test required (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Is there any other RDT&E needed after initial testing	0	$1,000,000	0	$0	$0	Is there any additional RDT&E funding needed

Table 4 represents the quantity of systems being procured and the event unit cost, which is the average unit price. Both of these inputs are program specific.

Table 4. System Procurement Cost and QTY of System

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Is the unit cost greater than the current system (Qty of Systems X Unit Cost) (Yes or No) Yes # of systems and answer next question, No use # of systems	0	$0	0	$0	$0	Plug in number specific to system.
Is the unit cost greater than the current system (Yes) (Qty of Systems X Unit Cost)	0	$0	0	$0	$0	Plug in number specific to system.
Is the QTY greater than the current system (Cost Current System)	0	$0	0	$0	$0	QTY greater
Is the QTY greater than the current system (Cost of current and additional cost)	0	$0	0	$0	$0	QTY greater

Table 5 represents the number of fieldings and support equipment needed to deprocessed, train and transfer the systems to the warfighter. For this portion of the model, all of the event unit costs are fixed. Depending on the program, you will fill in the number of CONUS and OCONUS fieldings and the quantity of new support equipment required per each fielding location. Per the DOD 7000.14-R Financial Management Regulation Volume 9, CONUS is defined as “the 48 contiguous states of the United States and the District of Columbia” (Department of Defense [DOD], 2019) and OCONUS is “the area outside of the 48 states of the United States and the District of Columbia.” (DOD, 2019). For special tools which are “designed to perform a specific task for use on a specific end item or a specific component of an end item and is not available in the common tool load that supports that end item/unit” (Department of the Army, 2018), one quantity is sufficient to cover 25 vehicles at each fielding location. This also applies to spare part packages, where one quantity is sufficient to cover 25 vehicles at each fielding location.

Table 5. Support Costs for Fieldings

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
How many fieldlings are required (CONUS)	0	$25,000	0	$0	$0	Estimated number of fieldings
How many fieldlings are required (OCONUS)	0	$50,000	0	$0	$0	Estimated number of fieldings
Is there new support equipment required	0	$20,000	0	$0	$0	New Support Equipment
Are new special tools required (1:25)	0	$10,000	0	$0	$0	1:25 ratio
Are there spare parts packages required (1:25)	0	$250,000	0	$0	$0	1:25 ratio

Table 6 represents the costs of support for development of technical manuals and support costs after the initial fieldings. For this portion of the model, all of the event unit costs are fixed, and depending on the program, you will fill in the required quantities. For the first row about Defense Logistics Agency (DLA) spares, if your requirement is new, you will input a quantity of one for this section as only one initial spare purchase by DLA is required. This initial spares purchase is to guarantee that when a unit makes a requisition, there will be supplies in the supply system to provide the unit. If this is not done, DLA will not procure the initial spares to support the requirement. DLA will not do this until they receive requisitions from the field, which will cause initial parts shortages and reduce unit readiness. For transportation requirements from the OEM, the quantity input will be the total amount of end items that will be shipped by the government to a CONUS location. For those end items that require OCONUS shipment, this quantity will be entered into the next row. However, all end items that require OCONUS shipment also need to be included in the CONUS shipment quantity, as these units need to be shipped to the OCONUS shipping location. For example, if there are 1,000 end items and 500 have to be shipped OCONUS you will put in a quantity of 1,000 for CONUS shipment and 500 for OCONUS shipment. The fourth and fifth rows are for manuals to support the system.

The fourth row is for electronic technical manuals (ETMs), which has a fixed unit cost. ETMs are required for all systems that need Military Standard (MIL-STD) manuals as the commercial manuals, if applicable, are not sufficient to sustain the system organically. Organic support is when the Army uses organic forces to sustain the system without the help of contractor support. According to an Army, article "Organic forces are those assigned to and forming an essential part of a military organization as listed in its table of organization" (Redfern et al., 2018, para. 10). The fifth row is for interactive technical manuals (IETMs) and this is a fixed unit cost. Depending on the program requirements if MIL-STD manuals are required, only one of these two will have an associated quantity. IETMs are more detailed and interactive, as the name states, as opposed to ETMs, which are simply electronic versions of paper manual. The next row is for if a new MOS is required to operate and maintain the new system. This would occur if the Army currently does not have a MOS that is trained to operate and maintain this type of system. The quantity associated with this would apply to the quantity of total new MOSs required to support the system at each fielding location. If you have 10 fielding locations and need four operators and one maintainer, you would enter a total quantity of five into this row.

The next two rows are for CLS either CONUS or OCONUS. CLS is required when the system is being fielded and it cannot be organically supported. This could be caused by two things: one the fielding location does not have the appropriate MOS maintain the system, or the more common reason, that maintenance manuals being developed have not been approved for release for organic support. For both rows, the quantities will be based upon the quantity of fielding locations, and the quantity of personnel at each location along with the years of support required. If you have three OCONUS fielding locations that require two FSRs at each location for one year the quantity would be six, and the years would be one.

The row for new construction equipment needed to support the new system is used if your system requires new facilities to be built to maintain the system at the fielding location. Therefore, the quantity will be based upon the total quantity of fielding locations. The next row is the sustainment costs associated with each new facility being built. These two rows will have the same quantity input. The last row for an increase in the OPTEMPO. If the new system replacing an existing one requires a higher OPTEMPO, meaning increased use, there will be an increase in maintenance costs for the fielding locations. The quantity for this row is based on the fielding locations that will now have increased OPTEMPO; this may not apply to all fielding locations. If this is a new system, the quantity in this field will be zero.

Table 6. Support Costs after Initial Fieldings

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Does DLA need to be primed for initial spares on the shelf	0	$20,000,000	0	$0	$0	Does DLA require funding
Is there transportation requirements for shipping vehicles from the OEM	0	$10,000	0	$0	$0	Number of shipments CONUS
Will additional transportation be required for the system (OCONUS)	0	$10,000	0	$0	$0	Number of shipments OCONUS
Are there technical manuals required (ETM)	0	$5,000,000	0	$0	$0	Does the system require an ETM
Are there technical manuals required (IETM)	0	$10,000,000	0	$0	$0	Does the system require an IETM
Is there a new Military Occupational Series (MOS) Required (Additional Operator or Maintainer)	0	$150,000	0	$0	$0	Does the system need new operators or maintainers
Will there be Contract Logistics Support (CLS) (CONUS)	0	$150,000	0	$0	$0	Does the system require contract Field Service Representatives CONUS and for how long
Will there be Contract Logistics Support (CLS) (OCONUS)	0	$360,000	0	$0	$0	Does the system require contract Field Service Representatives OCONUS and for how long
Is there any new construction needed to support the new system	0	$1,000,000	0	$0	$0	Does the system require new facilities
Will there be sustainment cost for facilities (# of Fielding Sites)	0	$10,000	0	$0	$0	Is there any additional funding required for sustainment of new facilities
Will the OPTEMP increase from the current system (10% as a baseline) (QTY of systems effected)	0	$5,000	0	$0	$0	Will the system see an increase of OPTEMPO use and how many vehicles

Table 7 captures total and average cost of the system. The average costs are derived by taking the total costs of the system and dividing it by the total quantity of systems being procured. This portion of the module requires no inputs, as the prior portions of the model feed into this for the outputs.

Table 7. Total and Average Cost of the Systems

Total	**Total Procurement Cost**
Average Cost Per System	**Average of Vehicle Cost**

Other considerations when inputting cost data into the model are to evaluate the survivability and the readiness of a system by conducting additional testing during development. Additional survivability testing can provide a cost avoidance by determining that a system can be repaired, as opposed to being replaced during wartime operations. Conducting additional survivability testing can determine if the system can be repaired at a lower cost than that of complete replacement. It can be used for enhancement testing as well to determine if newer technologies can be applied to the system now instead of incorporating these changes later, which usually costs considerably more

Additional reliability testing can provide long-term benefits to a system, as it can help to determine ways to reduce future O&S costs for repairs, cost avoidance, and repair times. The overall operational readiness of the system can be increased by reducing O&S costs for repairs and repair times. While the Army's goal is to maintain above a 90% readiness rate for all of their systems, historically, its systems fall below this rate.

The reason that systems fall below the Army's readiness rate goal is that as systems become older, parts become obsolete and increase in unreliability. In order to maintain the systems due to these issues, O&S costs tend to increase. PMs try to prevent this from happening however, but funding for modernization and maintenance is hard to obtain as a system becomes older. Working together with Engineering and Logistics during test can help with the maintainability of the system. By influencing, the system design to make repairs quicker, this will reduce down time of the systems and increase the systems readiness rate.

When applying additional testing for each section, it can provide assumptions to the PM and a metric to be measured after the system is developed and fielded. Table 8 can be used to determine the potential cost avoidance to a system by performing additional survivability and reliability testing. As this table provides the potential cost avoidance in the future by performing additional testing, it will not be used to reduce the overall cost of the system, but instead, as a data point for determining the amount of survivability and readability testing that should be done.

Table 8. Additional Survivability and Reliability Testing Cost Avoidance

Cost and Operational Readiness from Additional Testing						
Overall cost benefit to the system	**Procurement Cost X (10% of Fleet)**	**1 Test (1%)**	**2 Tests (2%)**	**3 Tests (3%)**	**≥ 4 Tests (5%)**	**Cost Benefit**
Survivability and Enhance ability (Is the CB comparable to the enhancement and survivability of the system) or Enhance ability (Can it be upgraded and does the cost benefit the upgrade)	Procurement Cost Times 10% of fleet	10% of fleet procurement cost times 1% Cost Benefit	10% of fleet procurement cost times 2% Cost Benefit	10% of fleet procurement cost times 3% Cost Benefit	10% of fleet procurement cost times 5% Cost Benefit	Is the additional testing a cost benefit or not
Overall benefit to the system	**Readiness**	**1 Test (>90%) > 1 Year**	**2 Tests (>90%) >2 Years**	**3 Tests (>90%) > 3 Years**	**≥ 4 Tests (>90%) > 4 Years**	**Benefit**
Reliability and Maintainability (RAM) and Performance (Does the CB correlate to readiness, better performance or being maintainable and reliable)	> 90%					Is the additional testing a benefit or not?

We applied the model to both the HMWWV and M-ATV to to determine afforability and to determine if the model was successful in collecting all of the costs associated with estimating a programs total cost. The program fillins for the HMWWV were derived from HMWWV costs summaries, which were provided by Cost and Systems

Analysis Office at U.S. Army Tank Automotive and Armorments Command (TACOM) in November 2019 (E. Murphy, personal communication, November, 25, 2019). The fillins for the M-ATV were from the historical files working on the M-ATV program, Capability Production Document for Mine Resistant Ambush Protected (MRAP) Family of Vehicles (FoV) Version 1.1 (T. Miller, personal communication, July 7, 2009) and the MRAP – All Terrain Vehicle (M-ATV) Life cycle Cost Estimate (T. Miller personal communication March 19, 2019). In Chapter V the results from the two models will be analyzed.

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V. ANALYSIS

Three scenarios were ran using the cost model were for the HMMWV, the M-ATV and the JLTV. Actual historical data for the HMMWV and M-ATV were based on the inputs from the capabilities development documents (CPDs) and budget lines for both programs quantities of vehicles and unit costs for production were used to produce an estimated total and average cost of the systems. JLTV numbers were based on initial budget and the selected acquisition report dated 2017 (T. Miller, personal communication, July 8, 2018). The HMMWV had numerous production years and quantities from 1983 – 2018, M-ATV production was from 2009 – 2011 and JLTV started production in 2016 and are currently being produced. Tables 9 through 13 are for the HMMWV, Tables 14 through 19 are for the M-ATV and Table 20 for the JLTV.

A. HMMWV MODEL ANALYSIS

For the RDT&E costs in Table 9, the initial RDT&E was a plug in number. For all other potential RDT&E program costs there was no additional RDT&E information provided by the program office that could be clearly defined for the purposes of using the model.

Table 9. HMMWV RDT&E Cost

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Initial RDT&E	1	$132,000,000	0	$132,000,000	$132,000,000	RDT&E cost based on program sunk cost.
Does the current requirement require additional testing than the current system? (Each Additional KPP)	0	$50,000	0	$0	$132,000,000	No information provided
Are there additional testing for survivability requirements (Qty X test X 25%)	0	$0	0	$0	$132,000,000	No information provided
Are there additional reliability requirements (Qty X test X 25%)	0	$0	0	$0	$132,000,000	No information provided
Are there additional enhancements required by the user (KSA) (Qty X test X 25%)	0	$0	0	$0	$132,000,000	No information provided
Are there additional performances test required (Qty X test X 25%)	0	$0	0	$0	$132,000,000	No information provided
Is there any other RDT&E needed after initial testing	0	$1,000,000	0	$0	$132,000,000	No information provided

Table 10 captures the procurement quantities and associated unit costs. Due to multiple years of various HMMWV procurements for this model, we focused on the three major production contracts in 1983, 1989 and 2000 for quantity and cost information. The model was designed to put in the multiple production years and averaging would not provide true cost comparison to actual numbers. As you can see from the information below the first HMMWV procured in 1983 had an average unit cost of $22,822 and in 2000 the average unit cost increased to $124,730.

Table 10. HMMWV Procurement Cost

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Is the unit cost greater than the current system (Qty of Systems X Unit Cost) (Yes or No) Yes # of systems and answer next question, No use # of systems	70,105	$22,822	0	$1,599,936,310	$1,731,936,310	1983 Procurement
Is the unit cost greater than the current system (Yes) (Qty of Systems X Unit Cost)	49,798	$32,129	0	$1,599,959,942	$3,331,896,252	1989 Procurement
Is the QTY greater than the current system (Cost Current System)	0	$22,822	0	$0	$3,331,896,252	N/A
Is the QTY greater than the current system (Cost of current and additional cost)	115,449	$124,730	0	$14,399,953,770	$17,731,850,022	2000 Procurement

In Table 11 for HMMWV fieldings and support package costs the assumption was to account for the number of fieldings required based on two thirds of the production quantity being fielded CONUS and one third being fielded OCONUS. After the total quantity of fieldings were broken out by CONUS and OCONUS the quantities were then reduced by a 25 to 1 ratio as we assumed that 25 vehicles were fielded at each location. The HMMWV did not require and new support equipment. Special tools and initial parts packages were required when the HMMWVs were fielded and these were procured on 1 to 25 basis. Based on each unit receiving initial spares there was no need for DLA to being procuring spares at the time of fielding. One thing to note is what when the HMMWV was fielded DLA did not exist. For transportation costs, we based this on the two-thirds CONUS one third OCONUS as we did with the fieldings. The HMMWV was fielded with paper technical manuals however, as technology evolved ETMs were developed and are now the standard manual for the HMMWV.

Table 11. HMMWV Fielding and Support Package Cost

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
How many fieldlings are required (CONUS)	6,276	$25,000	0	$156,900,000	$17,888,750,022	2/3 of total production QTY with a 1:25 Ratio.
How many fieldlings are required (OCONUS)	3,138	$50,000	0	$156,900,000	$18,045,650,022	1/3 of total production QTY with a 1:25 Ratio.
Is there new support equipment required	0	$10,000	0	$0	$18,045,650,022	N/A
Are new special tools required (1:25)	9,414	$10,000	0	$94,140,000	$18,139,790,022	1:25 Ratio
Are there spare parts packages required (1:25)	9,414	$250,000	0	$2,353,500,000	$20,493,290,022	1:25 Ratio
Does DLA need to be primed for initial spares on the shelf	0	$0	0	$0	$20,493,290,022	DLA was not primed for the HMMWV
Is there transportation requirements for shipping vehicles from the OEM	235,352	$10,000	0	$2,353,520,000	$22,846,810,022	2/3 of total production QTY
Will additional transportation be required for the system (OCONUS)	78,451	$10,000	0	$784,510,000	$23,631,320,022	1/3 of total production QTY
Are there technical manuals required (ETM)	1	$5,000,000	0	$5,000,000	$23,636,320,022	Page Based TMs
Are there technical manuals required (IETM)	0	$10,000,000	0	$0	$23,636,320,022	N/A

There was only one input to the Table 12 below. There were no additional costs for new MOS to operator or maintain the vehicles nor facilities. As the HMMWV was, the replacement for the Jeep and light duty trucks the MOSs and facilities were already in place to operate and support it. The HMMWV was organically maintained when fielded and as a result, there was not a requirement for CLS. The one input to the section of the model was OPTEMPO, which was due to vehicles operating in Iraq and Afghanistan prior to the MRAP Vehicles being fielded in 2007. Based on the model the cost associated with an increase in OPTEMPO is $5,000 per vehicle however, during our research we were able to find the actual costs of the OPTEMPO, which averaged $3,915 per vehicle (T. Miller, personal communication, July 8, 2018). This average was based upon repair parts and spare parts usage. Based on the actual cost data we can see that model is overstating the total

OPTEMPO cost by approximately $127,678,460. In order to prevent this, we are recommend changing the model to making this a program specific plug in number.

Table 12. HMMWV Support Cost

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Is there a new Military Occupational Series (MOS) Required (Additional Operator or Maintainer)	0	$150,000	0	$0	$23,636,320,022	No additional MOS required (63B) Switched to 91B
Will there be Contract Logistics Support (CLS) (CONUS)	0	$150,000	0	$0	$23,636,320,022	N/A
Will there be Contract Logistics Support (CLS) (OCONUS)	0	$360,000	0	$0	$23,636,320,022	N/A
Is there any new construction needed to support the new system	0	$1,000,000	0	$0	$23,636,320,022	N/A
Will there be sustainment cost for facilities (# of Fielding Sites)	0	$10,000	0	$0	$23,636,320,022	N/A
Estimated OPTEMPO increase from the current system (10% as a baseline or known number) times average cost times number of years	23,535	$5,000	5	$588,380,000	$24,224,700,022	OPTEMPO FY06 – FY10

Total cost for the HMMWV program from the model was a $24,224,700,022 with an average cost per system of $102,851 as shown in Table 13. If the cost model had accurately estimated the costs, the HMMWV total cost would have been $24,097,021,562 with an average cost per system of $102,309 (E. Murphy, personal communication, November, 25, 2019).

Table 13. HMMWV Total and Average Cost

Total	**$24,244,700,022**
Quantity of HMMWVs Procured	**235,352**
Average Cost Per System	**$102,851**

The HMMWV did not have any historical information on additional testing so there was no data to determine if there would have been a cost avoidance by performing additional survivability and reliability testing.

B. M-ATV MODEL ANALYSIS

Like the HMMWV the M-ATV RDT&E, cost was a plug in number from the MRAP FoV V1.1 CPD (T. Miller, personal communication, July 7, 2009). These costs were combined with initial development and testing of the system from 2009 through 2012. Initial development testing of prototype samples determined that a multiple award contract would be awarded to five contractors. After the multiple award contracts were awarded additional testing determined that Oshkosh Defense provided the best value to the government and was chosen to provide production M-ATVs. There was additional testing on the M-ATV and it went through years of survivability testing to increase the vehicles survivability in order to meet the ever-changing IED threat in Afghanistan. The MRAP program office through additional testing came up with a long-term solution of an Underbody Improvement Kit, which reduced replacement cost of procuring new vehicles, and made the M-ATV one of the safest vehicles on the battlefield against IEDs. Because of these testing requirements, there were only two RDT&E costs in Table 14 below.

Table 14. M-ATV RDT&E Cost

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Initial RDT&E	1	$398,000,000	0	$398,000,000	$398,000,000	Initial RDT&E unit cost based on program CPD.
Does the current requirement require additional testing than the current system? (Each Additional KPP)	0	$50,000	0	$0	$398,000,000	Part of base testing
Are there additional testing for survivability requirements (Qty X test X 25%)	0	$0	0	$0	$398,000,000	Part of base testing
Are there additional reliability requirements (Qty X test X 25%)	0	$0	0	$0	$398,000,000	Part of base testing
Are there additional enhancements required by the user (KSA) (Qty X test X 25%)	0	$0	0	$0	$398,000,000	Part of base testing
Are there additional performances test required (Qty X test X 25%)	0	$0	0	$0	$398,000,000	None
Is there any other RDT&E needed after initial testing	1	$1,000,000	0	$1,000,000	$399,000,000	Requirement for Underbody Improvement Kit (UIK)

The procurement quantities and the units funded cost in Table 15 were from historical program documents while working on the M-ATV program. There was an initial buy of 8,083 M-ATVs from June 2009 through December 2010 and a follow on contract for an additional 639 built with the underbody improvement kit (UIK) which ended in October 2012 bringing the total number of M-ATVs produced to 8,722. As the original production, number of 8,083 was converted to add the UIK the additional cost of this was reflected in the cost model. At the time, there were no other vehicles to compare prices against to determine if there was a delta between the two variants to either add or subtract the delta. Unlike the HMMWV, the M-ATV numbers and dollars were inputted into the model without any issues due to the known number of vehicles and contract award price for the production of the vehicles and the installation of the UIK. As you can see from the information below the cost of an M-ATV was approximately 484% more than the last production contract average price of the HMMWV.

Table 15. M-ATV Procurement Cost

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Is the unit cost greater than the current system (Qty of Systems X Unit Cost) (Yes or No) Yes # of systems and answer next question, No use # of systems	8,083	$459,395	0	$3,713,289,785	$4,112,289,785	Plug in number specific to system.
Is the unit cost greater than the current system (Yes) (Qty of Systems X Unit Cost)	8,083	$131,679	0	$1,064,361,357	$5,176,651,142	J&A for UIK upgrade
Is the QTY greater than the current system (Cost Current System)	0	$459,395	0	$0	$5,176,651,142	N/A
Is the QTY greater than the current system (Cost of current and additional cost)	639	$591,074	0	$377,696,286	$5,554,347,428	Additional requirement to bring the total to 8,722

Inputs for Table 16 were put in the model based on program data obtained while working on the M-ATV program and having to manage the logistics budget for the fieldings and sustainment of the systems. There was a low number of fieldings CONUS as they were only used for home station training prior to units deploying as 90% of the assets were shipped directly OCONUS. Because of 90% of the vehicles, being shipped OCONUS this also attributed to increased shipping costs. There was no additional support equipment needed for the M-ATV and all support equipment was already in Iraq and Afghanistan from previous MRAP fieldings. There were special tool kits procured in support of the M-ATV to perform maintenance on the systems and were based on a 1:25 vehicle ratio.

Due to lessons learned from previous MRAP fieldings and the long lead times of getting parts procured through DLA the program office created robust initial parts packages with an average cost of $2,478,517 for 1:25 ratio. This is approximately 10 times the initial spare parts package price in the model. Using the model cost the total cost of the M-ATV program would have been underestimated by approximately $548,000,000. As the M-ATV is a more up to date program, we recommend changing the model to make the amount for initial spare parts a program specific fill-in and not a set cost. When increasing this amount considerations have to be made for the environment that the system is going into. For instance if the model is used during peacetime the requirement for spare parts would be assumed to be less than during wartime.

In addition to this, the program office also requested that DLA provide $300,000,000 in spare parts to ensure parts were on the shelf when the warfighter needed them. This along with the initial spares needs to be revised based on the system environment as the DLA spare parts requirement for the M-ATV was 15 times the model cost ($20,000,000) for this requirement. The warfighter benefited with the repair parts packages available and DLA had parts on the shelf the M-ATV never dropped below a 90% operational readiness the whole time while conducting missions in Iraq and Afghanistan. The $10,000 initial transportation cost were based on first destination shipping of all vehicles CONUS another $10,000 for second destination shipping theater. The last requirement was an IETM for the vehicle and estimated cost of new IETM development is around $10,000,000.

When looking at the two unit price issues with the model, initial spares and DLA initial spares, the model is under estimating the program by approximately $828,000,000, which equates to $94,932 per vehicle.

Table 16. M-ATV Fielding and Support Package Cost

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
How many fieldings are required (CONUS)	26	$25,000	0	$650,000	$5,554,997,428	636 for HST CONUS APS, 1:25 Ratio
How many fieldings are required (OCONUS)	323	$50,000	0	$16,150,000	$5,571,147,428	8,086 for OEF, OIF and APS; 1:25 Ratio
Is there new support equipment required	0	$20,000	0	$0	$5,571,147,428	N/A
Are new special tools required (1:25)	349	$10,000	0	$3,490,000	$5,574,637,428	Ratio 1:25
Are there spare parts packages required (1:25)	349	$250,000	0	$87,250,000	$5,661,887,428	Ratio 1:25
Does DLA need to be primed for initial spares on the shelf	1	$20,000,000	0	$20,000,000	$5,681,887,428	Initial Class IX procurement
Is there transportation requirements for shipping vehicles from the OEM	8,722	$10,000	0	$87,220,000	$5,769,107,428	All vehicles were shipped from the OEM to SPAWAR
Will additional transportation be required for the system (OCONUS)	8,086	$10,000	0	$80,860,000	$5,849,967,428	Movement to OIF, OEF and APS 5 (Kuwait)
Are there technical manuals required (ETM)	0	$5,000,000	0	$0	$5,849,967,428	N/A
Are there technical manuals required (IETM)	1	$10,000,000	0	$10,000,000	$5,859,967,428	ITEM Requirement

For Table 17 the M-ATV did not require additional personnel to operate or conduct maintenance on the vehicles. However, due to the rapid acquisition of the systems and urgent requirement the M-ATV was originally support using Oshkosh Defense's commercial manual. As the commercial manuals were not sufficient, enough for organic maintenance support three years of CLS was required to for maintenance. The other input to the section of the model was the OPTEMPO of the systems, which was for 7,500 vehicles over five years. As with HMMWV, we were able to obtain the actual OPTEMPO costs for the M-ATV, which had an average of $9,403.77 per vehicle (T. Miller, personal communication, July 8, 2018). The actual cost of the OPTEMPO was almost double the amount used in the model. Due to this the model is understating the total OPTEMPO cost by $165,112,500 and based on this we recommend making the OPTEMPO cost a program specific plug in number.

Table 17. M-ATV Support Cost

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Is there a new Military Occupational Series (MOS) Required (Additional Operator or Maintainer)	0	$150,000	0	$0	$5,859,967,428	No additional MOS required (91B)
Will there be Contract Logistics Support (CLS) (CONUS)	39	$150,000	3	$17,550,000	$5,877,517,428	3 year FSR Support
Will there be Contract Logistics Support (CLS) (OCONUS)	284	$360,000	3	$306,720,000	$6,184,237,428	3 year FSR Support
Is there any new construction needed to support the new system	0	$1,000,000	0	$0	$6,184,237,428	N/A
Will there be sustainment cost for facilities (# of Fielding Sites)	0	$10,000	0	$0	$6,184,237,428	N/A
Will the OPTEMP increase from the current system (10% as a baseline or known number) times average cost times number of years	7,500	$5,000	5	$187,500,000	$6,371,737,428	7,500 fielded to OEF and OIF, OPTEMPO FY10 - FY15

As shown in Table 18 the M-ATV program total cost from the model is $7,338,715,110 with an average vehicle cost of $841,403. These numbers seem high however, the M-ATV mission was to conduct off road operations and save warfighters lives. If the cost model had accurately estimated the costs, the M-ATV total cost would have been $8,331,827,610 with an average cost per system of $949,821 (T. Miller, personal communication, July 8, 2018).

Table 18. M-ATV Total Cost

Total	**$7,338,715,110**
Quantity of M-ATVs procured	**8,722**
Average Cost Per System	**$841,403**

Due to the combat operations and the threat of the enemy decisions were made to proceed with the selection of the most survivable vehicle to protect the warfighter. Even though cost was not a deciding factor in the selection of the M-ATV it was proven to be extremely reliable since being fielding in 2009 and extremely survivable on the battlefield against IEDs. Due to the wartime conditions, the M-ATV program office had all the funding needed for testing to ensure the M-ATVs were reliable and survivable for the warfighter.

Some of the primary elements that the M-ATV program office needed was to decide how much testing was required to make the vehicle more survivable and test additional reliability attributes of the vehicles at the same time. As the vehicle design changed due to the different threats to the warfighters additional, testing was required to prove out the design to include additional armor requirements. The M-ATV proved out those tests and the operational readiness has always above 90% due to the design, survivability of the vehicle, the robust supply system and properly planning of CLS to assist the warfighter in maintaining their vehicles.

In Table 19, we applied the M-ATV numbers into this section of the model to show a cost avoidance with the additional testing that was conducted that proved out the survivability and the survivability of the systems. Using the formula for the survivability section and vehicle cost by 10% of the fleet the calculations per test showed a cost avoidance by repairing the system as opposed to replacing it and in O&S costs. The program office conducted more than five additional test for survivability which was evaluated at the 5% cost benefit verse the replacement of the systems. The systems have been extremely survivable which outweighed the testing cost from being repaired instead of being replaced. The $18M cost avoidance in the model was low due to the survivability of the M-ATV compared to the events the fleet endured during the first three years in Afghanistan. The additional testing for the reliability paid off with the M-ATV continually having an operational readiness rate above 90%. However, as we stated earlier these are cost avoidance amounts which are to be considered when determining a program affordable.

Table 19. M-ATV Cost and Operational Readiness Benefit

Cost and Operational Readiness Benefit from Additional Testing						
Overall cost benefit to the system	**Procurement Cost X (10% of Fleet)**	**1 Test (1%)**	**2 Tests (2%)**	**3 Tests (3%)**	**≥ 4 Tests (5%)**	**Cost Benefit**
Survivability and Enhance ability (Is the CB comparable to the enhancement and survivability of the system) or Enhance ability (Can it be upgraded and does the cost benefit the upgrade)	$371,328,979	N/A	N/A	N/A	$18,566,449	Yes
Overall Readiness benefit to the system	**Readiness**	**1 Test (>90%) 1 Year**	**2 Tests (>90%) 2 Years**	**3 Tests (>90%) 3 Years**	**≥ 4 Tests (>90%) >4 Years**	**Cost Benefit**
Reliability and Maintainability (RAM) and Performance (Does the CB correlate to readiness, better performance or being maintainable and reliable)	>90%	N/A	N/A	N/A	>5 Test	Yes

Based on the two successful programs that we ran the model against we determined that changes needed to be made to the model in order for it to be successful in helping determine if a program should proceed or be cancelled. When running the model both programs had varied OPTEMPO costs per vehicle. The M-ATV OPTEMPO was 88% more and the HMMWV was 22% lower than the set cost amount of $5,000. Based on the wide range of OPTEMPO cost per vehicle the cost model should be changed to make this a program specific plug in number.

The other model input that we decided to change was the DLA initial spares amount. The set cost amount that we had for the DLA initial spares was $20,000,000. However, M-ATV actual cost data for DLA initial spares amount was $300,000,000. This is 1500% more than the $20,000,000 fixed cost amount that we had in the model for all programs.

Overall, the HMMWV cost was overstated by approximately 1% and the M-ATV was understated by approximately 12.9%. Due to these variances by both programs, we decided that these inputs into the cost model should be changed to a program specific plug in number.

However, with the HMMWV model being overstated the model could have been left as is as it would have not resulted in cost breach. The same can be said for the M-ATV model even though it was understated by 12.9% it is still below the breach requirements. However, as both of them had differences in one of the two areas we believed updating the model moving was required. With these changes, we believe that the model is sufficient to use when determining affordability for other ACAT 1 programs to include the JLTV program.

C. MODEL UPDATES

We updated the model based on recommendations above and applied it to the JLTV program which is shown in Table 20 below. We used the baseline of RDT&E cost and did not add any additional testing. We used the AAO for the number to be procured and the total procurement cost for each system (T. Miller, personal communication, July 8, 2018). For fieldings, we assumed 75% of the AAO CONUS and 25% OCONUS to calculate the quantities. Special tools and initial spares followed the same 1:25 ratio distribution to vehicles. For DLA spares, we used $20M to prime the supply system of spares with DLA, as this amount is unknown. We added in transportation quantities for CONUS shipments based on 75% CONUS and 25% OCONUS. The last input to the model was the IETM and used a plug in number of $10M.

Table 20. JLTV Model Inputs

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Initial RDT&E	1	$988,000,000	0	$988,000,000	$988,000,000	Initial RDT&E unit cost based on program CPD.
Does the current requirement require additional testing than the current system?	0	$50,000	0	$0	$988,000,000	N/A
Are there additional testing for Survivability requirements (Qty X test X 25%)	0	$0	0	$0	$988,000,000	N/A
Are there additional reliability requirements (Qty X test X 25%)	0	$0	0	$0	$988,000,000	N/A
Are there additional enhancements required by the user (KSA) (Qty X test X 25%)	0	$0	0	$0	$988,000,000	N/A
Are there additional performances test required (Qty X test X 25%)	0	$0	0	$0	$988,000,000	None
Is there any other RDT&E needed after initial testing	0	$1,000,000	0	$0	$988,000,000	N/A
Is the unit cost greater than the current system (Qty of Systems X Unit Cost) (Yes or No) Yes # of systems and answer next question, No use # of systems	55,000	$216,000	0	$11,880,000,000	$12,868,000,000	Plug in number specific to system.
Is the unit cost greater than the current system (Yes) (Qty of Systems X Unit Cost)	55,000	$199,000	0	$10,945,000,000	$23,813,000,000	Plug in number specific to system.
Is the QTY greater than the current system (Cost current system)	$0	$0	0	0	$23,813,000,000	N/A
Is the QTY greater than the current system (Cost of current and additional cost)	0	$415,000	0	$0	$23,813,000,000	N/A
How many fieldings are required (CONUS)	1650	$25,000	0	$41,250,000	$23,854,250,000	75% of the Fleet (1:25 Ratio)
How many fieldings are required (OCONUS)	550	$50,000	0	$27,500,000	$23,881,750,000	25% of the Fleet (1:25 Ratio)
Is there new support equipment required	0	$20,000	0	$0	$23,881,750,000	N/A
Are new special tools required (1:25)	2,200	$10,000	0	$22,000,000	$23,903,750,000	Ratio 1:25
Is there spare parts packages required (1:25)	2,200	$250,000	0	$550,000,000	$24,453,750,000	Ratio 1:25
Does DLA need to be primed for initial spares on the shelf	1	$20,000,000	0	$20,000,000	$24,473,750,000	Initial Class IX procurement

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Is there transportation requirements for shipping vehicles from the OEM	55,000	$10,000	0	$550,000,000	$25,023,750,000	CONUS Shipments
Will additional transportation be required for the system (OCONUS)	13,750	$10,000	0	$137,500,000	$25,161,250,000	Movement to OCONUS Locations
Are there technical manuals required (ETM)	0	$5,000,000	0	$0	$25,161,250,000	N/A
Are there technical manuals required (IETM)	1	$10,000,000	0	$10,000,000	$25,171,250,000	ITEM Requirement
Is there a new Military Occupational Series (MOS) Required (Additional Operator or Maintainer)	0	$150,000	30	$0	$25,171,250,000	No additional MOS required (91B)
Will there be Contract Logistics Support (CLS) (CONUS)	0	$150,000	0	$0	$25,171,250,000	N/A
Will there be Contract Logistics Support (CLS) (OCONUS)	0	$360,000	0	$0	$25,171,250,000	N/A
Is there any new construction needed to support the new system	0	$1,000,000	0	$0	$25,171,250,000	N/A
Will there be sustainment cost for facilities (# of Fielding Sites)	0	$10,000	0	$0	$25,171,250,000	N/A
Estimated OPTEMPO increase from the current system (10% as a baseline or known number) times average cost times number of years	0	$5,000	0	$0	$25,171,250,000	N/A

Based on the JLTV inputs to the model Table 21 below shows the total cost of the program, total quantities and average cost per system. The average cost per system in our model was within 5% of the JLTV program objective unit cost (E. Murphy, personal communication, September 2, 2020).

Table 21. JLTV Total Cost

Total	**$25,171,250,000**
Quantity of JLTVs to be procured	**55,000**
Average Cost Per System	**$457,659**

We were unable to obtain information whether additional survivability and reliability testing for the JLTV was going to occur, therefore we were not able to run the cost avoidance portion of the model.

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VI. CONCLUSION

Affordability is a key factor when determining if a program should go forward or be cancelled. BBP is an initiative to look at program costs to ensure they are affordable. Our model was developed to aid in the determination of program affordability, and if program should proceed or be cancelled. We developed the model based on our experiences in DOD program management, and with cost data that we were able to obtain from the HMMWV and M-ATV programs. We used the HMMWV and M-ATVs programs, as the M-ATV was the replacement for the HMMWV in Iraq and Afghanistan. In addition to this, both of these programs were determined to be affordable as they went from initial concept to sustainment. Based on this we believed that if we were able to create a model that could accurately estimate the total costs of these programs, when compared to the actual cost data we had, that the model could be applied to the JLTV and other ACAT I vehicle programs. We chose the JLTV as it is planned to be the full replacement of the HMMWV.

While developing the model we were able to answer our primary research question: what are the primary elements to address in an affordability decision model for a "proceed or cancel" decision? As seen earlier, Table 21 shows the elements that we determined are required to support an affordability decision for a program. The table is color coded by funding type. Red is for RDT&E cost elements. Blue is for procurement cost elements. Orange is for O&S cost elements.

Table 22. Affordability Model

Question	QTY	Event Unit Cost	Years of Support (If applicable)	Total	Total Cost	Comments
Initial RDT&E	0	$500,000,000	0	$0	$0	Initial RDT&E unit cost based on program requirements.
Does the current requirement require additional testing than the current system? (Each Additional KPP)	0	$50,000	0	$0	$0	How many additional test required
Are there additional testing for survivablity requirements (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Are there additional reliablity requirements (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Are there additional enhancements required by the user (KSA) (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Are there additional performances test required (Qty X test X 25%)	0	$0	0	$0	$0	25% of each additional testing requirement
Is there any other RDT&E needed after initial testing	0	$1,000,000	0	$0	$0	Is there any additional RDT&E funding needed
Is the unit cost greater than the current system (Qty of Systems X Unit Cost) (Yes or No) Yes # of systems and answer next question, No use # of systems	0	$0	0	$0	$0	Plug in number specific to system.
Is the unit cost greater than the current system (Yes) (Qty of Systems X Unit Cost)	0	$0	0	$0	$0	Plug in number specific to system.
Is the QTY greater than the current system (Cost Current System)	0	$0	0	$0	$0	QTY greater
Is the QTY greater than the current system (Cost of current and additional cost)	0	$0	0	$0	$0	QTY greater
How many fieldings are required (CONUS)	0	$25,000	0	$0	$0	Estimated number of fielding's
How many fieldings are required (OCONUS)	0	$50,000	0	$0	$0	Estimated number of fielding's
Is there new support equipment required	0	$20,000	0	$0	$0	New Support Euipment
Are new special tools required (1:25)	0	$10,000	0	$0	$0	1:25 ratio
Is there spare parts packages required (1:25)	0	$250,000	0	$0	$0	1:25 ratio
Does DLA need to be primed for initial spares on the shelf	0	$20,000,000	0	$0	$0	Does DLA require funding
Is there transporation requirements for shipping vehicles from the OEM	0	$10,000	0	$0	$0	Number of shipments CONUS
Will additional transporation be required for the system (OCONUS)	0	$10,000	0	$0	$0	Number of shipments OCONUS
Are there technical manuals required (ETM)	0	$5,000,000	0	$0	$0	Does the system require an ETM
Are there technical manuals required (IETM)	0	$10,000,000	0	$0	$0	Does the system require an IETM
Is there a new Military Occupational Series (MOS) Required (Additional Operator or Maintainer)	0	$150,000	0	$0	$0	Does the system need new operators or maintainers
Will there be Contract Logistics Support (CLS) (CONUS)	0	$150,000	0	$0	$0	Does the system require contract Field Service Representatives CONUS and for how long
Will there be Contract Logistics Support (CLS) (OCONUS)	0	$360,000	0	$0	$0	Does the system require contract Field Service Representatives OCONUS and for how long
Is there any new construction needed to support the new system	0	$1,000,000	0	$0	$0	Does the system require new facilities
Will there be sustainment cost for facilities (# of Fielding Sites)	0	$10,000	0	$0	$0	Is there any additional funding required for sustainment of new facillites
Estimated OPTEMPO increase from the current system (10% as a baseline or known number) times average cost times number of years	0	$5,000	0	$0	$0	Will the system see an increase of OPTEMPO use and how many vehicles
Total						**Total Procurement Cost**
Average Cost Per System						**Average of Vehicle Cost**
Possible reduction in O&S cost from additional testing that can be a cost benefit						
Overall cost benefit to the system	**Procurement Cost X (10% of Fleet)**	**1 Test (1%)**	**2 Tests (2%)**	**3 Tests (3%)**	**≥ 4 Tests (5%)**	**Cost Benefit**
Survivability and Enhanceability (Is the CB comparable to the enhancement and survivability of the system) or Enhance ability (Can it be upgraded and does the cost benefit the upgrade)	Procurement Cost Times 10% of fleet	10% of fleet procurement cost times 1% Cost Benefit	10% of fleet procurement cost times 2% Cost Benefit	10% of fleet procurement cost times 3% Cost Benefit	10% of fleet procurement cost times 5% Cost Benefit	Is the additional testing a cost benefit or not
Overall benefit to the system	**Readiness**	**1 Test (>90%) > 1 Year**	**2 Tests (>90%) >2 Years**	**3 Tests (>90%) > 3 Years**	**≥ 4 Tests (>90%) ≥ 4 Years**	**Cost Benefit**
Reliability and Maintainability (RAM) and Performance (Does the CB correlate to readiness, better performance or being maintainable and reliable)	> 90%					Is the additional testing a cost benefit or not

Once we developed the model, we then ran the model for both the HMMWV and M-ATV programs. After this, we took the total estimated cost information from both models and compared it against the actual program cost information. During this comparison, we determined that the model needed to be changed, as we could not verify our estimated total costs for both programs. The HMMWV program actual costs were lower and the M-ATV higher than what the model estimated. As we stated earlier, as both of these programs were determined to be affordable we knew that our model had to be changed.

We changed the model from fixed to program specific plugins for OPTEMPO and DLA initial spares. . These changes were because the model overestimated the OPTEMPO costs for the HMMWV and underestimated the DLA initial spares cost. If these changes had been in our original model the model would have provided a total cost estimate that aligned with the actual cost data.

After we updated the model, we ran the model for the JLTV program. Based on the JLTV results, which were within 5% of government estimates, we verified that the changes to the model were required (E. Murphy, personal communication, September 2, 2020). To date the JLTV program has been determined to be affordable, which indicates that model will be useful in making more-informed affordability decisions by the Services. However, as the JLTV is a new system, which still has to make its way through the acquisition lifecycle there may be instances where affordability will have to be reviewed. In these instances, we believe this model can be used help determine if the JLTV remains affordable.

Our secondary research question was whether there are there any external parameters that need to be considered prior to using the affordability decision model. With running the model three times for three different programs, one in sustainment, one entering sustainment and one a new system we were able to determine external parameter that should be accounted for prior to using the model. The external parameter that we identified is if the program is being developed during a wartime environment. If the program is, being used during wartime there will be higher spare part and OPTEMPO costs. For spare parts, this is because the vehicles will be in high demand and the requirement for them to be operationally ready will be higher. Therefore, larger quantities of spare parts will be required to be procured when the system is being fielded to make sure that there are no spare part shortages. With the OPTEMPO if the vehicles are being used during a wartime environment the usage of the vehicles will dramatically increase. These external factors can be seen in our analysis and our recommendation for them to be program specific plug in numbers.

In addition, to answering our two research questions we also determined that our model cannot be used by itself to make a proceed or cancel decision for programs. However, the model should be used to support this decision, as there are other factors not relating to cost that should be considered as well. One area that we were unable to validate in our model was the portion on additional testing. For additional survivability and reliability testing and potential cost avoidance, we were unable to validate its benefit as we only had information on the M-ATV program. However, when evaluating program affordability additional survivability and reliability testing should be discussed and evaluated by senior leadership prior to making a proceed or cancel determination on a program. In the future, the benefits of additional testing should be researched, as we were not able to obtain this information. Many times programs, especially lower priority programs, do not have the funding or the time to execute an extensive test program. One other area that we would like to look at in the future is if this model could be used for lower ACAT vehicle programs.

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