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A comparative analysis of current and planned small arms weapon systems

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MBA PROFESSIONAL REPORT

A COMPARATIVE ANALYSIS OF CURRENT AND PLANNED SMALL ARMS WEAPON SYSTEMS

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December 2004

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13. ABSTRACT ***(maximum 200 words)***

Today, the threat to the United States is no longer a symmetric enemy with massive armor formations. No longer will the battlefield of the future resemble the rolling plains of Europe. Today's enemy is more asymmetric than ever, choosing not to meet the might of the US military head on, but in a series of small engagements against traditional non-combat arms units. The fight will take place most often in built up areas, where the US military machine cannot bring its full force to bear on a technologically inferior foe. Each soldier, regardless of job or unit, must have an increased capability to deal with this threat. As the Army develops new or improved tactical equipment for the individual soldier to combat this threat, it must answer one key question. Does the new system provide more capability and/or reduce cost? Current systems in use today are battle proven and meet this need, however many are aging and there are alternative systems available.

The purpose of this project is to determine which weapon system provides the best value to the Department of Defense. It does this by examining the background, capabilities, and cost of each system. It then uses a quantitative and qualitative approach to determine which weapon system is more advantageous in terms of suitability and effectiveness, and which system provides the more cost effective solution.

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A COMPARATIVE ANALYSIS OF CURRENT AND PLANNED SMALL ARMS WEAPON SYSTEMS

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Submitted in partial fulfillment of the requirements for the degree of

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A COMPARATIVE ANALYSIS OF CURRENT AND PLANNED SMALL ARMS WEAPON SYSTEMS

ABSTRACT

In today's world, the threat to the United States is no longer a symmetric enemy with massive armor formations. No longer will the battlefield of the future resemble the rolling plains of Europe. Today's enemy is more asymmetric than ever, choosing not to meet the might of the US military head on, but rather in a series of small engagements against traditional non-combat arms units. The fight will take place most often in built up areas, where the US military machine cannot bring its full force to bear on a technologically inferior foe. Each soldier, regardless of job or unit, must have an increased capability to deal with this threat. As the Army develops new or improved tactical equipment for the individual soldier to combat this threat, it must answer one key question. Does the new system provide more capability and/or reduce cost? Current systems in use today are battle proven and meet this need, however many are aging and there are alternative systems available.

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I. INTRODUCTION

This chapter provides general information, research questions, discussion of the issues, scope, methodology, benefits of the study, and organization of the study.

A. GENERAL INFORMATION

The XM8 rifle system began its life as the kinetic energy portion of the Army's Objective Individual Combat Weapon (OICW) program. The OICW was to be the individual weapon for the Army's Objective Force. It was designed to address engagement problems encountered by soldiers on the battlefield. The OICW incorporated range-estimating technology to ensure accurate fire and an air bursting munition to engage enemy personnel hiding behind cover. Problems meeting several key requirements eventually forced the Army to reduce priority on the project. The Army, rather than abandon the work, time, and effort placed into the XM29 OICW program, split the system and began pursuing each half of the system separately. Two weapons emerged from the OICW program: a weapon designed to fire airburst munitions, and the XM8 rifle system. The US Army Program Manager for Small Arms is pursuing each program independently, with each entering into the System Development and Demonstration phase of the Life Cycle Model. The purpose of this project is to determine which weapon system provides the best value to the Department of Defense by analyzing performance capabilities and cost.

B. RESEARCH QUESTIONS

1. Primary Question

Which weapon is more advantageous with regard to suitability and effectiveness?

2. Subsidiary Questions

a. Which weapon system provides increased capability for the user?

b. Which weapon system provides the more cost effective solution?

C. DISCUSSION

In today's world, the threat to the United States is no longer a symmetric enemy with massive armor formations. No longer will the battlefield of the future resemble the

rolling plains of Europe. Today's enemy is more asymmetric than ever, choosing not to meet the might of the US military head on, but rather in a series of small engagements against traditional non-combat arms units. The fight will take place most often in built up areas, where the US military machine cannot bring its full force to bear on a technologically inferior foe. Each soldier, regardless of job or unit, must have an increased capability to deal with this threat. As the Army develops new or improved tactical equipment for the individual soldier to combat this threat, it must answer one key question. Does the new system provide more capability and/or reduce cost? Current systems in use today are battle proven and meet this need, however many are aging and there are alternative systems available. The purpose of this project is to determine which weapon system provides the best value to the Department of Defense by analyzing performance capabilities and cost.

D. SCOPE OF PROJECT

The purpose of this project is to determine which weapon system provides the best value to the Department of Defense by analyzing performance capabilities and cost. The XM8 family of weapons is the proposed replacement for the M16A4 Rifle, the M4 Carbine, and the M249 Squad Automatic Weapon. Each current weapon will be compared to the planned replacement system to determine if the XM8 is a viable substitute for that system. Ultimately, this project will produce a candidate for the best value rifle system for the Department of Defense, relying on objective analysis of performance and cost data.

E. METHODOLOGY

The methodology used in this research project consisted of three distinct steps; gathering data, performance analysis, and cost analysis. The first step of this research project was to obtain the performance characteristics and cost data for current and planned systems. This data was obtained through published doctrinal manuals, articles, technical manuals, phone interviews, personal interviews, e-mail consultation, and Internet literature.

The second step was to conduct a quantitative performance analysis by defining performance characteristic variables, establishing screening criteria, weighting these

performance characteristic variables, then conducting analysis through the use of a decision matrix to determine the better performing weapon system. Additionally, a qualitative analysis of system performance characteristics was conducted to determine strengths and weaknesses of the systems.

The third step of the analysis was to conduct a comparative quantitative cost analysis of current systems against planned systems by defining relevant and non-relevant costs. The final step of the cost analysis was to compare the fielding costs, per the authorized quantities outlined in the Modified Table of Organization and Equipment (MTOE), of current systems, planned systems, and current systems with the same performance capabilities as the planned systems for a Unit of Action .

F. BENEFITS OF THE STUDY

This study serves as a basis for future research, analysis, and discussion in determining the best rifle system for the Department of Defense. The best value solution will serve to reduce cost for the DoD through deletion of redundant programs, maximized performance and reliable logistical support. Such research will be instrumental in providing to the soldier, marine, sailor, or airman the lethality necessary to defeat future enemies.

G. ORGANIZATION OF THE PROJECT

Chapter I: This chapter provides general information, research questions, discussion of the issues, scope, methodology, benefits of the study, and organization of the study.

Chapter II: This chapter presents the evolution of current individual soldier weapons and associated equipment. Additionally, it includes the performance characteristics and cost associated with these current systems; the M16A4 Rifle, M4 Carbine, M249 Squad Automatic Weapon, the AN/PAQ-4C and AN/PEQ-2A laser aiming lights, and the M68 and M145 optical sights.

Chapter III: This chapter describes two variants of the XM8 rifle system, the carbine and the Designated Marksman Automatic Rifle. This new system is intended to

replace the M4 Carbine, M16A4 Rifle, and M249 Squad Automatic Weapon. Included in this chapter is; background information, origins of the system, performance characteristics, and cost.

Chapter IV: This chapter consists of two quantitative performance analyses; the first analysis is the XM8 Carbine against the M4 Carbine and the M16A4 Rifle, the second analysis is the XM8 Designated Marksman Automatic Rifle against the M249 Squad Automatic Weapon. It also includes a qualitative analysis of non-relevant variables.

Chapter V: This chapter consists of two quantitative analyses; the first compares individual weapon costs of the XM8 Carbine to the M16A4 Rifle and M4 Carbine, second analysis compares individual weapon costs of the XM8 Designated Marksman Automatic Rifle to the M249 Squad Automatic Weapon. Additionally, it includes fielding costs for a Unit of Action (UA) from the 101st Infantry Division Air Assault per it's prescribed Modified Table of Organization and Equipment (MTOE) for current systems, planned systems, and current systems with the same performance capabilities as the planned systems.

Chapter VI: This chapter examines the primary and subsidiary research questions. Conclusions are then presented as well as recommendations for future actions.

II. CURRENT SYSTEMS

This chapter presents the evolution of current individual soldier weapons and associated equipment. Additionally, it includes the performance characteristics and cost associated with these current systems; the M16A4 Rifle, M4 Carbine, M249 Squad Automatic Weapon, the AN/PAQ-4C and AN/PEQ-2A laser aiming lights, and the M68 and M145 optical sights.

A. CURRENT WEAPON SYSTEMS BACKGROUND

Army analysis of battlefield statistics from WWI, WWII, and Korea, revealed most kills from small arms occurred at a range of less than 300 yards [Ref. 1]. This study led to the Army desiring a new rifle that was lighter, while retaining the same lethality as the M1 Garand or M14 rifles. The genesis of the M16 rifle occurred in 1956 when Eugene Stoner approached Winchester Corporation. Stoner developed a small but powerful .223 rifle cartridge [Ref. 1]. This new cartridge was smaller and lighter in weight, yet still powerful enough to meet the performance specifications the Army established. This new technology caused Winchester Corporation and Colt Manufacturing to form an alliance and begin manufacturing the AR15 rifle in 1959.

This new rifle met the need with reduced weight while retaining the same effective range and lethality as the M14. The Air Force, also looking for a new weapon, completed testing of the AR15 in 1961 and procured 8,500 of these AR15's, for use in their police force [Ref. 1]. Adoption of the AR15 by the Air Force re-designated the AR15 to the M16 in 1962 [Ref. 1].

The same year the Air Force adopted the M16, Colt Manufacturing participated in an Advanced Concept Technology Demonstration through DARPA (Defense Advanced Research Projects Agency). Colt Manufacturing supplied 1,000 M16's for field trials in Vietnam. DARPA's after action report revealed this new weapon and projectile had the satisfactory performance characteristics the Army sought; lighter weight and equal lethality of an M14. This report energized Robert S. McNamara, the Secretary of

Defense, to query the Army as to; "Why was the Army buying M14's when there was available a lighter, faster firing, and more effective weapon called the M16 [Ref. 2]?"

The initial weapons sent to combat troops in Vietnam before 1966, were plagued with many problems. This version of the weapon, the A0 model, still haunts the image of the M16 to this day. This initial weapon had spiraling major flaws associated with it. First, these initial M16's were used with a .223 cartridge containing the wrong type of propellant. The original tests conducted before combat in Vietnam, used improved military rifle powder in a controlled environment. This improved powder was cleaner burning and required little to no maintenance after firing the weapon. Second, the Army Ordnance Corps specified ball type ammunition, which was not used during testing or field trials in Vietnam. Ball type ammunition is cheaper, causes the weapon to fire faster, and actually increases fouling and residue build up. Troops in Vietnam before 1966 received ball type ammunition with their M16's. This ball type ammunition caused massive carbon residue build up and directly led to obstructed gas tubes and extensive fouling in the chamber areas. Additionally, cleaning kits were not issued with the M16A0. Cleaning kits allow the operator of the weapon to minimize the effects of ball type ammunition residue. Essentially, the problem facing the Army was the weapon they developed did not have the correct ammunition, nor was there a method or tool to correct this problem at the operator level.

As a direct result of these problems, extensive engineering changes to the M16 occurred: Positive forward assist, chromium plated barrel, improved gas system, and a field cleaning kit led the Army to adopt this weapon as the M16A1 in 1967. All of these engineering changes were designed to allow the Army to continue using ball type ammunition. Of note, weapons issued after these modifications displayed little to no malfunctions during combat in Vietnam. Colt manufactured some 3.7 million of these weapons to replace the aging M14 through the 1960's and the Vietnam War [Ref. 1].

By 1983, the M16A2 had come of age and replaced the A1 version in the Army. The A2 version is simply an improved A1 with a heavier barrel, improved sights, stronger butt stock, and elimination of the full automatic selector in favor of a three round burst capability [Ref. 1]. This three round burst capability was born out of combat

developer premise that aimed accurate fire is more lethal than large volumes of fire. This has been in debate since the Civil War and is still in debate among many in the infantry community.

In the 1990's, innovative technology and lessons learned from combat in Panama and Somalia caused further engineering changes to the M16A2. Three new versions were developed and fielded: the M16A3, the M16A4, and the M4. The A3 version is essentially an A2 with full automatic capability and a Rail Interface System (RIS) or 'Picatinny Rails' for optical sight attachment modularity [Ref. 1]. In 1994, limited numbers of the M16A3 version were fielded. The A4 version has the same rail capability as the A3, but instead of the full automatic capability, possesses a three round burst capability instead. The M16A4 and the M4 are still being fielding to this day and serve as the main individual weapon systems in ongoing combat operations.

1. M16A4 Rifle and M4 Carbine

The M16A4 rifle is the standard issue shoulder fired weapon in the U.S. military [Ref. 1]. The intended purpose of the rifle is to provide personnel with the capability to conduct offensive or defensive operations in all conditions. Both the M16A4 and the M4 are capable of two modes of operation; semiautomatic where the operator pulls the trigger and fires a single round, and a three round burst capability where the operator pulls the trigger and three rounds fire successively. The ammunition types that the M16A4 and the M4 is capable of firing are: M193 and M855 ball type ammunition, as well as M856 tracer ammunition [Ref. 3]. Nine major components make up each individual weapon. Basic Issue Items (BII) for the M16A4 and M4 include one 30 round magazine and a sling [Ref. 3].

Figure 1. M16A4 Rifle
[From Ref. 1]

During the same period of the development of the M16A4, senior leaders recognized that a new, shorter version of the M16A2 needed to be developed. This new weapon would capitalize on emerging technologies to meet the need of combat in urban areas. This weapon had to retain the same accuracy, range, and lethality as its predecessor, the M16A2 [Ref. 1]. This led to the development of the M4, which retains the same modular capability as the M16A4. Four distinct factors separate the M4 from the M16A4; reduced weight, shorter barrel, collapsible butt stock, and a decrease in effective direct fire range by 50 meters. After Action Reviews from combat operations during OIF resulted in a consensus that "every rifleman wanted an M4 rather than an M16A4" [Ref 4].

Figure 2. M4 Carbine
[From Ref. 6]

Since only one magazine is issued with each weapon, Army units must purchase additional magazines required for individual basic load of ammunition. Currently, the load-bearing vest holds six additional 30 round magazines. This provides the soldier 7 magazines total, one in the weapon and six carried. Additional equipment needed to operate the M16A4 and M4 correctly for training, combat, and administration includes: A blank firing adapter (BFA), a weapon cleaning kit, and an arms room storage rack which secures ten individual weapons. Of note is the fact that even though earlier maintenance issues plagued the M16 during the Vietnam era, the Army still does not issue cleaning kits as a basic issue item to accompany the weapon.

Table 1. M16A4 and M4 Performance and Cost Data
[From Ref. 3,5,6,7,8,9]

	M16A4 Rifle	M4 Carbine
Weight Empty	7.5 Pounds	5.9 Pounds
Weight 30 Round Magazine Empty	0.25 Pounds	
Weight 30 Round Magazine Loaded	1 Pound	
Weight Combat Ready	8.79 Pounds	7.5 Pounds
Length	39.6 Inches	29.75 Inches Collapsed 33 Inches Extended
Barrel Length	20 Inches	14.5 Inches
Effective Range	550 Meters	500 Meters
Muzzle Velocity	3,100 Feet per Second	2,970 Feet per Second
Maximum Range	3600 Meters	
Mode of Operation(s)	Semi-Automatic & 3-Round Burst	
Semi-Automatic Maximum Rate of Fire	45 Rounds Per Minute	
3-Round Burst Maximum Rate of Fire	90 Rounds Per Minute	
Semi-Automatic Sustained Rate of Fire	12 Rounds Per Minute	
3-Round Burst Sustained Rate of Fire	15 Rounds Per Minute	
Cyclic Rate of Fire	800 Rounds per Minute	
Mean Rounds Between Failure	< 6,000 Rounds	
Barrel Life Expectancy	15,000 Rounds	
Unit Cost	$587	
Blank Firing Adapter Cost	$4.69	
Weapons Cleaning Kit Cost	$10.70	
6 x 30 Round Magazines Cost	$72.46	
Total Cost	$674.85	

2. M249 Squad Automatic Weapon

The M249 Squad Automatic Weapon (SAW) machine gun is belt-fed, gas-operated, air-cooled and fires from the open bolt position [Ref. 10]. The intended role of the M249 SAW is to provide suppressive fire at extended ranges, allowing the infantry squad to conduct fire and maneuver, ultimately closing with and destroying the enemy. The M249 SAW's development and fielding resulted from the Army's decision to replace the M16A1 with the M16A2, in the 1980's. With the fielding of the M16A2 to infantry units the infantry squad no longer possessed a viable weapon to provide suppressive direct fires at extended ranges. Fabrique Nationale Manufacturing Inc. of Columbia, South Carolina produces the M249 SAW.

Figure 3. M249 SAW Base Model
[From Ref. 11]

The M249 is made up of 19 major components and is fielded with accompanying Basic Issue Items (BII). BII for the M249 includes; a sling with adapters to attach the sling to the weapon, a spare barrel, spare barrel bag, two 100 round assault pouches, and a heat shield [Ref. 10]. The combined weight of the BII is 7 pounds. The individual soldier in combat rarely carries the BII, rather the battalion or company logistical trains normally carries this spare equipment.

Figure 4. M249 SAW Paratrooper Model
[From Ref. 11]

This base model can be modified into a paratrooper (PARA) version. This version includes Picatinny rails mounted on top of the feed tray cover, a collapsible butt stock, and a shorter barrel. This modification of the M249 SAW does not degrade performance in any way.

The M249 SAW, still in service with the Army today, received rave reviews during recent combat in Operation Iraqi Freedom [Ref. 4]. The range of this weapon, coupled with a high rate of fire, makes it an excellent suppression weapon against enemy troops or soft-skinned targets.

The M249 gunner has the ability to carry three separate loads of ammunition, a 200 round plastic box, a 100 round soft assault pouch, or a 30 round magazine from the M16/M4. The individual rounds in the 200 round box and the 100 round assault pouch come linked together, whereas individual rounds in the 30 round magazines are not. Operation Iraqi Freedom lessons learned concluded that soldiers prefer the 100 round assault pouch to the 200 round plastic box [Ref. 4]. The ammunition types that the M249 is capable of firing are: M855 ball type ammunition; M856 tracer ammunition; and the M995 armor piercing round [Ref. 10]. Additional operating characteristics of the M249 SAW include; an adapter to mount the weapon on the M1025/1026 HMMWV, and the ability to mount the M249 on a ground mounted tripod for more accurate direct fires. Currently, the United States Marine Corps is the only service that uses the M249 SAW with a tripod.

Additional equipment and costs needed to operate the M249 correctly for training, combat, and administration includes; a blank firing adapter (BFA), weapons cleaning kit, a minimum of four 100 round ammunition pouches, and an arms room storage rack. Important operational and physical characteristics, as well as unit cost are depicted below.

Table 2. M249 SAW Base Model and Paratrooper Model Performance and Cost Data
[From Ref. 5,8,9,10,11,12]

	M249 Base	M249 Paratrooper
Weight	17 Pounds	16.75 Pounds
200 Round Ammunition Box Weight	6.92 Pounds	
100 Round Pouch Weight	3 Pounds	
30 Round Magazine Weight	1 Pound	
Length	40.75 Inches	31 Inches Collapsed 36 Inches Extended
Barrel Length	20.5 Inches	16 Inches
Effective Range Point Target	800 Meters	
Effective Range Area Target	1000 Meters	
Maximum Range	3600 Meters	
Cyclic Rate of Fire	850 Rounds Per Minute	
Rapid Rate of Fire	100 Rounds Per Minute	
Sustained Rate of Fire	50 Rounds Per Minute	
Mean Rounds Between Failure	> 19,000 Rounds w/2 barrels	
Barrel Life Expectancy	>30,000 Rounds w/2 barrels	
Muzzle Velocity	3,001 Feet per Second	
Unit Cost	$2653	Base Model $2653 Shorter Barrel $452 Collapsible Butt Stock $495 Total $3600
Blank Firing Adapter Cost	$4.69	
M249 SAW Cleaning Kit Cost	$26.12	
2 x 100 Round Ammunition Pouches	$50.75	
Total Cost	$2734.56	$3681.56

B. CAPABILITY ADD-ONS

Taking full advantage of technology, the Army fielded capability add-ons to enhance the lethality of the previously listed individual soldier weapons. These additional items provided increased accuracy in all conditions for the individual soldier. This analysis will focus on current systems available to the infantry soldier including; laser aiming lights consisting of the AN/PAQ-4C Light Aiming Infrared and the AN/PEQ-2A Target Pointer Illuminator/Aiming Light; and optic sights consisting of the M68 Reflex Sight and the M145 Machine Gun Optic Sight.

1. Laser Aiming Lights

The intended role of the AN/PAQ-4C Light Aiming Infrared and AN/PEQ-2A Target Pointer Illuminator/Aiming Light (TPIAL) is to provide individual soldier direct fire weapon systems the ability to engage targets at night with pinpoint accuracy. Both

accomplish this by emitting a continuous infrared beam that is visible only through night vision devices. Essentially, the individual soldier designates a point of impact with the laser aiming light and fires the weapon. The bullet flies along the same path as the continuous beam, then impacts at the point previously designated by the soldier. The soldier does not have to keep the beam on his intended target. The major difference in the two is that the AN/PEQ-2A beam is stronger and adjustable to illuminate a target area, as well as pinpoint an intended target. This is a major enhancement for small unit leaders to direct fires onto an intended target. The AN/PAQ-4C and AN/PEQ-2A received outstanding reviews during Operation Iraqi Freedom. One Brigade Commander commented that, "the enemy never seemed to grasp that we could see and hit them at night [Ref. 4]."

Figure 5. AN/PAQ-4C Laser Aiming Light
[From Ref. 18]

The AN/PAQ-4C and AN/PEQ-2A has two modes of activation. The first and most preferred method is to use the direct on/off lever attached directly on the laser aiming light. The second method is to use an attached cable with a pressure switch. This allows the soldier to place the activation switch in the exact location that he desires. Additionally, the AN/PEQ-2A has two modes of operation, training and tactical. The tactical mode consists of a non-eye safe laser, whereas the training mode offers an eye safe laser for force-on-force use. The AN/PAQ-4C has only one operational mode, yet it is safe for force-on-force training.

Figure 6. AN/PEQ-2A Laser Aiming Light
[From Ref. 15]

The limiting performance factor of both laser-aiming lights is not the beam, but rather, it is the soldier's individual night vision device. Current night vision goggles (AN/PVS-7B/7D) or the monocular version (AN/PVS-14) do not have the ability to see well beyond 300 meters. However, the AN/PEQ-2A has an illumination role capability, whereas the AN/PAQ-4C does not. The AN/PEQ-2A user can illuminate an area 30 meters wide, resembling an infrared spotlight. This has two purposes; number one, the user can designate areas for his soldiers to focus direct fires on, and additionally, it provides extra artificial illumination for increased visibility in the infrared spectrum beyond the 300 meter limiting factor of current night vision goggles.

The AN/PAQ-4C and AN/PEQ-2A is compatible with the M16 rifle, M4 carbine, and the M249 SAW. Additionally the AN/PEQ-2A is also mountable to the M240 machine gun and the M2 50-caliber machine gun, which is beyond the scope of this report. The laser aiming light mounts to each weapon by hardware accessories that accompany the piece of equipment. Both mount near the front sight post on the M16A4 rifle and the M4 carbine. There are two possible configurations on the M249 SAW, on top of the feed tray cover or on the side near the front sight post. Insight Technology of Manchester, New Hampshire manufactures both the AN/PAQ-4C and AN/PEQ-2A. Both aiming lights do not require additional equipment to operate other than that found in the Basic Issue Items.

Two major drawbacks of the laser-aiming lights plague soldiers today; zeroing and arms room storage. Zeroing either one is a time consuming and arduous task. Without a proper zero, the bullet will not hit the desired impact point. The second drawback is the secure storage requirement of any weapon a laser aiming light accompanies. Standard arms room racks for the M16A4, the M4, and the M249 will not secure properly with either laser aiming light attached. Current security regulations cause the user to remove the piece of equipment each time the soldier places the weapon into the standard arms room rack, thus losing its zero. Important operational and physical characteristics, as well as unit cost for the AN/PAQ-4C and AN/PEQ-2A are depicted below.

Table 3. AN/PAQ-4C and AN/PEQ-2A Performance and Cost Data [From Ref. 8,14,15,16]

Variable	AN/PAQ-4C	AN/PEQ-2A
Length	5.5 Inches	6.4 Inches
Width	2.5 Inches	2.8 Inches
Height	1.2 Inches	1.2 Inches
Weight	0.36 Pounds	0.47 Pounds
Battery Life	100 Hours	100 Hours
Life Expectancy	10,000 Cycles of the Laser	
Mean Time Between Maintenance (Re-Zero)	(Operational Requirements Document Threshold) 500 rounds M16/M4, 2,000 Rounds M249, (Objective) 2,250 Rounds	
Compatibility	M16 Series, M4, M249 SAW	M16 Series, M4, M249 SAW
Unit Cost	$518	$1000

2. Optical Sights

The M68 is a reflexive (non-telescopic) sight that uses a red collimated dot to allow the operator to fire with both eyes open [Ref. 17]. This dot follows the vertical and horizontal movement of the operator's eye [Ref. 17]. Thus, the operator simply needs to place the red dot on the intended target, pull the trigger, and the bullet will strike that point.

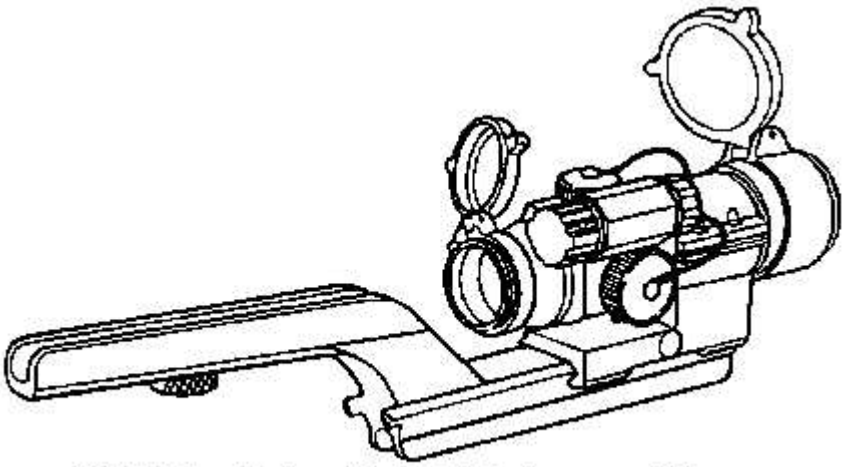

Figure 7. M68 Optical Sight
[From Ref. 18]

There are three advantages to using the M68. First, the M68 increases situational awareness through the ability to have both eyes open. Second, the M68 eliminates the need to align both the front and rear sight post. Because the operators situational awareness is increased and the need to align both the front and rear sight post is eliminated, the operator gains the third and most important advantage on the battlefield; increased probability of hit with a decrease in target engagement time [Ref. 18].

The M68 mounts to the M16 rifle or the M4 carbine in one of two methods. The first method is direct attachment to the Picatinny rail system; this is the most common and preferred method. The second method is to use the mount that attaches to the M16 or M4 carrying handle. Aim Point is the manufacturer of the M68 Reflex Sight. The M68 does not require additional equipment to operate other that that found in the Basic Issue Items.

Figure 8. M145 Machine Gun Optic Sight
[From Ref. 20]

The intended use of the M145 Machine Gun Optic Sight is to allow individual soldiers to engage targets at increased distances with more accuracy. The M145 Machine Gun Optic Sight mounts to the M249 SAW and the M240 series machine guns, via Picatinny rails. This telescope is a fixed 3.4-power sight that allows the individual soldier to accurately engage targets out to 1200 meters [Ref. 19]. However, not its intended use, but the M145 has the capability to mount to the M16A4 and M4's picatinny rails. This provides soldiers with a powered sight for longer-range shots.

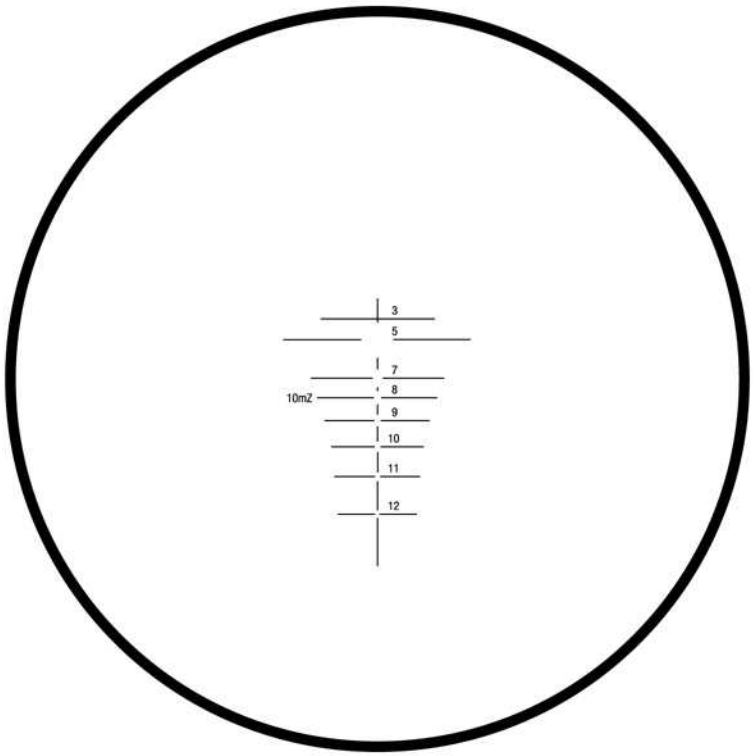

Figure 9. M145 Sight Picture
[From Ref. 20]

This sight is battery powered and includes an illuminated reticle pattern with a built in trajectory round compensation from 300 to 1200 meters [Ref. 19]. This illuminated reticle pattern along with the power of the telescope aids the user by absorbing all available ambient light. In essence, natural light conditions around dawn and dusk appear as daylight to the user. Armament Technology is the manufacturer of the M145, and Aim-Point is the manufacturer of the M68. The M145 does not require additional equipment to operate other that that found in the Basic Issue Items.

Both the M68 and M145 possess the same drawbacks as the previously listed laser aiming lights. First, the user must have a proper zero for the sight to be effective in its intended role. Second, standard arms room racks will not secure properly with either sight attached. The drawback of this is the same as the laser aiming lights. The user must re-zero the equipment each time, only to remove it and lose zero to meet arms room physical security requirements. This wastes training time and resources. Important

operational and physical characteristics, as well as unit cost for the M68 Reflex Sight and the M145 Machine Gun Optic Sight are depicted below.

Table 4. M68 and M145 Performance and Cost Data [From Ref. 8,17,19,20,21]

Variable	M68	M145
Length	5 Inches	6.5 Inches
Width	2 Inches	2.2 Inches
Height	2 Inches	3.4 Inches
Weight	0.38 Pounds	1.5 Pounds
Battery Life	75-500 Hours	175 Hours
Life Expectancy	Mid Life Army Refit Expected at 10 Years	
Mean Time Between Maintenance (Re-Zero)	6,000 Rounds	
Compatibility	M16 Series, M4	M249 SAW
Unit Cost	$330	672

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III. PLANNED SYSTEM

This chapter describes two variants of the XM8 rifle system, the carbine and the Designated Marksman Automatic Rifle. This new system is intended to replace the M4 Carbine, M16A4 Rifle, and M249 Squad Automatic Weapon. Included in this chapter is; background information, origins of the system, performance characteristics, and cost.

A. BACKGROUND INFORMATION

The XM8 rifle system began its life as the kinetic energy portion of the Army's Objective Individual Combat Weapon (OICW) program. The OICW was to be the individual weapon for the Army's Objective Force. It was designed to address engagement problems encountered by soldiers on the battlefield. The OICW incorporated range-estimating technology to ensure accurate fire and an air-bursting munition to engage enemy personnel hiding behind cover. Problems meeting several key requirements eventually forced the Army to reduce priority on the project. The Army, rather than abandon the work, time, and effort placed into the XM29 OICW program, split the system and began pursuing each half of the system separately. Two weapons emerged from the OICW program: a weapon designed to fire airburst munitions, and the XM8 rifle system.

Figure 10. XM8 Carbine
[From Ref. 22]

According to Army Lieutenant Colonel Matthew Clarke, Product Manager for Individual Soldier Weapons, if tests being conducted on the XM8 are successful, it could replace the Vietnam-era M16 rifle and M4 carbine as the standard weapon system for all

infantry soldiers [Ref. 23]. Operational tests for the weapon system are currently scheduled to begin in fiscal year 2005 [Ref. 24]. Soldiers have already had access to the weapon in its carbine variant, conducting tests at Aberdeen Proving Ground, Maryland [Ref. 24].

In the first generation of the XM8 rifle system, there were four variants: The baseline carbine variant, a sharpshooter rifle variant, an automatic rifle variant, and a compact variant [Ref. 22]. These weapons were designed to replace the M4 carbine, M16A4 rifle, and M249 Squad Automatic Weapon. In the second generation, which evolved based on tester input; the designated marksman sharpshooter and automatic rifle (DMAR) variants are combined. If the weapon is used in the automatic rifle role, it will be utilized with a 100 round magazine [Ref. 25]. The DMAR would replace the M249 Squad Automatic Weapon; however, the DMAR is not intended to replace the M249 in a light machine gun role [Ref. 26]. The DMAR would be employed as an automatic rifle rather than as a light machine gun. For the purposes of this project, the compact variant will not be evaluated, as it does not have a comparable Legacy system it is intended to replace.

Figure 11. XM8 DMAR
[From Ref. 22]

The XM8 Carbine is being designed at the Heckler & Koch Defense Design Center in Sterling, Virginia [Ref 22]. If accepted as a weapon for use by the US Army, they will be manufactured at a plant in Columbus, Georgia, nearby the Fort Benning Army installation.

B. ORIGINS OF THE SYSTEM

The XM8 operating system is a modification of the Armalite AR-18 rifle. The AR-18 rifle was developed by Eugene Stoner for the Armalite Company in the early 1960s. It was designed primarily as a competitor to the AR-15 (Armalite prototype of the M16), and was intended to be manufactured much less expensively and on simplified machinery when compared to the AR15 [Ref. 27].

Figure 12. AR-18 Rifle
[From Ref. 27]

The path from the AR18 to the XM8 is rather lengthy. The AR18, when it was not adopted by the US Armed Forces in the 1960s, served as a platform for further development of rifle systems in various other countries. The AR-18 design served as a starting point for the British SA80 / L85 bull-pup assault rifle. Second, the AR-18 served as a starting point for the Singapore SAR-80 assault rifle, designed by Chartered Industries of Singapore with the help of the George Sullivan (who help designed the AR18 itself). Lastly, the relatively new German Heckler & Koch G36 assault rifle bears a lot of similarity internally to the AR18 [Ref. 27].

C. GENERAL SYSTEM DESCRIPTION

The XM8 is magazine fed, gas-operated, air-cooled, and fires from the closed bolt position [Ref. 22]. It has integrated attachment points designed to accept a wide array of sighting and pointing devices used by the Army today. The weapon system's modularity includes interchangeable assembly groups such as the barrel, hand guard, lower receiver, butt stock modules and sighting system with removable carrying handle [Ref. 22]. The weapon also has a 5-position collapsible butt stock, a flat butt plate, an adjustable sniper stock, or a folding stock [Ref. 28]. The unique butt stock system allows the operator to

exchange butt stocks without tools. An optional butt cap for maximum portability and an optional folding or sniper butt stock with adjustable cheek piece for special applications exist [Ref. 22].

The ambidextrous nature of the XM8 controls allows for seamless operation regardless of whether the shooter is right or left handed [Ref. 29]. Controls accessible by right and left handed firers include a centrally located charging handle that doubles as an ambidextrous forward assist when required, ambidextrous magazine release, bolt catch, safety/selector lever with semi and full automatic modes of fire and release lever for the multiple position collapsible butt stock [Ref. 29]. The benefit of having controls accessible by either hand is that the operator can keep his firing hand on the pistol grip of the weapon while clearing a round from the chamber or exchanging a magazine.

Basic Issue Items will be the same as for the M4/M16. No special equipment is necessary, and spare barrels will not be issued to individual soldiers [Ref. 30].

1. Operating System

The XM8 operating system has a short stroke gas piston, located above the barrel, a square-shaped bolt carrier and the typical rotating bolt with six locking lugs [Ref. 31]. The XM8 gas system does not introduce propellant gases into the weapon's receiver during firing [Ref 29]. Gases introduced into the chamber of a weapon create fouling which can cause the weapon to malfunction. In the XM8, similar to the AR18 and German G36, gas impacts directly on an operating rod fixed to the bolt carrier [Ref. 32].

G36 Bolt and Carrier. Unlike an M16 type operating system where the gas used to operate the rifle is vented directly back into the receiver and to the working parts, the forearm is where the gas is vented. The XM8 bolt and carrier operate on a premise similar to the G36.

Figure 13. XM8 Operating System
[From Ref. 31]

This piston is used to operate the bolt, which ejects the spent casing and inserts a new round into the breech. Despite using this design for his AR18 rifle, Stoner was not convinced of its operating efficiency. He considered this design cumbersome, introducing vibrations and uneven force distribution onto the bolt [Ref. 33]. Regardless, the lack of gases in the breach translates into a weapon that does not require frequent cleaning to function. The XM8 system can fire more than 15,000 rounds before cleaning or lubrication is required [Ref. 29].

2. Barrel

Barrel lengths for the entire XM8 family of weapons vary depending on the variation of the XM8. The barrel is nine inches long for the compact carbine. Other barrel lengths include a 12.5 inch barrel for the standard carbine variant and 20 inches for the designated marksman automatic rifle version [Ref 23]. The automatic rifle version utilizes a heavy barrel, thus allowing it to withstand prolonged firing expected from an automatic rifle fitted with a 100 round magazine, as well as providing for accurate fires when used by the designated marksman. Its hammer-forged barrel has a Mean Rounds Before Failure (MRBF) of more than 20,000 rounds [Ref 23]. The extended MRBF translates into less frequent servicing of the weapon and a longer service life.

3. Receiver

The XM8 rifle system will have a common receiver that allows the weapon to be reconfigured into any of its many variants. The receiver life expectancy should be equal to or greater than the M4, but as the weapon is still in development with only limited tests conducted to date, this information is yet to be confirmed [Ref. 30].

4. Optics

In order to save weight and space, the XM8 rifle system has a built in battery-powered sight, which is comprised of a red dot close-combat optic that incorporates an infrared laser aimer and illuminator. There are two sights available, depending upon the variant. The first is an Integrated Sighting Module (ISM) 1 power sight, which is a combination of the M68 close combat optic with an AN-PEQ/2A-like capability. This sight offers no magnification to the shooter, but does have the red dot aiming system allowing for rapid acquisition of targets. The AN/PEQ-2 capability gives an operator the

ability to illuminate an area or pin point a target with a laser beam. The other sight is an Advanced Magnified Optic (AMO) or 4-power sight, which is a combination of the M145 Advanced Combat Optic and the AN-PEQ/2A [Ref. 34]. The non-magnified sight is for use on the Carbine. The 4-power sight is for the Designated Marksman Automatic Rifle [Ref. 35]. The shooter controls the sight‘s functions through a wireless switch that can be mounted anywhere on the weapon [Ref. 7]. The weapon also includes back up sights in the form of traditional front and rear iron sights, which can be folded down when not in use [Ref. 25]. The primary sight will be factory zeroed on the weapon when delivered, and will not require constant re-zeroing in the field [Ref. 36]. The inclusion of this sight eliminates the need for a detachable optic or pointing device.

5. Material Composition

The XM8 system weapons will be comprised of high strength fiber reinforced plastics with non-slip surfaces where the operator must handle the weapon [Ref. 28]. Use of the polymers creates a weapon that is lightweight, yet still able to withstand the stresses the operator may inflict upon the weapon. The polymers can be colored to blend with whatever environment is encountered.

6. Rates of Fire

The XM8 has a cyclic rate of fire of 850 rounds per minute and a sustained rate of fire of 85 rounds per minute and up to 210 rounds per minute for the designated marksman automatic rifle [Ref. 28].

7. Ammunition

The XM8 weapon system utilizes 10, 30, or 100 round magazines. The 10 and 30 round magazines for the XM8 are made of clear plastic to allow the operator to see how many rounds are remaining. The XM8 family of weapons fires the full line of 5.56mm ammunition available [Ref. 29].

8. Costs

The current projected cost for the XM8 family of weapons is approximately the same for all variants, with a potential 10% premium for the Designated Marksman version. Current estimate for the weapon itself is $600; the integrated sight module is

approximately $1200. This is for the systems in full rate, steady state production [Ref. 30]. A weapons rack for the XM8 family of weapons has yet to be designed. A comparable rack would cost between $1500 and $2000 and could hold 10 M16-sized rifles [Ref. 37].

Table 5. XM8 Carbine/Designated Marksman Automatic Rifle Performance and Cost Data
[From Ref. 7,24,25,30,35]

	XM8 Carbine	XM8 DMAR
Weight	7.14 Pounds	9.00 Pounds
Number of Major Components	11 Parts	12 Parts
Average Operator Assembly/Disassembly Time	< 4 Minutes	< 4 Minutes
Maximum Effective Range	500 meters	800 meters
Cyclic Rate of Fire	850 Rounds per Minute	850 Rounds per Minute
Mean Rounds Before Failure	15,000 Rounds	15,000 Rounds
Barrel Life Expectancy	20,000 Rounds	20,000 Rounds
Muzzle Velocity	2,695 Feet per Second	3,005 Feet per Second
Cost (Weapon and Sight)	$1800	$1800

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IV. PERFORMANCE ANALYSIS

This chapter consists of two quantitative performance analyses; the first analysis is the XM8 Carbine against the M4 Carbine and the M16A4 Rifle, the second analysis is the XM8 Designated Marksman Automatic Rifle against the M249 Squad Automatic Weapon. It also includes a qualitative analysis of non-relevant variables.

A. METHODOLOGY

System evaluation encompasses a broad analytical approach to the evaluation of an acquisition program from earliest concept definition through post deployment and sustainment [Ref. 38]. The major objective of system evaluation is to address the demonstrated system for use by typical users in realistic operational environments [Ref. 38]. This analysis will compare the performance of the XM8 family of weapons against their comparable current systems in use. The steps of this analysis include; defining the relevant variables, establishing screening criteria, and weighting the variables. From this process, the analysis will proceed with a side-by-side comparison, a non-weighted decision matrix, and a weighted decision matrix. The benchmarks for this method will be an average of current and planned systems. Additionally, non-relevant performance variables will be analyzed according to strengths and weaknesses.

Two separate analyses will be conducted, both independent of each other. The first analysis will be the M16A4 Rifle and/or M4 Carbine equipped with an AN/PEQ-2A laser aiming light, and an M68 optical sight against the planned replacement system, the XM8 Carbine. The second analysis will be the M249 SAW equipped with a collapsible butt stock, an AN/PEQ-2A laser aiming light, and an M68 optical sight against the planned replacement system the XM8 DMAR.

B. RELEVANT PERFORMANCE VARIABLES

1. Reliability

Reliability is the probability that an item can perform its intended function for a specified interval under stated conditions [Ref. 39]. Two sub-variables in this analysis; Mean Rounds between Failures (MRBF) and barrel life expectancy will define reliability.

The first sub-variable; Mean rounds between failures is the total number of rounds fired divided by the number of operator cleared failures. This sub-variable is an indication of how often the weapon will jam, and need corrective action applied to it by the operator. The higher the MRBF, the better the weapon is suited for prolonged combat.

The second sub-variable of reliability is barrel life expectancy. For both the XM8 family of weapons and the current systems, the limiting component as far as service life of the weapon, is the barrel. Since the bullet passes through the barrel of any of the above weapons, this component tends to wear out the fastest and cause a weapon to be re-built or labeled no longer suitable for service. Barrel life is directly proportional to life expectancy of a weapon system. Therefore, we will use this to determine the life expectancy of the weapon system. While not as important to the user as some of the other characteristics of a system, the life expectancy of a weapon is important. Any system should have sufficient life expectancy to justify spending funds to procure it. The thought process for this sub-variable is that the higher the number of rounds has, the longer the weapon will be in use, and therefore the funds spent on the weapon will be a positive return on investment.

2. Weight

The weight of a weapon designed for the individual soldier, versus a crew-served weapon, is directly proportional to its performance on the battlefield. Numerous studies since World War II have proven that, soldiers that have to shoulder a heavier weapon will become fatigued faster and lose their ability to place accurate fires on the enemy during extended combat actions. Its importance in determining the overall effectiveness of a weapon is paramount. Weight of the weapon for this analysis includes a laser aiming light, an optical sight, and a 30 round or 100 round magazine for its respective weapon.

3. Suitability

Suitability answers the question as to whether or not the specific item will meet its intended purpose. Two sub-variables in this analysis; maximum effective range and cyclic rate of fire will define suitability. The maximum effective range refers to the maximum distance which a soldier can engage a target and hit it with a high degree of

probability. The thought process behind the use of this variable is that a fielded weapon must be able to match or exceed the weapons that future or current adversaries may use.

The second sub-variable, cyclic rate of fire is; the number of rounds fired continuously through a weapon in one minute. Comparison of the cyclic rates of fire will provide insight into which weapon is able to fire more rounds faster, a capability that many soldiers desire in high intensity conflict. Additionally, this provides a basis for examining the weapons usage in a suppressive fire role. The logic behind this sub-variable is that a higher the cyclic rate of fire yields more bullets fired at the enemy, which means that another force is able to maneuver to destroy.

4. Lethality

Lethality is the killing or stopping power of a bullet when fired from a weapon. This analysis will use muzzle velocity to define lethality. Muzzle velocity is the speed at which a bullet travels to its intended target. If the bullet projectile speed is extremely high and the projectile is relatively pointed and hard, the projectile will tend to pass through a material like flesh while retaining a high speed and energy [Ref. 40]. The shock wave in front of the projectile and the suction (vacuum) caused behind it by its rapid passing can cause extensive damage to a material like flesh [Ref. 40]. The logic behind this variable is that the higher the muzzle velocity the more lethal the round is.

5. Maintainability

Maintainability is the probability that an item will conform to specified conditions within a given period of time when corrective or preventive action is performed in accordance with prescribed procedures and resources [Ref. 41]. Two sub-variables in this analysis are the number of major components and the average operator assembly and disassembly time of the weapon will define maintainability. The number of major components refers to the number of parts when field stripped, in accordance with the technical manual, to conduct operator maintenance. This sub-variable gives an indication as to what amount of effort, time wise, required in order to maintain the system. The thought process for this category is that the weapon that has fewer major parts will take less time to clean. For the current systems, this includes the laser aiming light and the optical sight.

The second sub-variable of maintainability is the average operator assembly and disassembly time, into the weapons major components. The thought process for using this sub-variable is that, the less time it takes a soldier to disassemble and then reassemble the weapon, the less complex the weapon is and the easier it is to clean/maintain. Average operator maintenance time would be a better variable, however, this is dependent upon numerous other factors. How well a soldier maintains his weapon depends upon how "dirty" it is and the standards set by the soldier's leaders. How "dirty" the weapon is depends upon such factors as; type of ammunition fired, number of rounds fired, and the environment in which the weapon operates.

6. Relevant Performance Variable Screening Criteria & Weighting

The planned system must meet or exceed the screening criteria for recommendation as a better performing weapons system. System performance variables serve as the basis for screening criteria. Screening criteria were defined by allowing tradeoffs for capability enhancements in other areas. Weighting of the relevant variables was developed by determining which relevant variable was the most important, and then rank ordering the remainder. The results of this ranking, starting with the most important in rank order, are reliability, weight, suitability, lethality, and maintainability.

a. Reliability

The planned system must meet or exceed current system mean rounds between failure and barrel life expectancy. Mean rounds between failure will carry a weight of 0.20, and barrel life expectancy will carry a weight of 0.18.

b. Weight

The planned system must weigh no more than the current system, with a weighting of 0.17.

c. Suitability

The planned system must not have more than a 10% decrease in cyclic rate of fire or maximum effective range, when compared to current systems. Cyclic rate of fire will carry a weight of 0.11, and maximum effective range will carry a weight of 0.10.

d. Lethality

The planned system must not have more than a 10% decrease in muzzle velocity when compared to current systems. Muzzle velocity will carry a weight of 0.09.

e. Maintainability

The planned system must not have more than a 25% increase in average operator assembly and disassembly time or number of major components. Average operator assembly and disassembly time will carry a weight of 0.08, and number of major components will carry a weight of 0.07.

C. PERFORMANCE ANALYSIS

1. XM8 Carbine vs. M16A4 Rifle & M4 Carbine

This analysis clearly indicates that the XM8 Carbine is a better performing weapon than the M16A4 Rifle or M4 Carbine. The XM8 Carbine is the clear winner when analyzing the reliability variable expressed as two sub-variables; MRBF and Barrel life expectancy. The higher MRBF, the highest weighted variable, is directly attributable to the operating system that the XM8 Carbine employs. This higher MRBF represents an increase in capability of 2.5 times the current system.

The increase in barrel life expectancy, the second highest weighted variable, is because the XM8 Carbine manufacturing process uses hammer-forged steel for the barrel. The manufacturing process of the M16A4 Rifle and M4 Carbine does not use hammer-forged steel. This process strengthens the steel used in the barrel and ultimately yields a longer barrel life expectancy. This increase in barrel life expectancy represents a 33% increase in capability.

Table 6. XM8/M4/M16A4 Side-by-Side Comparison
[From Ref. 3,7,25]

Variables		XM8 Carbine	M4 Carbine	M16A4 Rifle	Advantage
Reliability	MRBF	15,000 Rounds	< 6,000 Rounds	< 6,000 Rounds	XM8
	Barrel Life Expectancy	20,000 Rounds	15,000 Rounds	15,000 Rounds	XM8
Weight	Pounds	7.14 Pounds	8.35 Pounds	9.64 Pounds	XM8
Suitability	Maximum Effective Range	500 Meters	500 Meters	550 Meters	M16A4
	Cyclic Rate of Fire	850 Rounds per Minute	800 Rounds per Minute	800 Rounds per Minute	XM8
Lethality	Muzzle Velocity	2,695 Feet per Second	2,970 Feet per Second	3,100 Feet per Second	M16A4
Maintainability	# Of Major Components	11 Parts	11 Parts	11 Parts	Tie
	Average Operator Ass./Disass. Time	< 4 Minutes	4 Minutes	4 Minutes	Tie
MOST ADVANTAGEOUS					XM8

A major capability upgrade is the decrease in weight of 1.21 pounds (14%) when comparing the XM8 Carbine to the M4 Carbine and a 2.5-pound decrease (26%) for the M16A4 Rifle. This equates to a soldier carrying a lighter load, which is directly proportional to his performance on the battlefield. The clear advantage in the weight category is the XM8 Carbine.

Analyzing the suitability variable, the XM8 Carbine is clearly superior to the M4 Carbine in both maximum effective range and cyclic rate of fire. When compared to the M16A4 Rifle, the XM8 Carbine has a higher cyclic rate of fire by 50 rounds per minute but falls short by 50 meters in maximum effective range. The fact that the M16A4 Rifle has increased range is directly attributable to the 20-inch barrel it possesses, versus a 12.5-inch barrel for the XM8 Carbine. However, since most combat occurs at ranges of 300 yards or less, this is not a major determining factor in the overall performance analysis.

Conversely, the higher cyclic rate of fire of 850 rounds per minute for the XM8 Carbine, and 800 rounds per minute for the M16A4 Rifle and M4 Carbine, is a major performance factor. This higher cyclic rate of fire ultimately means that the user is able

to fire nearly one round per second more. This represents a 6% increase in capability for the user. Additionally, this has the capability to allow for better suppressive fires against an enemy force.

The lethality variable is the killing power of the weapon itself. The muzzle velocity of the XM8 Carbine is less than the M4 Carbine by roughly 10.5% and less than the M16A4 Rifle by 15%. This is directly attributable to the shorter barrel of the XM8 Carbine. A longer barrel allows more combustion to take place inside the barrel and propel the round to higher velocities. However, since the M4 Carbine and M16A4 Rifle are combat proven for lethality, this small decrease in lethality is not considered significant and the XM8 muzzle velocity is more than sufficient to meet the needs of the user. Additionally, the difference between the XM8 Carbine and the M16A4 Rifle muzzle velocity is roughly 400 feet-per-second. The increased elapsed time for a round fired from the XM8 to travel the 500-meter maximum effective range is a mere 0.14 seconds.

The maintainability variable yields a tie between the planned and current systems in use. The XM8 Carbine contains the same number of major components as the current systems. However, in this case, the same number of major components in both systems does not directly result in the same average operator maintenance time. The design of the XM8 Carbine allows gas to impact directly on the operating rod fixed to the bolt carrier. This piston operates the bolt, which means reduced gases in the breach and ultimately yields a weapon that is less likely to foul from carbon build up due to the presence of the spent gases. The M16A4 Rifle and M4 Carbine allow gas to directly influence the bolt, having the opposite effect of the XM8 operating system. To the soldier, the XM8 translates into a weapon that does not carbon-foul as fast and potentially takes less time to clean than current systems.

The listed average operator assembly/disassembly time for the XM8 Carbine is less than four minutes. Whereas, the time standard for assembly and disassembly of the M16A4 Rifle or the M4 Carbine is 4 minutes, which is the standard for a soldier earning the Expert Infantryman's Badge (EIB). The XM8 possesses a slight advantage in this category.

Table 7. XM8/M4/M16A4 Decision Matrix

XM8/M4/M16A4 Decision Matrix			Non-Weighted Evaluation			Weighted Evaluation			
Variables		Benchmark	XM8 Carbine Score	M4 Carbine Score	M16A4 Rifle Score	Weight	XM8 Carbine Score	M4 Carbine Score	M16A4 Rifle Score
Reliability	MRBF	9,000 Rounds	1	0	0	0.20	0.20	0	0
	Barrel Life Expectancy	16,667 Rounds	1	0	0	0.18	0.18	0	0
Weight	Pounds	8.38 Pounds	1	1	0	0.17	0.17	0.17	0
Suitability	Cyclic Rate of Fire	817 Rounds per Minute	1	0	0	0.11	0.11	0	0
	Maximum Effective Range	517 Meters	0	0	1	0.10	0	0	0.11
Lethality	Muzzle Velocity	2,921 Feet per Second	0	1	1	0.09	0	0.09	0.09
Maintainability	Average Operator Ass./Disass. Time	4 Minutes	1	1	1	0.08	0.08	0.08	0.08
	# of Major Components	11 Parts	1	1	1	0.07	0.07	0.07	0.07
MOST ADVANTAGEOUS = Higher Number			**6**	4	4	1.00	**0.81**	0.41	0.34

2. XM8 Designated Marksman Automatic Rifle vs. M249 Squad Automatic Weapon

The analysis conducted here clearly indicates that the XM8 DMAR is a better performing weapon than the M249 SAW. The XM8 Carbine indicates clear advantage when analyzing the reliability variable expressed as two sub-variables; MRBF and Barrel life expectancy. The XM8 DMAR is issued as a single weapon with one barrel. The M249 SAW is issued as a single weapon with two barrels. Therefore, the data provided for comparison below is actually half that of the number listed for the reliability variable. The higher MRBF is directly attributable to the operating system and the reduced number of major components that the XM8 DMAR employs. This higher MRBF represents a 58% increase in capability.

The increase in barrel life expectancy is due to the XM8 DMAR being equipped with one barrel that has a higher life expectancy than a single M249 SAW barrel. The XM8 DMAR manufacturing process uses hammer-forged steel for the barrel, whereas the

M249 SAW manufacturing process does not. This process strengthens the steel used in the barrel and ultimately yields a longer barrel life expectancy. This barrel life expectancy represents a 33% increase in capability.

Table 8. XM8 DMAR/M249 SAW Side-by-Side Comparison [From Ref. 7,10,11,22,25,30]

[From Ref. 7,10,11,22,25,30]Variables		XM8 DMAR	M249 SAW	Advantage
Reliability	MRBF	15,000 Rounds	>19,000 Rounds w/ 2 Barrels	XM8 DMAR
	Barrel Life Expectancy	20,000 Rounds	30,000 Rounds w/ 2 Barrels	XM8 DMAR
Weight (Combat Load)	Pounds	12 Pounds	21.72 Pounds	XM8 DMAR
Suitability	Maximum Effective Range	800 Meters	800 Meters	Tie
	Cyclic Rate of Fire	850 Rounds per Minute	850 Rounds per Minute	Tie
Lethality	Muzzle Velocity	3,005 Feet per Second	3,001 Feet per Second	M249 SAW
Maintainability	# Of Major Components	12	21	XM8 DMAR
	Average Operator Ass./Disass. Time	< 4 Minutes	9 Minutes	XM8 DMAR
OVERALL MOST ADVANTAGEOUS				XM8 DMAR

The XM8 DMAR provides the user with a decrease in weight of 9.72 pounds (55%), when compared to the M249 SAW. This equates to a soldier carrying a significant lighter load, which is directly proportional to soldier performance on the battlefield. The clear advantage in the weight category is the XM8 DMAR.

The XM8 DMAR and the M249 SAW tie in the suitability category, when using the maximum effective range and cyclic rate of fire variables. However, the XM8 DMAR possesses a 4x optical sight where the M249 SAW with a M145 optical sight is 3.4x. This seems insignificant but the XM8 DMAR possesses a slight quantitative edge. The cyclic rate of fire for each weapon is the same at 850 rounds per minute or 14.2 rounds per second.

The lethality variable is the killing power of the weapon itself. The muzzle velocity of the XM8 DMAR is 4 feet per second more than that of the M249 SAW. This is of little consequence since the elapsed time to travel the maximum effective range is a mere 0.001-second.

The XM8 DMAR is strongly favored over the M249 SAW in the maintainability category, as the XM8 DMAR possesses nine less major components to maintain. Additionally, the design of the XM8 Carbine allows gas to impact directly on the operating rod fixed to the bolt carrier. This piston operates the bolt, which means reduced gases in the breach and ultimately yields a weapon that is less fouled from carbon build up. The M249 SAW allows gas to directly influence the bolt, having the opposite effect of the XM8 operating system. The analysis indicates that the number of major components and the XM8 operating system will lead to a reduction in operator maintenance time.

The reduced number of parts is a main contributor in the 5-minute reduction time for assembly and disassembly of the XM8 DMAR. The M249 SAW's time standard for the EIB is nine minutes. The operator will save a full five minutes, representing a 225% increase in capability to place the weapon back into service when disassembly is required.

Table 9. XM8 DMAR/M249 SAW Decision Matrix

XM8 DMAR/M249 SAW Decision Matrix			Non-Weighted Evaluation		Weighted Evaluation		
Variables		Benchmark	XM8 DMAR Score	M249 SAW Score	Weight	XM8 DMAR Score	M249 SAW Score
Reliability	MRBF	12,250 Rounds	1	0	0.20	0.20	0
	Barrel Life Expectancy	17,500 Rounds	1	0	0.18	0.18	0
Weight	Pounds	16.86 Pounds	1	0	0.17	0.17	0
Suitability	Cyclic Rate of Fire	850 Rounds per Minute	1	1	0.11	0.11	0.11
	Maximum Effective Range	800 Meters	1	1	0.10	0.10	0.10
Lethality	Muzzle Velocity	3,003 Feet per Second	1	1	0.09	0.09	0
Maintainability	Average Operator Ass./Disass. Time	6.5 Minutes	1	0	0.08	0.08	0
	# of Major Components	16.5 Parts	1	0	0.07	0.07	0
MOST ADVANTAGEOUS = Higher Number			**8**	3	1.00	**0.91**	0.21

D. NON-RELEVANT PERFORMANCE VARIABLES

The non-relevant performance variables that are worthy of including in this analysis are the laser aiming lights and optical sights, length of the weapon, arms room security procedures, common repair parts, and accuracy. These variables were not included in the quantitative analysis because of their extreme difficulty to define quantitatively. They will be listed here to illustrate potential strengths or weaknesses.

1. Laser Aiming Light/Optical Sight

The laser aiming light/optical sight combination used on the XM8 Carbine is the same technology as the AN/PEQ-2A and the M68 optical sight. The major difference is that on the XM8 Carbine and XM8 DMAR the sight is combined, whereas on current systems they exist as two separate entities. Performance wise, there is no difference with the exception of battery life. The combined sight for the XM8 is claimed to have a

battery operating life of 400 hours versus an AN/PEQ-2A battery life of 100 hours, and an M68 battery life between 75-500 hours.

The XM8 DMAR combined sight differs from the XM8 Carbine sight in that the optical is 4x powered. The current system in use is the M145 that possesses a 3.4x power. In essence, the combined optical sight of the XM8 DMAR is more powerful. However, this is of little consequence considering that a man size target 1,000 meters away now appears as if it is roughly 300 meters away, it is still a very small target. Additionally, unless the operator is using tracer ammunition, which has a burnout distance of roughly 900 meters, or is in an environment that he can walk the rounds on target, by kicking up dust from round impact, the probability of the user hitting the target is very low. A slight qualitative edge is apparent due to the combination sight on the XM8 DMAR.

2. Overall Length

Length is selected as a non-relevant performance variable because it really comes down to individual preference. However, after action reports from combat operations during OIF resulted in a consensus that "every rifleman wanted an M4 Carbine versus a M16A4 Rifle [Ref. 4]." The implied interpretation indicates a shorter weapon is better. Thus, overall length differential became a non-relevant variable. The XM8 Carbine, with the butt stock collapsed, is only ¼ of an inch longer than the M4 Carbine. With the butt stock extended, these two weapons have the same exact length. The M16A4 Rifle, which does not have a collapsible butt stock, is six inches longer when the XM8 butt stock is extended and nine inches longer when the butt stock is collapsed.

The overall length of M249 and XM8 DMAR is, again, non-relevant because the difference is ¼ of an inch. The length of the M249 SAW is 40.75 inches, where the length of the XM8 DMAR is 40.5 inches.

3. Arms Room Security Procedures

The current sighting systems in use, laser aiming lights and optical sights, are not compatible with current arms room racks. For proper security measures, these capability add-ons are removed from the weapon any time it is returned to the arms room. When a

soldier retrieves this equipment from the arms room, he is required to re-zero both the laser aiming light and the optical sight. On average, it takes a 100 man infantry company an entire day and well into the night to accomplish this on a 25-meter live fire range.

This is a disadvantage of the current systems because the additional range operation required to re-zero is resource intensive and supercedes other valuable training tasks. The XM8 combination sight is an integral part of the weapon and will be stored in the arms room with it attached. The advantage is not losing system zero during storage and the day the infantry company used to spend zeroing this equipment is now available for other training. This represents a significant advantage in regaining the amount of training time and resources lost in one year just to accomplish zero of laser aiming lights and optical sights.

4. Common Repair Parts

The XM8 family of weapons provides an additional advantage over the current fielded systems in the repair parts category. This is because the XM8 variants share a high commonality of components. The difference between the XM8 Carbine and DMAR variants is four components; the barrel, hand guards, the combination sight, and on the XM8 DMAR version, the addition of bipod legs. The difference between the M4 Carbine and M16A4 Rifle is three components; the barrel, hand guards, and a collapsible butt stock on the M4 Carbine. However, when comparing the M4 Carbine or M16A4 Rifle to the M249 SAW, the difference in components is significant. There is not a single major component of the M249 SAW that is compatible with the M4 Carbine or the M16A4 Rifle. This is a major weakness of the current systems when analyzing common repair parts.

Since the XM8 family uses one common operating group, the repair parts inventory decreases at virtually all levels of supply. Considering the number of major components of the XM8 Carbine, and adding the major component differences of the XM8 DMAR, the total number of major components required is 15. Comparing this to the M4 Carbine's nine major components, plus the component differences of the M16A4 Rifle, the total number of major components is 12. However, since the M249's 19 major

components are not compatible with the M4 Carbine or the M16A4 Rifle, this increases the total number of major component repair parts for current systems to 31.

5. Accuracy

Accuracy is a non-relevant variable because of two major factors. The first is that the XM8 weapons have been limited to prototype testing and evaluation. Therefore, only limited test data is available for a true quantitative comparison. However, since both barrels are a right hand twist of one in seven turns and the muzzle velocity is extremely close, performance will most likely be very similar.

V. COST ANALYSIS

This chapter consists of two quantitative analyses; the first compares individual weapon costs of the XM8 Carbine to the M16A4 Rifle and M4 Carbine, second analysis compares individual weapon costs of the XM8 Designated Marksman Automatic Rifle to the M249 Squad Automatic Weapon. Additionally, it includes fielding costs for a Unit of Action (UA) from the 101st Infantry Division Air Assault per it's prescribed Modified Table of Organization and Equipment (MTOE) for current systems, planned systems, and current systems with the same performance capabilities as the planned systems.

A. METHODOLOGY

Two separate quantitative analyses will be conducted, both independent of each other. This analysis does not include sunk costs or the expected operating costs as the system ages. The first analysis will focus on the purchase cost of each individual weapon. The M16A4 Rifle and/or M4 Carbine equipped with an AN/PEQ-2A laser aiming light and M68 optical sight will be compared against the planned replacement system, the XM8 Carbine. The second analysis will be the M249 SAW equipped with a collapsible butt stock, an AN/PEQ-2A laser aiming light and an M68 optical sight against the planned replacement system the XM8 DMAR.

The second quantitative analysis will be the fielding cost of the current and planned systems to a Unit of Action. This analysis will use the MTOE as the basis of issue and compare fielding costs for current systems, planned systems, and current systems with the same performance capabilities as the planned systems.

B. INDIVIDUAL WEAPON SYSTEM PROCUREMENT COST

1. XM8 Carbine vs. M16A4 Rifle & M4 Carbine

The price to field a fully operational XM8 Carbine that satisfies all of the training, administrative, and combat functions is $95.07 less per weapon than an M16A4 Rifle or M4 Carbine with the same capability. This is due to three relevant sub prices of the overall price; the rifle, the laser aiming light and optical sight combination, and the arms room storage rack. The non-relevant costs are the; blank firing adapter, cleaning kit, and

six additional magazines. These costs are non-relevant because these items are compatible with either weapon. However, they do add to the total fielding costs by an increase of $87.85 per fielded weapon.

Table 10. XM8 Carbine vs. M16A4 Rifle & M4 Carbine Relevant Cost Comparison [From Ref. 8,30]

Relevant Costs	XM8 Carbine	M16A4 Rifle / M4 Carbine
Rifle	$600	$587
Laser Aiming Light	$1200 (One Sight Dual Capability)	$1000
Optical Sight		$330
Weapon Rack Slot	$43.83	$21.90
TOTAL	$1843.83	$1938.90

The first relevant price is the rifle itself. The M16A4 Rifle and M4 Carbine are less expensive than the XM8 Carbine by $13 (2%) per weapon. A more cost effective rifle in five key areas offsets this $13 increase in cost; Higher mean rounds between failure, a longer barrel life expectancy, reduced weight, faster fires than current systems, and is easier to maintain than current systems.

Reliability wise, the XM8 Carbine is a better performing system. The XM8 Carbine has an increase in barrel life expectancy of 5,000 rounds per weapon when compared to the M16A4 Rifle and M4 Carbine. The M16A4 Rifle and M4 Carbine have an operating cost of $0.04 per round fired, ($587 ÷ 15,000 rounds). The XM8 Carbine operating cost is $0.03 per round fired, ($600 ÷ 20,000 rounds). This represents a total operating cost savings of $0.01 per round fired for the XM8 Carbine or consumer gain of $50 per weapon ($0.01 x 5,000 rounds). Additionally, this increase in rifle cost is offset by higher mean rounds between failure that is 2.5 times greater than the current system(s).

The second key area or capability that the cost offset addresses is a decrease in weight of 1.21 pounds (14%) when comparing the M4 Carbine to the XM8 Carbine, and a 2.5-pound decrease (26%) for the M16A4 Rifle. The XM8 Carbine is a 14% and 26%

decrease in weight, respectively for a 2% increase in price. Considering the long-term effect weight has on the individual soldier over sustained combat, this is a capability well worth the additional cost.

Additional capability provided by the XM8 includes an increased cyclic rate of fire of 50 rounds per minute and a system that is easier to maintain, when comparing the XM8 to the M16A4 Rifle or M4 Carbine. As discussed earlier, the configuration of the XM8 Carbine causes less residual carbon to be built up after firing. This, along with the number of components and the assembly/disassembly time, provides the user with a rifle that is easier to maintain.

The second and most relevant cost is the $130 savings of the combined laser aiming light/optical sight combination that exists on the XM8 Carbine. Currently, every soldier in the field is not provided a laser aiming light or optical sight. The XM8 system provides every soldier the capability to hit targets at night using the laser aiming light. Additional capability gained with optical sights includes an increase in accuracy of direct fires and situational awareness. The combined sight that the XM8 uses offers no increase or decrease in performance capability when comparing the M68 and the AN/PEQ-2A to the combined sight. However, there is an increase in time and resources available because the individual user does not have to zero it for operational or training use, only to remove before proper arms room storage. The time and resources saved allows leaders to train other tasks and the resources saved include ammunition and live fire range time. This savings is not easily calculated, but is extremely significant.

The final relevant cost is the weapons rack for arms room storage. Since the XM8 Carbine is still in the developmental process, a specific weapons rack is yet to be developed. A current rack, the universal arms room rack, is suitable for storing the weapons. This rack complies with existing security measures. This rack is consists of a metal wall locker with shelves for storing weapons. It is capable of holding up to 24 M16/M4 style rifles or XM8 Carbines, at a per unit price of $1052, or $43.83 for a single XM8 Carbine weapon rack slot [Ref. 9]. The M16A4/M4 rack is capable of holding only 10 weapons at a cost of $219, or $21.90 for a single M16A4/M4 weapon rack slot [Ref. 8]. This is a difference of $21.93 per weapon rack slot.

2. XM8 Designated Marksman Automatic Rifle (DMAR) vs. M249 Squad Automatic Weapon (SAW)

The price to field a fully operational XM8 DMAR that satisfies all of the training, administrative, and combat functions is $3,041.84 less per weapon than an M249 SAW with the same capability. This is due to the same three relevant sub prices from the XM8 Carbine; the rifle, the laser aiming light and optical sight combination, arms room storage rack, and a collapsible butt stock. The non-relevant costs are the; blank firing adapter, cleaning kit, and two additional 100 round assault pouches. No information is available for the cost of a 100 round magazine used with the XM8 DMAR variant. The cost of the 100 round assault pouch used with the M249 SAW is considered representative and is substituted for this item. These costs are non-relevant because these items are compatible with either weapon. However, they do add to the total fielding costs by adding to the cost in the amount of $81.56 per fielded weapon.

Table 11. XM8 DMAR vs. M249 SAW Relevant Cost Comparison [From Ref. 8,13,21,30]

Relevant Costs	XM8 DMAR	M249 SAW
Rifle	$600	$2653
Collapsible Butt Stock	N/A	$495
Laser Aiming Light	$1200 (One Sight Dual Capability)	$1000
Optical Sight		$672
Weapon Rack Slot	$43.83	$65.67
TOTAL	$1843.83	$4885.67

The first relevant price is the rifle portion itself. The XM8 DMAR is cheaper than the M249 SAW by $2,053 per weapon. Additionally, this $2,053 decrease in cost is enhanced by procuring a weapon that is more reliable, with reduced weight, is easier to maintain, and is equal in suitability to the current system.

Reliability wise, the XM8 DMAR is a better performing system. The XM8 DMAR has an increase in barrel life expectancy of 6,000 rounds per weapon when compared to the M249 SAW. The M249 SAW has a relatively high operating cost of $0.18 per round fired, ($2,653 ÷ 15,000 rounds). The XM8 DMAR operating cost is $0.03 per round fired, ($600 ÷ 20,000 rounds). This represents a total operating cost savings of $0.15 per round fired for the XM8 DMAR, an advantage of $900 per weapon

($0.03 x 6,000 rounds). Additionally, this decrease in rifle cost buys a higher mean rounds between failure that is 1.6 times greater than the current system(s).

The second key area is a 55% decrease in weight from an M249 SAW combat ready weight (optical sight and laser aiming light only) of 18.72 to 9 pounds for the XM8 DMAR. The final cost savings area of the rifle is a decrease in the number of major parts from 19 for the M249 SAW to 12 for the XM8 DMAR. As discussed earlier, the configuration of the XM8 Carbine causes less residual carbon to be built up after firing. This, along with the number of components and the assembly/disassembly time, provides the user with a rifle that is easier to maintain. Again, this equates to a reduced operator maintenance time.

There is no increase or decrease in suitability when using maximum effective range or cyclic rate of fire, and only 4 feet per second advantage gained in muzzle velocity when comparing the XM8 DMAR to the M249 SAW.

The second relevant cost savings of the XM8 Squad Automatic is that it is equipped with a collapsible butt stock. The M249 SAW, when issued, does not have this capability. Rather, it is an added capability that costs $495 per weapon.

The third relevant cost is the $472 savings of the combined laser aiming light/optical sight combination that exists on the XM8 DMAR. Currently, every soldier in the field is not provided a laser aiming light or optical sight. The XM8 system provides every soldier the capability to hit targets at night using the laser aiming light. Additional capability gained with optical sights includes an increase in accuracy of direct fires and situational awareness. The combined sight that the XM8 uses offers no increase or decrease in performance capability when comparing the M68 and the AN/PEQ-2A to the combined sight. However, there is an increase in time and resources available because the individual user does not have to zero it for operational or training use, only to remove before proper arms room storage. The time saved allows leaders to train other tasks and the resources saved include ammunition and live fire range time.

The final relevant cost is the weapons rack for arms room storage. Since the XM8 DMAR is still in the developmental process, the same universal weapons rack used for

the Carbine version would be appropriate for use with the XM8 Squad Automatic Weapon. This rack is capable of holding up to 24 XM8 DMAR, at a per unit price of $1052, or $43.83 for a single XM8 DMAR weapon rack slot. The current M249 SAW rack is capable of holding nine weapons at a cost of $591, or $65.67 for a single M249 SAW rack slot. This is a difference in favor of the XM8 DMAR of $21.84.

C. FIELDING COSTS

Soon after Operation Iraqi Freedom, the Chief of Staff of the Army (CSA) General Peter Schoomacher, directed that returning Brigade Combat Teams (BCT's) form themselves into more deployable and self-sustaining Units of Actions (UA's). Additionally, he sought to increase the number of BCT's/UA's from 33 to 45. These UA's are to be more lethal because of technology superiority. Below is a comparison of the fielding costs of a UA of the 101st Infantry Division Air Assault per their prescribed Modified Table of Organization and Equipment (MTOE) with current systems, planned systems, and current systems with the same capability as planned systems.

1. Current Systems

A UA of the 101st Infantry Division Air Assault is comprised of six battalions and one Headquarters Company [Ref. 9]. The MTOE prescribes the following current fielded weapons and equipment [Ref. 9]. This represents a total price of $4,177,801.77.

Table 12. UA Current System Fielding Costs
[From Ref. 8,9,13,30]

Weapon/Equipment	Total Numbers (MTOE)	Cost	Total Cost	Weapon Rack Costs
M16A4 Rifle	1551	$ 674.85	$1,046,692.35	$34,164
M4 Carbine	1246	$ 674.85	$840,863.10	$27,375
M249 SAW	212	$ 2734.56	$579,726.72	$14,184
M249 SAW Light	85	$ 3681.56	$312,932.60	$5,910
AN/PAQ-4C	855	$ 518	$442,890	N/A
AN/PEQ-2A	544	$ 1000	$544,000	N/A
M68	932	$ 330	$307,560	N/A
M145	32	$ 672	$21,504	N/A
Sub Total Costs			$4,096,168.77	$81,633
TOTAL COST				$4,177,801.77

2. Planned Systems

The current proposed replacement plan calls for a one-for-one swap of the XM8 Carbine replacing the M16A4 Rifle and the M4 Carbine, as well as the XM8 DMAR replacing the M249 SAW and M249 SAW Light. To conduct this replacement, the total price for a UA is $5,975,899.77.

Table 13. UA Planned System Fielding Costs
[From Ref. 9,30]

Weapon/Equipment	Total Numbers (MTOE)	Cost	Total Cost	Weapon Rack Costs
XM8 Sharp Shooter	2797	$1,887.85	$5,280,316.45	$123,084
XM8 Squad Automatic	297	$1,881.56	$558,823.32	$13,676
Sub Total Costs			$5,839,139.77	$136,760
TOTAL COST				$5,975,899.77

To replace the current fielded weapon systems with the XM8 system for an Air Assault UA the increase in procurement cost is $1,798,098. However, this does not consider the capability increase that the UA receives, the reduced maintenance time, reduced supply support required, and significantly reduced range support resources achieved from eliminating the requirement to re-zero.

3. Current Systems with Planned Capability

The current Air Assault UA MTOE does not have each weapon system with a laser aiming light or an optic device. Additionally, only 85 of the required 297 M249 SAW's have the collapsible butt stock and shorter barrel. Therefore, a fair analysis must include matching each current fielded weapon system with the same capability as the planned weapon systems plus the universal arms room rack capability.

As mentioned earlier the M16A4 Rifle and M4 Carbines replacement is the XM8 Carbine. This version of the XM8 has an optical sight and a laser aiming light with illuminator. To match capability of the XM8 Carbine the M16A4 Rifle and the M4 Carbine must have the M68 and the AN/PEQ-2A.

The M249 SAW replacement is the XM8 DMAR. This version of the XM8 possesses a 4x powered optical sight, a laser aiming light with illuminator, and a collapsible butt stock. To match capability all the UA's M249's would have to have a M145, AN/PEQ-2A, and only the collapsible butt stock associated with it. Additionally,

for arms room storage to keep the laser aiming lights and optical sights on the weapons, the universal arms room rack would replace the current arms room racks. For a current UA of the 101st to have the same capability as the XM8 system, the cost would be $7,212,712.77. This would be a cost increase of $1,236,813.00 per Air Assault UA.

Table 14. UA Current System Fielding Costs with Same Capability as Planned [From Ref. 8,9,13,30]

Weapon/Equipment	Total Numbers (MTOE)	Cost	Total Cost	Weapon Rack Costs
M16A4 Rifle	1551	$674.85	$1,046,692.35	$68,380
AN/PEQ-2A	1551	$1000	$1,551,000	
M68	1551	$330	$511,830	
M4 Carbine	1246	$674.85	$840,863.10	$54,704
AN/PEQ-2A	1246	$1000	$1,246,000	
M68	1246	$330	$411,180	
M249 SAW w/ Collapsible Butt Stock	297	$3229.56	$959,179.32	$26,300
AN/PEQ-2A	297	$1000	$297,000	
M145	297	$672	$199,584	
Sub Total Costs			$7,593,770.77	$81,633
TOTAL COSTS				$7,212,712.77

In summary, to field an entire UA with the XM8 is effectively less expensive than upgrading existing equipment to the same capability performance level as the XM8 family. The increase in capability and modernization of the weapons will potentially save the Army $76.5 million fielding the planned 45 UA's with the XM8 system over current systems.

VI. CONCLUSIONS AND RECOMMENDATIONS

This chapter examines the primary and subsidiary research questions. Conclusions and recommendations are presented as well as recommendations for further future actions.

A. PRIMARY RESEARCH QUESTION

Which weapon system provides the best value to the Department of Defense in terms of performance capabilities and cost?

Overall, the XM8 provides an increased capability to the user and costs less per fielded weapon. Based on the quantitative analysis it is our conclusion that the XM8 family of weapons provides the best value for the Department of Defense, in both performance and cost. However, this primary research question is more completely answered by the responses to the two subsidiary questions. The conclusions to these research questions and accompanying recommendations are presented below.

B. FIRST SUBSIDIARY QUESTION

Which weapon is more advantageous with regard to suitability and effectiveness?

1. Conclusion

The XM8 Carbine is clearly the better performing weapon and provides the user with increased capability in reliability, weight, suitability, and maintainability. The ability of all XM8 variants to save significant training days, personnel, funding and other resources currently expended re-zeroing weapons cannot be overstated. The XM8 Carbine's advantages, when compared solely to the M16A4 Rifle, are a higher mean rounds between failure, a longer barrel life expectancy, is 26% lighter, fires faster, and is less time consuming to clean. The advantage that the M16A4 Rifle possesses over the XM8 is an increased maximum effective range and muzzle velocity. When comparing the XM8 Carbine solely to the M4 Carbine, the only advantage the M4 Carbine possesses is muzzle velocity. The M4 Carbine ties the XM8 Carbine only in maintainability. In all three-performance comparisons, the XM8 DMAR emerged as the better performing weapon through its increased capability.

The XM8 DMAR is clearly the better performing weapon when compared to the M249 SAW and provides the user with increased capability in reliability, weight, lethality, and maintainability. The XM8 DMAR offers no performance disadvantages, when compared to the M249 SAW. Suitability, maximum effective range and cyclic rate of fire are the only performance characteristic in which the M249 SAW can match the XM8 DMAR. In all three-performance comparisons, the XM8 DMAR emerged as the better performing weapon through its increased capability.

2. Recommendations

After completion of operational test and evaluation, it is recommended that the Department of Defense adopt the XM8 family of weapons to replace the M16A4 Rifle, the M4 Carbine, and the M249 Squad Automatic Weapon.

C. SECOND SUBSIDIARY QUESTION

Which weapon system provides the more cost effective solution?

1. Conclusion

The individual weapon system procurement cost of the XM8 Carbine is $95.07 less per weapon than an M16A4 Rifle or M4 Carbine, and the XM8 DMAR is $3,041.84 less per weapon than an M249 SAW. Additionally, the XM8 combination sight is an integral part of the weapon and will be stored in the arms room with it attached. The system does not lose zero during storage and the day the infantry company used to spend zeroing this equipment is now available for other training. This represents a significant advantage in regaining the amount of training time and resources lost in one year just to accomplish zero of laser aiming lights and optical sights.

There is additional savings to the Department of Defense when comparing the fielding costs of the XM8 weapon system to that of current systems. To field an entire Unit of Action with XM8 family capability is $1,236,813.00 less than upgrading existing equipment. This increase in capability and modernization of the weapons will potentially save the Army $76.5 million fielding the planned 45 UA's with the XM8 system over current systems.

2. Recommendations

The Department of Defense should adopt the more cost effective XM8 family of weapons to replace the M16A4 Rifle, the M4 Carbine, and the M249 Squad Automatic Weapon.

D. FUTURE STUDY RECOMMENDATIONS

1. Conduct a complete Doctrine, Organization, Training & Education, Material, Leadership, Personnel, and Facility (DOTMLPF) analysis of replacing the M16A4 Rifle, the M4 Carbine, and the M249 Squad Automatic Weapon with the XM8 weapons system.

2. Conduct a cost analysis to determine how much class IX repair part money is saved by converting to the "common" XM8 weapons system.

3. Conduct an after fielding performance analysis to determine if the XM8 weapons system performed to its expected reliability data.

4. Conduct an analysis to determine how much is gained with respect to time and resources from the addition of a laser aiming light/optical sight that stays on the weapon permanently.

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LIST OF REFERENCES

1. Global Security Organization. "M16 5.56mm Semiautomatic Rifle & M4 5.56 mm Carbine." [http://www.globalsecurity.org/military/systems/ground/m16.htm]. 29 February 2004.

2. Ezell, Clinton, *The Great Rifle Controversy*, pp. 135. Stackpole Books, 1984

3. U.S., Department of the Army, *M16A4 and M4 Army Technical Manual 9-1005-319-10,* pp. 00-02. U.S. Government Printing Office, Washington D.C., October 1998.

4. Smith, Jim, "Operation Iraqi Freedom: PEO Soldier Lessons Learned (Special Report)," *Infantry Bugler*, Winter 2003/2004, pp. 6, August 2004.

5. Colt Manufacturing. "M4 5.56 mm Carbine." [http://www.colt.com/mil/M4.asp]. 13 August 2004.

6. Colt Manufacturing. "M16 5.56 mm Rifle." [http://www.colt.com/mil/M16.asp]. 13 August 2004.

7. Ross, John G, "1 Killer Weapon: 8 Things You'll Love About the XM8," *Army Times*, 1 March 2004, 26 July 2004.

8. Saslav, Andy, C/2-9 IN Commander, Camp Casey, Republic of Korea. Email message. Subject: Re: Cost Data, on 4 March 2004.

9. Daniel, Shawn, 3rd BDE S4 101st Airborne Division, Fort Campbell Kentucky. Email message. Subject: Re: MTOE & Cost Data, 31 August 2004.

10. U.S., Department of the Army, *M249 Army Technical Manual 9-1005-201-10 w. Change 2*, pp. 1-7. U.S. Government Printing Office, Washington D.C., July 1991.

11. FNH Manufacturing USA, Inc. "M249 Squad Automatic Weapon." [http://www.fnhusa.com/contents/mg_m249para.htm]. 12 August 2004.

12. Telephone conversation between Rusty Spitzer, M249 SAW Technician, FN Manufacturing and MAJ Doug Lowrey, 31 August 2004.

13. Telephone conversation between Tina Lineberry, M249 SAW Contracting Specialist, FN Manufacturing and MAJ Doug Lowrey, 31 August 2004.

14. U.S., Department of the Army, *AN/PAQ-4C Army Technical Manual 11-5855-301-12&P*, pp. 1-5. U.S. Government Printing Office, Washington D.C., December 1997.

15. U.S., Department of the Army, *AN/PEQ-2A Army Technical Manual 11-5855-308-12&P*, pp. 1-7. U.S. Government Printing Office, Washington D.C., May 2000.

16. Telephone conversation between Mike Gilroy, AN/PAQ-4C and AN/PEQ-2A Equipment Technician, Insight Technology and MAJ Doug Lowrey, 31 August 2004.

17. U.S., Department of the Army, *M68 Reflex Sight Army Technical Manual 9-1240-413-12&P*, pp. 1-4. U.S. Government Printing Office, Washington D.C., October 1997.

18. PM Small Arms. "M68 Reflex, Sight with Mount." [http://www.pica.army.mil/CCACLight/ccl-a/products/m68_sight.htm]. 12 August 2004.

19. U.S., Department of the Army, *M145 Machine Gun Optic Sight Army Technical Manual 9-1240-415-13&P*, pp. 1-5. U.S. Government Printing Office, Washington D.C., February 2000.

20. Armament Technology. "3.4 x Optical Sight Specifications." [http://www.armament.com/elcan/elc34spec.htm]. 12 August 2004.

21. Telephone Conversation between D. Kelly III, M145 Equipment Technician, Rock Island Arsenal Small Arms Team and Major Doug Lowrey, 19 August 2004.

22. Heckler & Koch Defense." XM8 Lightweight Modular Weapon System." [www.hkdefense.us/corporate/media/pdf/XM8_sheet111703.pdf]. 12 July 2004.

23. Kennedy, Harold. "Army Tests New Rifle That Could Replace M16, M4." [http://www.nationaldefensemagazine.org/article.cfm?Id=1343]. 12 July 2004.

24. Cox, Matthew. "XM8 Prototypes Surpass M16, Experts Say." *Army Times*. 11 October 2003. [www.armytimes.com]. 12 July 2004.

25. Cox, Matthew. "XM8 Update: Your Fix Is In." *Army Times*. 30 August 2004. [www.armytimes.com]. 3 September 2004.

26. Telephone Conversation between LTC Michael Clark, PM Small Arms, and MAJ Doug Lowrey, 28 September 2004.

27. World Guns Website. “Armalite AR-18 Assault Rifle (USA).” [http://world.guns.ru/assault/as36-e.htm]. 12 July 2004.

28. Military.Com. “Wave of the Future: The XM-8 Battle Rifle.” [www.military.com/NewContent/0,13190,Gear_051104_XM8,00.html?ESRC=airforce-a.nl]. 12 July 2004.

29. Heckler & Koch Defense. “The XM8 System.” [www.hkdefense.us/pages/military-le/rifles-carbines/xm8.html]. 12 July 2004.

30. Ahmad, Dave. PM XM8, Picatinny Army Depot, NJ. Email message. Subject: Re: RFI on XM8, 19 August 2004.

31. World Guns Website. “G36 Rifle (FRG).” [http://world.guns.ru/assault/as14-e.htm]. 20 July 2004.

32. Principles of Firearms. “Gas.” [http://www.rkba.org/guns/principles/operating-systems/gas.html]. 20 July 2004.

33. McNaugher, Thomas, *The M16 Controversies*, pp. 152-153, Praeger Publishers, 1984.

34. Paul, Greg MAJ,APM Sensors and Lasers, Ft Belvoir, VA. Email Message. Subject: Request for info on XM8 optics, 20 September 2004.

35. Moore, Kevin, Equipment Specialist, Rifle-Carbine Team, TACOM Rock Island, Il. Email message. Subject: Re: Request for information on XM8, 7 September 2004.

36. Lund, Henric. “Heckler & Koch XM-8.” [www.bellum.nu/armoury/wm/HKXM8.html]. 12 July 2004.

37. Olson, Byron. PM XM8, Picatinny Army Depot, NJ. Email message. Subject: Re: RFI on XM8, 26 August 2004.

38. U.S., Department of the Army, *Pamphlet 73-1: Test and Evaluation in Support of Systems Acquisition*, pp. 32. Government Printing Office, Washington D.C., 30 May 2003.

39. Defense Systems Management College, *Integrated Logistics Support Guide*, pp. A-8. Washington, DC: U.S. Government Printing Office, Washington D.C., May 1986.

40. Guns and Crime Organization. “Lethality (“Deadliness’). [http://www.gunsandcrime.org/lethalty.html]. 30 September 2004.

41. Defense Systems Management College, *Integrated Logistics Support Guide*, pp. A-5. Washington, DC: U.S. Government Printing Office, Washington D.C., May 1986.

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