3-2005

Determining PACAF Transportation Alternatives to the General Purpose Vehicle

Andrew H. Pate

DETERMINING PACAF TRANSPORTATION ALTERNATIVES TO THE GENERAL PURPOSE VEHICLE

THESIS

Andrew H. Pate, Captain, USAF

AFIT/GLM/ENS/05-20

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the U.S. Government.

AFIT/GLM/ENS/05-20

DETERMINING PACAF TRANSPORTATION ALTERNATIVES
TO THE GENERAL PURPOSE VEHICLE

THESIS

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

Andrew H. Pate, M. H. R.

Captain, USAF

March 2005

APPROVED FOR PUBLIC RELEASE; DITRIBUTION UNLIMITED.

AFIT/GLM/ENS/05-20

DETERMINING PACAF TRANSPORTATION ALTERNATIVES
TO THE GENERAL PURPOSE VEHICLE

Andrew H. Pate, M. H. R.
Captain, USAF

Approved:

______________________________________ ________
Marvin A. Arostegui, Lt Col, (USAF) (Chairman) date

______________________________________ ________
William A. Cunningham III, Ph.D., (Member) date

Acknowledgments

I would like to express my appreciation to my faculty advisor, Lt Col Marvin Arostegui, and reader, Dr. William Cunningham, for their guidance, encouragement and support throughout this thesis effort. Additionally, I would like to thank the PACAF LRS Squadron Commanders for their valuable insight and assistance in completing my research.

To my wife and daughter, I cannot thank you enough for the encouragement, patience, understanding and sacrifice you demonstrated during my AFIT tenure. I truly could not have done it without your help.

Andrew H. Pate

Table of Contents

List of Figures

Page

AFIT/GLM/ENS/05-20

Abstract

Vehicle fleets under gird the mission of Air Force bases. Under funding for vehicle replacement requirements raised concerns and has led to purchasing alternative vehicles classified as equipment items to supplement budget shortfalls. In order to effectively use funds and meet mission requirements, Pacific Air Force (PACAF) commanders need an adjustable multifactor decision tool that will allow them to make an informed purchasing decision from among appropriately classified equipment item vehicles.

This research will discuss existing regulatory restrictions to alternative transportation purchases, consider available alternative vehicles, and determine the attributes important to vehicle purchases. A review of current Air Force Instruction on vehicles and purchases, as well as researching commercially available alternative vehicles, and conducting an investigative questionnaire resulted in the development of a multifactor weighted decision making model.

Through application of the Analytic Hierarchy Process based on responses to the investigative questionnaire, an optimum alternative vehicle for PACAF was discovered. This research concludes with the development and application of a multifactor weighted decision making tool appropriate for assisting with alternative vehicle choices. Further, the research concludes that either the John Deere Gator or Kawasaki Mule are the optimum alternative vehicle choices for PACAF units.

DETERMINING PACAF TRANSPORTATION ALTERNATIVES
TO THE GENERAL PURPOSE VEHICLE

I. Introduction

Background

The Air Force, like the other military branches of service, is financially bound by annual appropriations that are determined by the President and Congress through the Fiscal Year Defense Budget. The budget lays out how much money will be allocated to programs across the branches of service and gives the Air Force its spending limits for the next fiscal year. It is at this point that the funding is divided among the many competing needs. In 2003, the Air Force was funded at 33% of the total requirement for vehicle replacement (HQ USAF, 2004). In 2004, the funding increased to 41% of the total requirement needed for vehicle replacement (HQ USAF, 2004). To make up the deficit in procurement funding, the Air Force, as well as many other government agencies, has often turned to leasing vehicles to help replenish and modernize vehicle fleets. This is possible because the money required for vehicle lease is coded differently for budget purposes than that of traditional procurement funding. As a result, a typical vehicle fleet assigned to a base organization will be comprised of both government owned and government leased assets.

After successive years of under funding the total vehicle replacement requirement, many units have been left with a shortfall in assigned transportation assets.

This shortfall could ultimately result in a negative impact to the unit's mission. In an effort to counter any potential mission degradation caused by having too few transportation assets, many units began looking for and purchasing alternative transportation options. The alternative vehicles purchased are typically classified as equipment items and; as such, have been funded through operations and maintenance funds which are at the discretion of the unit commander. With no definitive guidelines regarding either the requirements needed for purchase or the specific classification of alternative vehicles, some units procured assets that are now considered in excess of current Air Force guidance regarding alternative vehicle purchases.

Vehicle managers need an understanding of what type of vehicles are authorized to be classified as equipment items and are available for purchase with operations and maintenance funds. In addition, once vehicle types are identified, managers need a tool that will facilitate the purchase decision by taking multiple factors of varying significance into consideration. This tool will allow them to make a more informed decision about which type of vehicle will best serve the unit given its specific mission requirements.

Problem Statement

Pacific Air Force (PACAF) commanders need an adjustable multifactor decision tool that will allow them to make an informed purchasing decision from among appropriately classified equipment item vehicles. This research will develop a decision making model and make a recommendation as to the best type of alternative vehicle for PACAF units based on a summation of values from PACAF Logistics Readiness Squadron Commanders.

Investigative Questions

What regulatory restrictions exist concerning alternative transportation purchases?

What are the transportation alternatives to the general purpose vehicle?

What attributes are important when considering a vehicle purchase?

The three investigative questions are answered through: 1) a review of current Air Force Instructions and policy letters; 2) a review of the commercial marketplace; and 3) a review of significant vehicle attributes impacting commercial fleet purchases.

Research Objectives

The objective of this research is to develop a multiple criteria decision making tool that will select the most appropriate transportation alternative to the general purpose vehicle given a unit's specific needs. The first step is to identify the regulatory restrictions to purchasing new vehicles. This information will be used to limit the vehicle alternatives considered as well as to form an understanding of the process required for legal vehicle purchase in the military context. Next, based on the restrictions discovered, identification of commercially available alternatives to the general purpose vehicle will be accomplished. These vehicles will be used as possible alternatives and their specific value to the military unit evaluated based on squadron commander's input using the multiple criteria decision making model. Finally, the multiple criteria decision making model will be developed, to include the categories in which the alternatives will be judged against.

Research Methodology

This study will be completed in two phases. In the first phase, a qualitative analysis of the existing regulatory restrictions for purchasing transportation alternatives to the general purpose vehicle will be conducted, as well as an examination of available transportation alternatives. In the second phase, this framework will be applied to a multifactor weighted decision making model.

Scope of Research

This research focuses on determining the most appropriate transportation alternative to the general purpose vehicle for PACAF units. Due to the particular focus on the mission and geographic location of PACAF units, the results may not be applicable to other Air Force units with varying objectives and locations. In addition, the results may not be applicable to other services with differing objectives for use and operating locations.

Further, while it is recognized that there are an almost endless number of alternatives possible to the general purpose vehicle, this research will focus on those possibilities that meet the sponsoring organization's requirements as it pertains to cost, functionality of use, capability, and accessibility for procurement. The purpose of this further limitation is to receive maximum benefit from the results by the sponsoring agency.

Relevance

This topic is relevant by virtue of the number of alternative transportation purchases being made. Having a decision tool available to objectively assist in the vehicle purchase decision will result in selecting vehicles that are better equipped and suited for each individual unit's mission.

Outline of Thesis

This thesis is divided into the following five chapters: Introduction, Literature Review, Methodology, Findings and Analysis, and Conclusions. A brief description of each follows.

Chapter 1: Introduction - This chapter discusses the background, focus of research, research objectives, and relevance of this thesis document.

Chapter 2: Literature Review – The literature review chapter begins by discussing the background of the golf cart and Low Speed Vehicle and their initial entrance to use on public roads. Next, current governing regulations for both the Low Speed Vehicle and the golf cart are reviewed. Finally, a discussion on fleet purchasing decisions is presented.

Chapter 3: Methodology – The methodology chapter begins with a discussion regarding the need for Multiple Criteria Decision Making models followed by a review and brief explanation of the more widely used models. Next, the Analytical Hierarchy Process is explained and demonstrated in detail. Lastly, a review of the data collection process is presented.

Chapter 4: Findings and Analysis – This chapter presents the results of the investigative questions as well as a summary of the Multiple Criteria Decision Making model questionnaire.

Chapter 5: *Conclusions and Recommendations* – An application of the questionnaire results is made to alternatives to the general purpose vehicle. Recommendations for further research are provided.

Key Terms (Department of Transportation, 1998)

The following key terms are defined to assist the reader in this analysis:

Sub-25 mph vehicle: any 4-wheeled vehicle whose top speed is not greater than 25 miles per hour. This classification includes all of the vehicles in the groups below, except those speed-modified golf cars whose top speed is greater than 25 miles per hour.

Conventional golf car (also known as golf cart): either a fleet golf car or a personal golf car.

Fleet golf car: a golf car used solely to carry one or more people and golf equipment to play golf. These are sold to golf courses.

Personal golf car: a golf car used to carry one or more people and may carry golf equipment to play golf. These are sold to individual people who may use them to travel on public roads to and from golf courses and to play golf, to travel on public roads for purposes unrelated to golf, or for all of these purposes.

Speed-modified golf car: a conventional golf car that was modified, after its original manufacture, so as to increase its speed. While some speed-modified golf cars have a top speed of 20 to 25 miles per hour, others have a higher top speed. That modification may currently be accompanied by the addition of safety equipment required for the on-road use of the golf car.

Neighborhood electric vehicle: any 4-wheeled electric vehicle whose top speed is not greater than 25 miles per hour. Some of these vehicles look more like a passenger car than a conventional golf car.

Low-speed vehicle: any 4-wheeled motor vehicle whose top speed is greater than 20 miles per hour, but not greater than 25 miles per hour. This group can include neighborhood electric vehicles, and speed-modified golf cars, whose top speed is greater than 20 miles per hour, but not greater than 25 miles per hour.

Other Government Motor Vehicle Conveyances (OGMVC): self-propelled assets providing a basic transportation capability (i.e. golf carts, ATVs, quad-runners, etc) not meeting specifications of 49 CFR 571.500 Federal Motor Vehicle Safety Standard. This government classification includes the fleet and personal golf car as listed above as well as vehicles such as the John Deere Gator and Kawasaki Mule (HQ USAF, 2004).

II. Literature Review

Introduction

When looking at the transportation alternatives to the general purpose vehicle, it is important to establish a basis of understanding with regard to how the Air Force and commercial industry define the term "vehicle". A motor vehicle, as defined by the National Highway Traffic Safety Administration (NHTSA), is "a vehicle manufactured primarily for use on the public streets, roads, and highways" (Department of Transportation, 1998). This is somewhat in contrast to the Air Force's definition of a motor vehicle. While the Air Force recognizes the same basic requirements to constitute a motor vehicle, it adds a distinction of asset procurement. Air Force Instruction 24-301 paragraph 5.1 states,

> "Federal law controls the purchase of passenger-carrying vehicles for government use. Congress authorizes the purchase of government vehicles through the Appropriations Act and sets statutory price limitations for purchasing certain vehicles. (Department of the Air Force, 2001)"

Based on this statutory limitation, only assets procured in this manner are considered and treated as vehicles. Given the lack of procurement funds discussed in Chapter One, this literature review will focus on identifying alternative forms of transportation. The alternatives discussed meet the user's requirement for transportation and follow the definitional guideline to not be considered a traditional motor vehicle as related to Air Force procurement guidelines.

A search was conducted to determine the transportation alternatives to the general purpose vehicle that would meet the operational, definition, and procurement requirements as previously discussed. The result yielded two alternative forms of transportation that would meet these three criteria; the golf car and the low speed vehicle (LSV). A background and explanation of these two alternatives follow.

Background of the Golf Car and LSV

The demographics of the American population are changing. This is in part, due to the aging of the baby boomer generation as well as the increase in planned and retirement communities across America (Department of Transportation, 1998). Based on this, the transportation needs of many communities are changing as well. Specifically, many are finding that the use of a traditional motor vehicle isn't necessary for many of the short distance trips taken each day (Department of Transportation, 1998). Planned and retirement communities provide for a more controlled and; often, speed reduced operating environment which lends itself to use of a smaller, lower speed method of transportation, such as a golf car, that is less expensive (Department of Transportation, 1998). As a result of this growing market, manufactures have begun to develop a transportation alternative to the traditional motor vehicle that will specifically serve this new and emerging client base.

The NHTSA reports that it was common practice among states to allow golf cars to operate on public roads within a specified distance from a golf course (Department of Transportation, 1998). Golf cars were defined at the time to be a vehicle that was capable of a top speed of 15 miles per hour or less. As planned communities grew in size and number, many states passed legislation that allowed local governments to determine the use of golf cars on public roads subject to speed and operational limitations (Department of Transportation, 1998). NHTSA further reports that many states began to recognize a new class of golf car that was faster and more capable than the traditional golf car. As a result, states began to replace old statutory definitions of golf cars having a top speed of 15 mph with verbiage that acknowledged their new capability of achieving 25 mph. Additionally, some states recognized the newer, faster golf cars as a new class of vehicle, calling them Neighborhood Electric Vehicles (NEV) (Department of Transportation, 1998).

As a result of the growing utilization of golf cars on public roadways and petitions from the golf car industry, in June of 1998 the NHTSA reviewed its definition of low speed vehicles and took steps to clearly define the requirements needed to be classified as a LSV (Department of Transportation, 1998). While low speed vehicle is the technically correct term for this class of vehicle, industry has adopted the name of neighborhood electric vehicle to describe vehicles subject to Federal Motor Vehicle Safety Standard (FMVSS) 500. Additionally, FMVSS 500 requires NEVs to have standard safety equipment that includes windshields, mirrors, headlights, signal lights, tail and brake lights, reflectors, safety belts, a parking brake, and vehicle identification numbers (Department of Transportation, 1998). Further, under FMVSS 500, low speed vehicles do not have to have doors or bumpers, and they are not required to meet any crashworthiness tests (Department of Transportation, 1998).

The Insurance Institute for Highway Safety, in July of 2004, reports that 19 states (Arizona, California, Colorado, Florida, Georgia, Hawaii, Indiana, Iowa, Michigan, Nevada, New York, North Carolina, North Dakota, Oklahoma, Oregon, Tennessee, Utah, Virginia, and Washington) allow LSV use on public roads with speed limits up to 35 mph (Insurance Institute for Highway Safety, 2004). Kansas allows LSVs to be operated on public roads with speed limits up 40 mph (Insurance Institute for Highway Safety, 2004). However, 27 states have not passed specific laws that allow LSV use on public roads although their current laws allow for LSV operation. Finally, six states have not passed legislation regarding LSV use but their existing laws prohibit LSV use on public roads (Insurance Institute for Highway Safety, 2004).

For the purpose of this research, there are two industry defined types of vehicles that will qualify as alternatives to the general purpose vehicle. The first type is the traditional golf car. With a top speed limit of less than 20 miles per hour and seating capabilities of two to six passengers, golf cars provide what appears to be an effective and economical alternative to the traditional motor vehicle.

The second type of vehicle that falls into this category is the LSV. The classification of the LSV, as previously discussed, is based on speed and as such, LSVs falling into this category vary in description from a standard looking golf car to vehicles that look very much like small cars. Currently produced LSVs have speeds that reach 25 mph and come in varying models that can accommodate two or four passengers as well as some models featuring utility beds in varying lengths (Department of Energy, 2004b).

The Department of Energy (DOE) promotes alternative fuel transportation through its energy efficiency and renewable energy program, Clean Cities (Department of Energy, 2004b). In an effort to raise awareness of the alternative vehicle choices that consumers have, DOE posts a vehicle buyer's guide on its website for consumers or fleet managers that lists all manufacture's models known to the DOE. In reviewing the NEV section of the alternative fuel choices, consumers will find six different companies listed: Big Man, Columbia ParCar, Dynasty Motorcar, Global Electric Motorcars (GEM), Scooterteq, and Western Golf Cars (Department of Energy, 2004b). These six manufacturers have a total of 27 different models available for different applications; ranging from basic golf car design, industrial warehouse use, security patrol applications, and convertibles with permanent doors, to high end NEVs that look very much like a compact car. The site also lists manufacturer contact information that includes company phone numbers and a web site addresses (Department of Energy, 2004b).

NEV use in America has sharply increased in the last several years and total sales in the US topped 6200 units in 2003 (Department of Energy, 2004a). The NEV is considered a practical alternative to the full size motor vehicle by industry and has found a home in such places as universities, police departments, warehouse distribution centers, government agencies such as military bases and State Department activities, and airports. As an example of their acceptance by industry, in June 2004, the G-8 summit hosted in Georgia, used eight GEM NEVs as transport vehicles for the world leaders (CNN, 2004). Each world leader had a GEM at their disposal for travel on the secluded Sea Island resort. NEVs can also be found extensively on many Air Force bases to include Luke Air Force Base in Arizona (Department of Energy, 2001).

A review of governing policy regarding golf car and LSV classification and use was conducted to establish the legal definitions of both vehicles from the Department of Transportation's standpoint as well as from the Air Force. In addition to the legal definition, Air Force instructions were researched to discover current policy in regards to golf car and LSV procurement and use.

LSV Regulations

The Air Force has followed the lead of the NHTSA in defining LSVs. In Air Force Instruction 24-301 paragraph 6.28.2, LSVs are defined as:

> Low Speed Vehicles are any four-wheeled conveyance with a top speed greater than 20 mph, but less than 25 mph. LSVs are classified as motor vehicles and must meet specific Federal Motor Vehicle Safety Standards (49 CFR 571.500) to operate primarily on military installation's public roads. LSVs must be equipped with specified headlamps, stop lamps, turn signal lamps, reflex reflectors, parking brakes, rear view mirrors, windshields, seat belts, and vehicle identification numbers. (Department of the Air Force, 2001)

In addition to the above requirements, the Air Force has specified in paragraph 6.28 that LSVs will be configured to carry no more than two passengers (driver plus one passenger) and that LSVs are non-registered assets, procured as equipment items using unit funds, and accounted for by the owning unit (Department of the Air Force, 2001).

AFI 24-302, reiterates the requirements for procurement, operator care, and discusses using LSVs to fulfill part of the unit's total transportation needs. Specifically, the instruction requires units to coordinate purchase requests through the offices of ground safety and vehicle management to ensure that LSVs meet all operational safety requirements, and to verify the unit's arrangements to fund all maintenance and safety inspection services as required by the manufacturer.

Pacific Air Forces (PACAF) has published a supplement to AFI 24-301 dated June 2003. In the supplement, PACAF takes a slightly different view than that of the Air Force but is in the process of rewriting the instruction. The revision will mirror the Air Force Instruction with added PACAF stipulations and follows the lead of the NHTSA in defining a low speed vehicle. The command supplement also designates the mission support group commander as being responsible for administering the wing's LSV management program (PACAF, 2003).

Golf Car Regulations

As previously mentioned, required safety equipment for golf cars operating on a public roadway is regulated by state and local agencies. In addition to any state or local regulations, golf cars are subject to speed and operational limitations as well, based on where they are operating.

The Air Force follows the definition of the NHTSA and echoes their safety requirements for use on military installations (Department of the Air Force, 2005). Likewise, PACAF's supplement 1 to AFI 24-301 reflects Air Force policy and requires the same procedures for purchase as specified for LSVs (PACAF, 2003).

Fleet Purchasing Decisions

When considering the purchase of a LSV or golf car as an addition to a vehicle fleet, many factors must be considered to determine which vehicle will best accomplish the buying organization's varying needs. The National Association of Fleet Administrators (NAFA) conducted a survey to determine which vehicle attributes were most important to fleet administrators. The survey found that job suitability was ranked most important, followed by repair record and serviceability/ease of repair tied for second, and safety record and warranty program tied for third (Black, 1999). Other factors found to be important were initial cost and the manufacturing country of the vehicle (Black, 1999). It is pertinent to note that the country of manufacture was important when the vehicles were being bought by government agencies as many will not buy an import vehicle as part of their government vehicle fleet (Black, 1999). A second survey commissioned by Hyundai Motor America reports that consumers believe three vehicle attributes are important when considering a vehicle purchase: reliability, safety, and efficiency (PR Newswire, 2003). While surveys are valuable for understanding consumer preferences as a whole, it is also important to consider the actions of large scale fleet managers and purchasers to determine priorities the large fleet owner has. Analysis of this segment has revealed that many of the factors found to be important are similar to those discovered through the previously mentioned surveys. Specific vehicle considerations include: vehicle price, options, maintenance costs, reliability, resale value, ease of service, and safety (Adams, 1990).

Conclusion of Literature Review

Overall, this literature review has given a background of golf cars and the low speed vehicle. Additionally, current policy and instructions governing golf car and low speed vehicle procurement and use within Air Force units have been presented. Finally, the factors important to fleet managers when purchasing a vehicle were discussed. This baseline of information will be used to develop a weighted multivariate decision tool.

III. Methodology

Chapter Overview

This chapter describes the procedures used to reach a vehicle purchase decision based on multiple competing vehicle factors. The chapter begins by discussing the need for a multiple criteria decision making tool followed by a brief explanation of the more common multiple criteria decision making models. Next, the Analytic Hierarchy Process is discussed in detail to include an example of its use in a vehicle purchase situation. Finally, an overview of the data collection used in this study is presented.

The Need for Multiple Criteria Decision Making Models

The answer to most purchase questions for comparable items can be broken down into a single quantitative question and answer. For example, when determining which type of pain reliever to buy, name brand or generic, many consumers will make the purchase decision based on lowest price once comparability of the product is established. This is a relatively easy decision to make and arriving at the optimal solution is simply a matter of determining the lowest price for the two comparable products. In this situation, price becomes the single criterion by which the consumer is basing the final decision.

Arriving at a solution is not as easy; however, when there are multiple criteria that must be evaluated before a final purchase decision can be made. Consumers are faced with many choices as it pertains to their purchasing options. They have the opportunity to purchase items based on a myriad of factors, to include quality, craftsmanship, features, price, and production location. This wide array of factors will undoubtedly complicate the purchasing process and may make the optimal or “best” decision, based on their specific requirements, difficult to achieve. One particular reason for the complexity of the decision process relates to the conflict that may arise between the varying criteria of the different alternatives. It is in this situation that Multiple Criterion Decision Making (MCDM) models are especially valuable.

Multiple Criterion Decision Making Models

There are several MCDM that have been developed to aide in the decision process: 1) Single Objective Approach; 2) Goal Programming Approach; 3) Interactive Approach; 4) Compromise Programming Approach; 5) Electre Approach; 6) Parametric Approach; and 7) De Novo Programming Approach (Tabucannon, 1988). A brief review of each technique follows.

Single Objective Approach. This basic MCDM optimizes one objective and converts the remaining objectives to constraints. In doing so, maximums or minimums are established for each secondary objective and must be met for attainment (Tabucannon, 1988).

Goal Programming. Solutions from goal programming are achieved by minimizing the deviation from the decision maker's originally stated goals. The variables used in goal programming are assigned weights to prioritize criteria and the values assigned to the criteria become the goals for selections (Battin et al, 1992; Tabucannon, 1988).

Interactive Approach. The interactive approach allows the user to state a set of priorities at the beginning of the problem and allows for their adjustment throughout the problem solving process. The ability to make adjustments on the part of the decision maker takes advantage of an interactive process but is also very time intensive. However, with very complex problems many priorities may not be fully known or understood; thus, adjustments along the way allow for more difficult problems to be solved (Tabucannon 1988).

Compromise Programming. In compromise programming, an ideal solution, which reaches each criterions individual optimum, is plotted for reference. Since the ideal solution is not feasible, compromise programming seeks to minimize the distance geographically from the ideal (Battin et al, 1992, Tabucannon, 1988).

Electre Approach. This interactive MCDM handles qualitative and discrete alternatives and allows the decision maker to give initial preference and priority information. The goal of Electre is to choose the alternative that satisfies the most criteria without violating any one criterion (Tabucannon 1988).

Parametric Approach. When a decision maker's preferences are not known in advance of analysis being conducted, the parametric approach may be the best MCDM. This process generates many possible solutions so it is necessary to limit points to only those deemed efficient and; occasionally, to introduce new criteria to further reduce the possible solution outcomes. When the pared down list of solutions is obtained, it can then be presented to the decision maker for final determination (Tabucannon, 1988).

De Novo Programming. This MCDM approaches problem solving in a different manner than most other decision tools. Rather than optimizing the system for a given problem, De Novo Programming seeks to design an optimal system. Using a systems approach to optimization, alternatives are researched rather than using only the few initially present (Battin et al, 1992, Tabucannon, 1988).

When solving MCDMs, it is important to note that criteria are conflicting if the full satisfaction of one prevents the full satisfaction of another (Battin et al, 1992). For example, a consumer may want to purchase a fuel efficient truck with a lot of torque to pull machinery. The conflict arises between the high torque capability and fuel efficiency. Specifically, high torque capability is usually the result of a larger, more powerful engine which is less fuel efficient than a smaller, less capable engine.

A tabular representation of a decision involving multiple alternatives and multiple criteria is presented in Figure 1. The matrix has three main components that form its representation of the decision problem. First, the a_1 through a_n represent the different alternatives available, while the c_1 through c_m represent the different criteria. The v_{mn} represent the values of each alternative with respect to each criteria. A criteria in this matrix can be defined as conflicting when no alternative dominates all other alternatives on every criterion (Tabucanon, 1988). An alternative is deemed superior to another when all of its criterion values are ranked higher than criterion values for another alternative (Tabucannon, 1988).

	c_1	c_2	…	…	c_m
a_1	v_{11}	v_{12}			v_{1m}
a_2	v_{21}	v_{22}			v_{2m}
:	:	:			
:	:	:			
a_n	:	:			

Figure 1: Multiple Criterion Decision Matrix (Tabucannon, 1988)

For illustration, examples of both conflicting and non-conflicting criteria are presented in Figure 2. A decision matrix is non-conflicting when all the criteria of one alternative is larger (assuming maximization is the goal) than the criteria of other, possible alternatives (Tabucannon, 1988). An example can be seen on the left side of Figure 2. The criteria for alternative one are larger than the criteria for alternative two in each of the separate criterion categories being considered. A decision matrix is said to be conflicting when the criteria for any one alternative conflict with the criteria of another alternative for the given scenario. The truck example referenced earlier will be used to demonstrate and can be seen on the right side of Figure 2. If criteria one was torque measured in foot pounds and criteria two was reported miles per gallon, then the decision matrix is in conflict. The conflict occurs in the criteria of the two alternatives. Specifically, alternative one has higher torque but has a lower miles per gallon rating than alternative two.

	c_1	c_2
a_1	5	15
a_2	3	12

Non-conflicting Criteria

	c_1	c_2
a_1	330	12
a_2	175	18

Conflicting Criteria

Figure 2: Decision Matrix Examples (Adapted from Tabucannon, 1988)

It can be seen that in simple problems with few alternatives and criteria, a decision maker can easily understand the options presented by the decision matrix; and, if there is a conflict, make a decision based on the value of the criteria. However, when the decision maker is facing a larger problem with many alternatives and many criteria, the ability to logically select the “best” answer is significantly more difficult. It is in these types of situations that a more encompassing decision tool is needed. Specifically, a method or tool that will allow the decision maker to pare down the possible outcomes; one that will allow the decision maker to assign values to the different criteria based on the decision maker's needs and requirements. Thomas Saaty developed such a MCDM tool in the 1970's called the Analytical Hierarchy Process.

The Analytic Hierarchy Process

The Analytical Hierarchy Process (AHP) is a multiple criteria decision making tool that incorporates a hierarchical approach for finding a solution to a problem (Saaty, 1982). The AHP method allows a decision maker to establish a ranking of alternatives through the use of a pairwise comparison of criteria. The ranking of alternatives is developed by establishing a rating system for each alternative which is based on evaluation of subjective values assigned to the alternative's criteria (Saaty, 1990). One substantial benefit of the AHP is that it allows both qualitative as well as quantitative data to be analyzed within the same decision matrix (Saaty, 1982). In so doing, the AHP allows qualitative factors, such as quality to be compared with quantitative factors, such as price. Saaty points out that there are ten main advantages to the AHP that make it a flexible and powerful tool in multiple criteria decision making, shown in Figure 3 (Saaty, 1982). To illustrate the AHP an example follows.

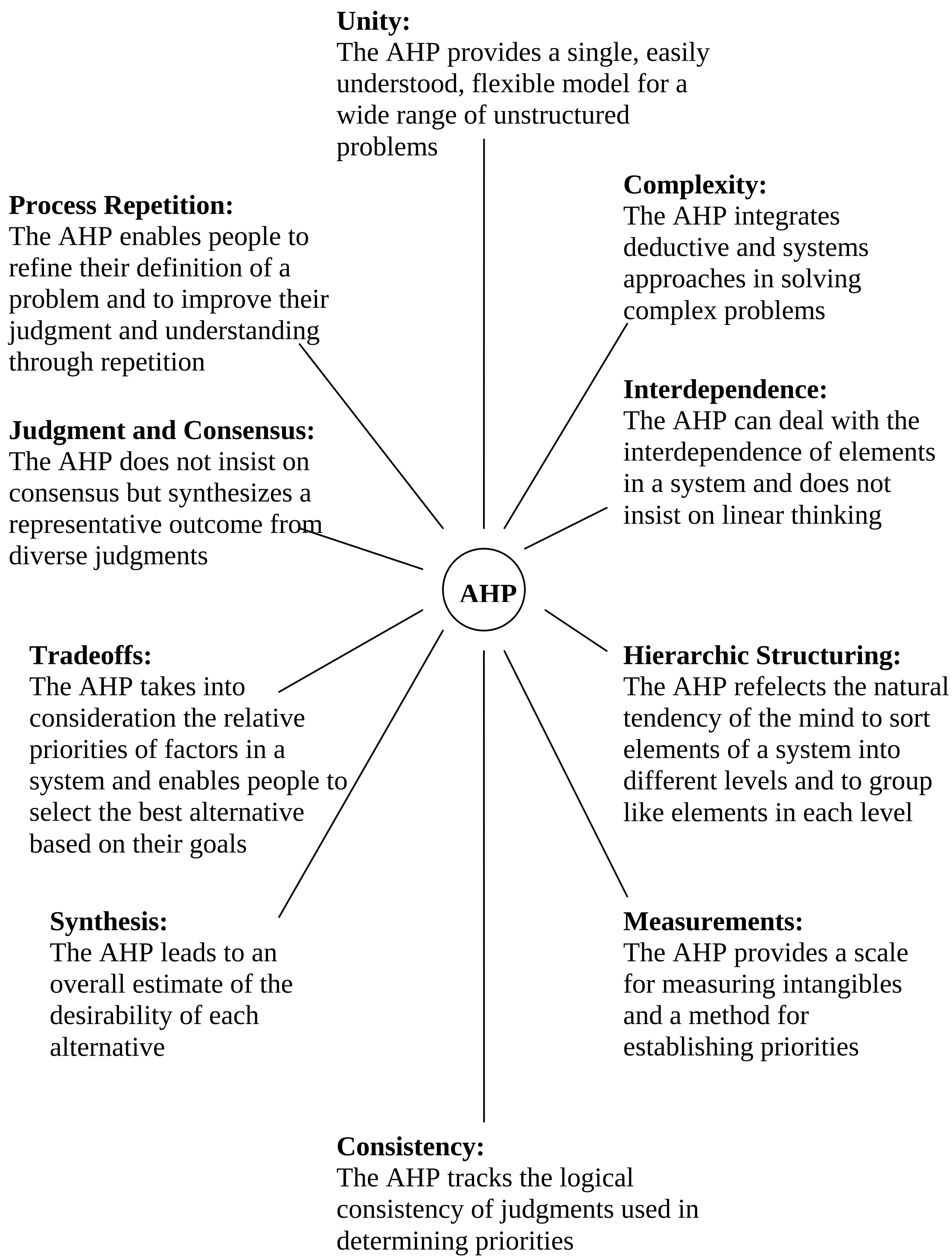


Figure 3: Ten Advantages of the Analytic Hierarchy Process (Saaty, 1982)

A consumer is in the market to buy a new truck and has narrowed the choice to a Ford F-150, Chevrolet Silverado, or a Dodge Ram. The consumer now wants to make the final choice based on the following factors: cost, engine, utility bed size, towing capacity, and comfort. In an effort to organize the decision process and in following with the AHP, the consumer will next build a hierarchy that represents the criteria and alternatives of the decision (Figure 4).

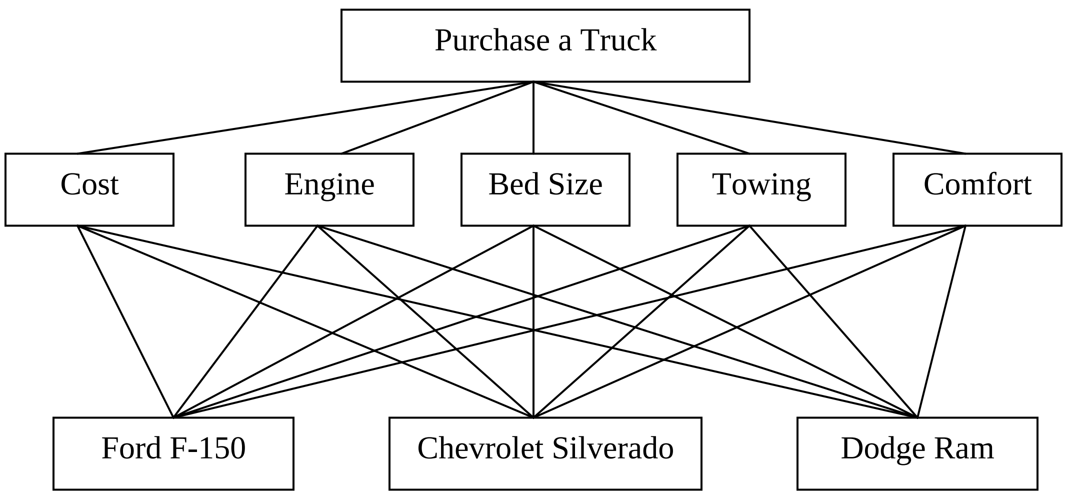


Figure 4: Hierarchy for Vehicle Buying Decision

The consumer next must perform a pairwise comparison of each criterion in relation to the vehicle purchase to determine its relative importance. To perform the pairwise comparison, the consumer will rate how important one criterion is in relation to every other criterion. The AHP uses a numerical scale with values ranging from 1 through 9 to make the comparisons, with 1 being equivalence, 3 being weak, 5 being strong, 7 being very strong, and 9 being absolute (Saaty, 1982). Even numbers are used in the AHP as intermediate values between two adjacent judgments (Saaty, 1982). To build the comparison matrix, the consumer should list the attributes being considered in both a column and row, keeping the order of the judged criteria. Comparing a criterion to itself will always be equal so a 1 is placed in each position on the main diagonal of the matrix. The matrix is then filled in by comparing the criterion of the first row with the criterion in each column. Once this process has been completed to the right of the main diagonal, the reciprocal value may be entered into the corresponding location to the left of the main diagonal. An example is presented in Figure 5.

Buy a Truck	Co	En	Bs	To	Cm
Co	1	3	3	5	9
En	1/3	1	3	5	7
Bs	1/3	1/3	1	4	7
To	1/5	1/5	1/4	1	6
Cm	1/9	1/7	1/7	1/6	1

Co - Cost
En - Engine
Bs - Bed Size
To - Towing Capacity
Cm - Comfort

Figure 5: Matrix of Comparisons on Purchasing a Truck (Adapted from Luethke, 1987)

Once the pairwise comparisons have been accomplished, the consumer will synthesize the judgments to obtain an overall set of priorities in relation to each criterion (Saaty, 1982). In this process, the alternatives are rated against one another for each criterion being considered. Thus, for the example of which truck to buy as presented in this illustration, there would be five matrices required to rate the alternatives (brand of truck) against the five determining criteria. An example of one of the matrices, representing cost, is presented in Figure 6.

Cost	Chevrolet	Ford	Dodge
Chevrolet	1	3	5
Ford	1/3	1	3
Dodge	1/5	1/3	1

Figure 6: Pairwise Comparison of Alternatives in Relation to Cost Criterion

The cost matrix shows that the Chevrolet is weakly favored based on price to the Ford and strongly favored to the Dodge model. Additionally, the matrix shows that the Ford model is weakly favored over the Dodge and that the Dodge model is favored less to both the Ford and Chevrolet models based on cost. This process is repeated for each of the criteria being considered. To continue with the synthesis process, a series of calculations will need to be accomplished. First, adding the values in each column to obtain a column total and then dividing each entry by that column total will produce a normalized matrix as seen in Figure 7 (Saaty, 1982). This normalized matrix will allow for comparison between elements (Saaty, 1982). Once complete, the average is taken by adding across each row of the normalized matrix and then dividing by the number of values in that row. This synthesis produces the overall priority or preference in percentage form relative to the criteria being considered as shown in Figure 8 (Saaty, 1982).

Cost	Chevrolet	Ford	Dodge
Chevrolet	0.6521	0.6923	0.5555
Ford	0.2173	0.2307	0.3333
Dodge	0.1304	0.0769	0.1111

Figure 7: Normalized Matrix (Adapted from Saaty, 1982)

Cost	Chevrolet	Ford	Dodge	Total s/3
Chevrolet	0.6521	0.6923	0.5555	0.6333
Ford	0.2173	0.2307	0.3333	0.2604
Dodge	0.1304	0.0769	0.1111	0.1061

Figure 8: Overall Rating of Alternatives Based on Cost (Adapted from Saaty, 1982)

This process is then repeated for each criterion being considered under the decision. The outcome will show how each alternative ranks for each criteria. Once the alternatives have been compared and ranked for each criterion, a synthesis of the five matrices is required. To produce the synthesized matrix, the resulting percentage values will be used from each criterion's matrix and compiled into one; thus, producing a matrix containing the ranked results for each alternative across the five criteria (Figure 9). Once the ranking of each alternative is known based on the five criteria, a synthesis and weighting for the criteria themselves is needed. Using the same procedure as previously discussed, the original pairwise comparison matrix, Figure 10, produces a weighted rating for each of the five criteria. The weights obtained are a result of the decision maker's original assessment of the importance of each criterion in the decision process. The final step in the AHP is to multiply the overall weighted criteria with the ranked criteria values for each alternative. This will result in a value for each criterion that represents its relative importance in the overall decision process as shown in Figure 11 (Saaty, 1982). Finally, add across the rows for each alternative and the resulting totals will be the final ratings for the three alternatives as illustrated in Figure 11. In this example, Chevrolet ranked number 1, followed by Ford and then Dodge. The consumer now has the information to make an informed decision on purchasing a new truck based on both importance of the features offered as well as subjective judgments of those criteria for the three alternatives being considered. Now that the AHP has been explained and demonstrated, a discussion of consistency in comparisons is necessary (Saaty, 1982).

	Co	En	Bs	To	Cm
Chevrolet	0.6333	0.5821	0.6479	0.1279	0.6479
Ford	0.2604	0.3091	0.2298	0.5119	0.1221
Dodge	0.1061	0.1095	0.1221	0.3601	0.2298

Figure 9: Rating of Each Alternative Across Criteria

Buy a Truck	Co	En	Bs	To	Cm	Totals/5
Co	0.5056	0.6415	0.4057	0.3296	0.3	0.4365
En	0.1685	0.2138	0.4057	0.3296	0.2333	0.2702
Bs	0.1685	0.0712	0.1352	0.2637	0.2333	0.1744
To	0.1011	0.0427	0.0338	0.0659	0.2	0.0887
Cm	0.0561	0.0305	0.0193	0.01	0.0333	0.0300

Figure 10: Weighted Value of each Criteria

	Co	En	Bs	To	Cm	Totals
Chevrolet	0.2764	0.1570	0.1130	0.0113	0.0194	0.5774
Ford	0.1137	0.0835	0.0400	0.0454	0.0036	0.2864
Dodge	0.0463	0.0296	0.0213	0.0319	0.0069	0.1361

Figure 11: Final Ratings for each Alternative

Consistency in evaluating criterion can be demonstrated mathematically by the following equations:

If A = 2B
and B = 2C
then A = 2(2C) = 4C
(Luethke, 1987).

The preceding equations state that if A is equal to twice as much as B, and B is equal to twice as much as C, then A is equal to four times C. If in performing the AHP the value A were not equal to four times C then the equations would be considered inconsistent (Saaty, 1982). As important as it is to be consistent in evaluating criteria in relation to the decision process, it is recognized that being perfectly consistent is rarely possible (Saaty, 1982). Often, circumstances change in relation to personal preferences and by doing so a change in the subjective evaluation of a criterion will occur (Saaty, 1982). To compensate for this natural tendency towards inconsistency, the AHP provides a measure for it by means of a consistency ratio (Luethke, 1987). The consistency ratio is the deviation from consistency, the consistency index, divided by the random consistency for a matrix of the same size (Luethke, 1987). To calculate the consistency ratio, the consistency index is divided by the random consistency value (Saaty, 1982). Saaty indicates that if the resulting consistency ratio is greater than 10 percent, the judgments are suspect and may be random in nature. To correct this, the judgments may need to be revised.

Data Collection

In order for the AHP to produce credible results, an assessment of the importance of each vehicle factor, both individually and in relation to each other, must be determined. To gain this information, a two-part questionnaire was submitted to each Logistics Readiness Squadron (LRS) Commander in PACAF (Appendix B). In part one, each squadron commander was asked to rate the importance of eight vehicle attributes in relation to each other. The eight vehicle factors used in the study were developed in part from those vehicle attributes determined to be important in the civilian vehicle management community as discussed in the previous chapter, as well as, in consideration for the location and operating environment of the military users. Specifically, the eight factors are: initial procurement cost, maintenance costs per year, reliability rate, ease of service, fuel efficiency, warranty time period in years, delivery time in weeks, and job suitability. Job suitability is further broken down into the following four subcategories:

availability of a utility bed, engine preference, daily operating range, and daily operating hours.

In part two of the questionnaire, commanders and their Vehicle Management Superintendent were asked to distribute a total of 100 points across possible options related to that vehicle attribute signifying their preferences from among the options given. For example, under the category of Procurement Cost, commanders were asked to distribute the points across the procurement cost options: $6,000, $9,000, $12,000, and $15,000. The points were used to establish the relative importance of price from within the procurement cost category. Once the relative importance for the various options has been established, it is used to calculate a percentage of the total possible 20 points that alternative will receive if it falls within that option's parameters. The 20 point figure used was arbitrarily selected and is intended to keep final point values at least greater than one. An example is demonstrated in Figure 12.

			Procurement Cost					
Respondent	**1**	**2**	**3**	**4**	**5**	**6**	**response totals / 6**	**total points awarded**
$6,000	15	60	65	70	50	15	45.833	9.1666
$9,000	20	25	10	20	20	40	22.500	4.5
$12,000	60	10	20	5	25	40	26.667	5.3334
$15,000	5	5	5	5	5	5	5.000	1
total =	100	100	100	100	100	100	100.000	20

Figure 12: Example Questionnaire Response

Following the $6,000 option under procurement cost, the six responses are summed and then averaged to obtain the 45.833 value. This equates to the $6,000 option being worth 45.83% of the total possible 20 available points. Thus, if one of the alternative vehicles being considered for purchase was to be $6,000 or less, that vehicle would earn 9.166 points for the decision matrix. This process is repeated for each of the vehicle attributes and their subcategories as applicable.

Chapter Summary

This chapter has reviewed and illustrated the concept of Multiple Criterion Decision Making as well as discussed the data collection method used in this study. In Multiple Criterion Decision Making, several techniques were reviewed and the Analytical Hierarchy Process was thoroughly illustrated with a simple example of how the model might be used in a vehicle purchase scenario. The ability of the model to allow the decision maker to specify priorities in the form of criteria and the weight of those criteria make the AHP a particularly useful MCDM model. By weighting the criterion and performing pairwise comparisons on both the criteria and the alternatives, the decision maker has the ability to specifically focus on those attributes of the alternatives that influence the decision processes the most. Additionally, the ease of use and capability to handle large, complex problems in a systematic manner enhance the value of this decision making tool.

IV. Results and Analysis

Chapter Overview

The purpose of this chapter is to present the results of the research in an effort to answer the overall question of determining the most appropriate transportation alternative to the general purpose vehicle for PACAF units. The chapter begins with an analysis of the original investigative questions presented in Chapter One. Next, the eight vehicle attributes used in the research questionnaire are discussed. This is followed by a summation of the questionnaire results, which includes a discussion of which vehicle attributes were determined to be most important to Logistics Readiness Squadron Commanders. The chapter concludes with a presentation of the results for each respondent as well as the results for PACAF taken as a whole.

What regulatory restrictions exist concerning alternative transportation purchases?

A review of the relevant Air Force Instructions and Policy letters was conducted to ascertain the current regulatory restrictions concerning alternative transportation purchases. In an update to AFI 24-302, AF/ILG clearly specifies Air Force policy regarding LSV and OGMVC purchases. The instruction states that slow moving conveyances such as low speed vehicles, golf cars, and low speed utility vehicles, will be managed in one of two categories; LSVs or OGMVCs, which were previously defined in Chapters One and Two (Department of the Air Force, 2005). As both categories are classified as equipment items as opposed to motor vehicles, LSVs and OGMVCs must be purchased in accordance with (IAW) Federal Acquisition Regulations (FAR), Defense FAR Supplement, Air Force FAR Supplement, related Air Force Instructions and Air

Force Policy Directive 64-1, The Contracting System, and managed IAW AFMAN 23-110, USAF Supply Manual, and AFI 91-207, Air Force Traffic Safety Program (Department of the Air Force, 2005). Specific purchase requests will be processed through the wing ground safety office for coordination, vehicle management office for coordination, and the equipment management section within the management systems flight of the Logistics Readiness Squadron for approval (Department of the Air Force, 2005).

What are the transportation alternatives to the general purpose vehicle?

The transportation alternatives to the general purpose vehicle were researched and include assets from the LSV and OGMVC categories. Chapter Two presented six different companies producing LSVs as defined by FMVSS 500. The six companies include: Big Man, Columbia ParCar, Dynasty Motorcar, Global Electric Motorcars (GEM), Scooterteq, and Western Golf Cars. These six manufactures have a total of 27 different models available for different applications ranging from basic golf car design, industrial warehouse use, security patrol applications, and convertibles with permanent doors, to high end NEVs that look very much like a compact car. Prices for models offered from the six companies range from just under $6,000 to over $14,000 depending on features and refinement of the particular LSV. The OGMVC category is much more broadly defined than the LSV category and is meant to encompass all other conveyances not previously covered by either the traditional motor vehicle or LSV categories. As such, there are many more companies that offer products that fall into this definition. A few of the more prominent offerings in this category include manufactures of traditional golf cars such as Club Car and E-Z-Go, and all-terrain vehicle manufacturers such as John Deere and Kawasaki. Prices for models in this category range from $3,000 to over $11,000. For the purposes of this research, three vehicles were chosen for analysis based on their overwhelming presence in military and other government agency organizations. The three vehicles include the Global Electric Motorcar, the John Deere Gator, and the Kawasaki Mule. Vehicle specifications can be found in Appendix A. Additional LSVs were considered, but ultimately were not included in the research due to a lack of available information.

What attributes are important when considering a vehicle purchase?

In an effort to determine what vehicle attributes are relevant in the vehicle purchasing process, a review of factors considered important in buying a new vehicle in the civilian setting was accomplished. Information was obtained from three different journal articles which reported information from: The National Association of Fleet Administrators (NAFA); Fleet Administrator for FMC Corp Larry Dakof, and a survey commissioned by Hyundai Motor America. The eight vehicle factors used in the study were developed in part from those vehicle attributes determined to be important in the civilian vehicle management community as discussed in previous chapters as well as in consideration for the location and operating environment of PACAF units. Specifically, the eight factors are: initial procurement cost, maintenance costs per year, reliability rate, ease of service, fuel efficiency, warranty time period in years, delivery time in weeks, and job suitability. Job suitability is further broken down into the following four subcategories: availability of a utility bed, engine preference, daily operating range, and daily operating hours.

Vehicle Attributes

A brief discussion of each of the eight vehicle attributes, along with graphs indicating how commanders and their vehicle management superintendents responded to part two of the questionnaire, in both aggregate percentage and individual response, follows. The responses received will be applied to three vehicles: the Global Electric Motorcar, the John Deere Gator, and the Kawasaki Mule; in an effort to answer the research question.

It is important to note that some of the graphs indicate preferences that are contrary to the anticipated value curve; which would demonstrate a continually decreasing preference towards less desirable vehicle attributes. Such attributes include an increase in vehicle price or decrease in vehicle capability or performance. Due to the nature of the data collection procedure, the researcher was not able to ascertain directly from the respondents what factors may have contributed to this contrary view. However, one possible explanation could lie in the belief that, for example, paying a higher initial price would result in the purchase of a higher quality vehicle which may translate into reduced maintenance costs and greater in commission rates. A similar argument could be made for each of the other responses that demonstrated a directional change in the value curve.

Procurement Cost. The procurement cost refers to the amount the unit will initially pay for the purchase of the vehicle. The range in price was derived from research of the available alternatives capable of fulfilling the categorical requirements of this research. The specific price range, \$6,000 to \$15,000 in \$3,000 increments, is intended to cover the spectrum of those vehicles currently being offered. It is important to note that respondent two, three and six all provided the same weighted scores for procurement cost. For this reason, respondent two and three are not showing on the graph below; however, their value curve is the same as respondent sixes' which is shown.

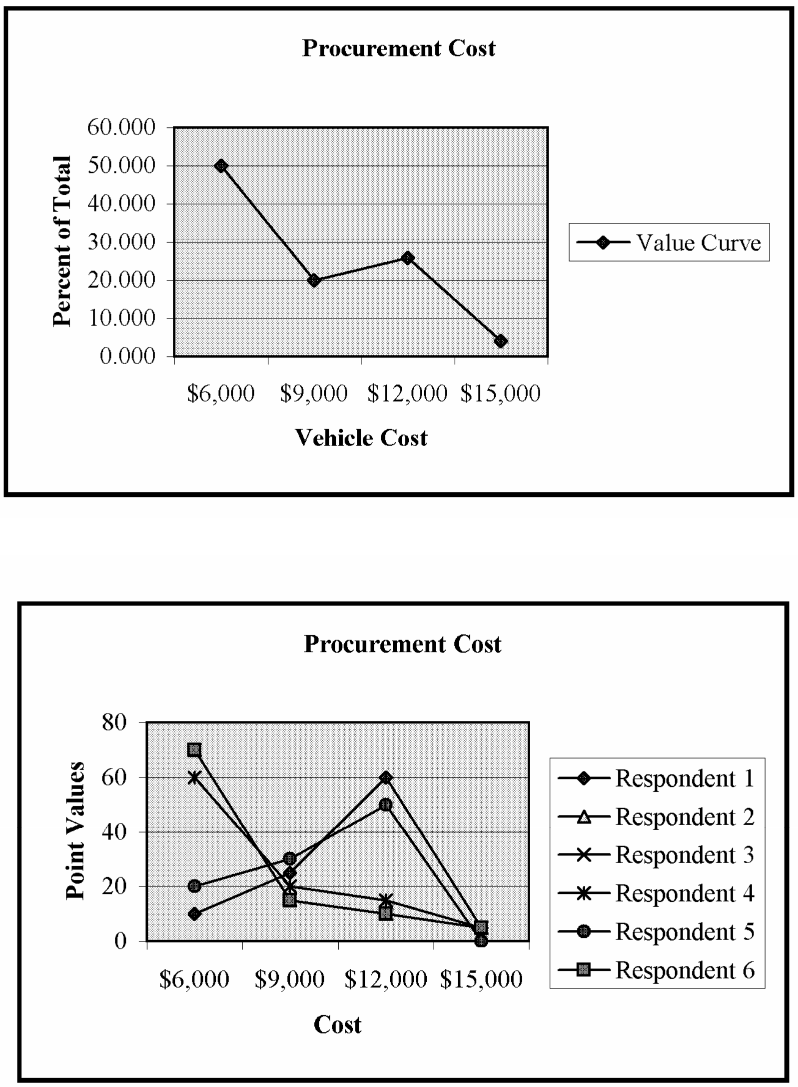
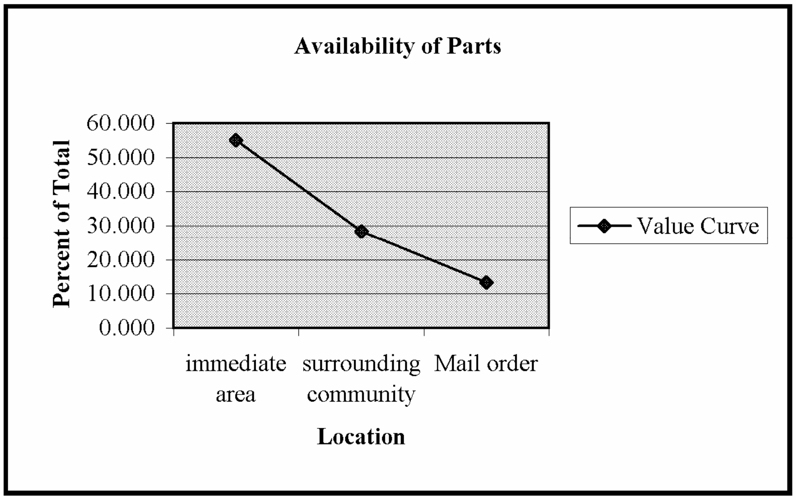


Figure 13: Procurement Cost Charts

Ease of Service. The ease of service category demonstrates the availability of parts for repair of the vehicle being purchased. Due to the locations of units covered in this research, the ability to account for the difficulty in obtaining parts needed to be addressed.



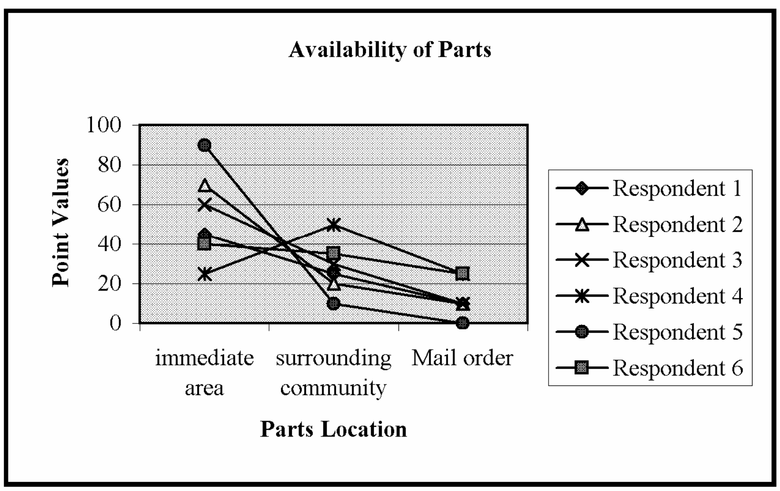
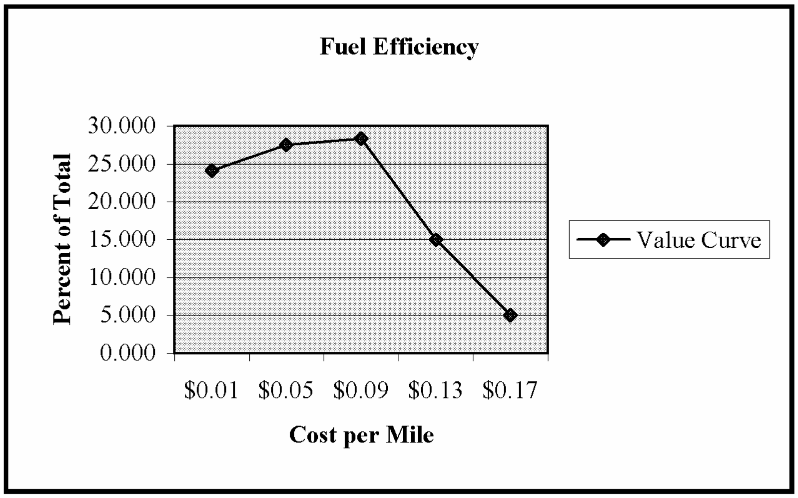


Figure 14: Availability of Parts Charts

Fuel Efficiency. Fuel efficiency refers to the cost in gas or electricity required per mile of operation. The spectrum of prices covers the lowest known fuel efficiency cost per mile up to the upper end of efficiency standards. The GEM efficiency rate was calculated using the average price per kilowatt hour (kwH) from each of the nine PACAF units as reported by the PACAF utilities management section multiplied by approximate kwH amount of power required to fully charge a GEM (Marshall, 2004; GEM 2005). The specific values used were .094 kwH for PACAF units and 7.2 kwH of power for charging GEM vehicles. Fuel efficiency rates for John Deere Gator vehicles were obtained by dividing the cost to fill the tank using regular unleaded gasoline by the average mileage obtained per tank. Gasoline prices used were those reported by the Department of Energy as the national average for unleaded gasoline on 8 January 2005 (DOE, 2005). Specific numbers for the Gator were \$1.77 per gallon multiplied by 5.3 gallons equaling \$9.38 per tank. This number was then divided by 220 which is the miles per tank based on a .6 gallon per hour utilization rate (Deere, 2005). The resulting computation produces a \$0.042 per mile cost in terms of gasoline usage. The Kawasaki Mule efficiency rate was figured in a similar manner. The Kawasaki has a 4.1 gallon tank which requires \$7.25 to fill based on the previous gas price data. The fill price is divided by 170 which is the miles capable per tank based on a similar .6 gallon per hour utilization rate (Kawasaki, 2005). The resulting computation produces a \$0.042 per mile cost in terms of gasoline usage. Interpolation was used to more accurately reflect point value awards when required based on actual fuel efficiency rates for the different vehicles. When used, numbers were rounded to the closest whole number.



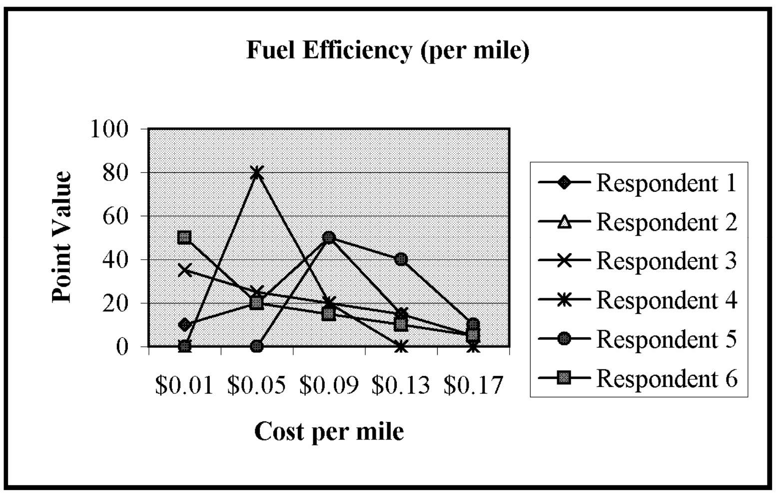
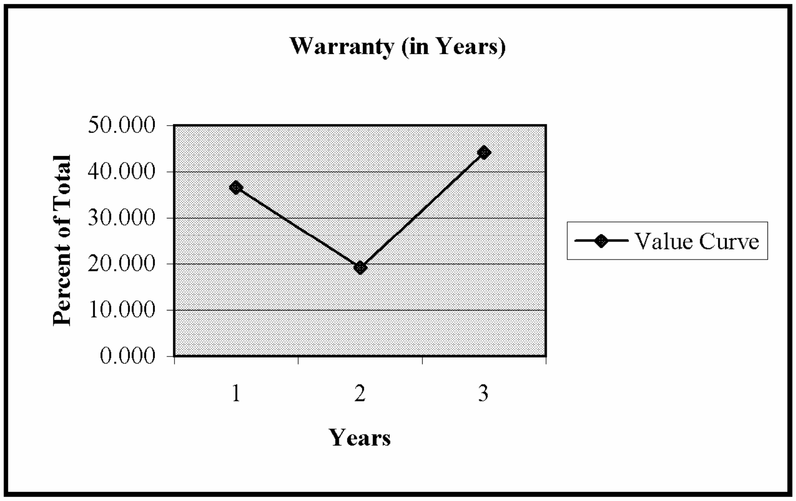


Figure 15: Fuel Efficiency Charts

Warranty. The warranty refers to coverage from the manufacturer for mechanical or cosmetic defects. The specific values of one to three years cover the warranty periods available. Warranty information for the three vehicles used in this portion of the study was obtained from each of the manufacturer's websites (Deere, 2005; GEM, 2005; Kawasaki, 2005).



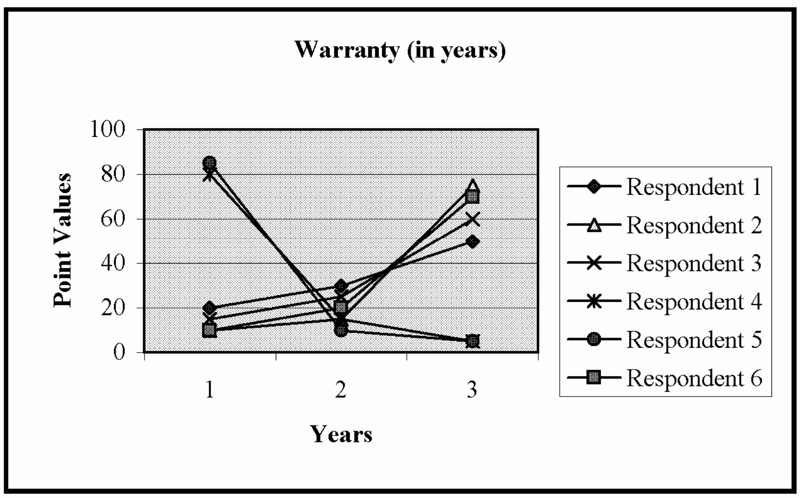


Figure 16: Warranty Charts

Delivery in Weeks. Delivery times refer to the amount of time required for the unit purchasing the vehicle to receive the asset from either the manufacturer or a retail outlet. Delivery times used reflect the range of possible values. GEM shipment times were derived through product detail information found on the GSA Advantage website (GSA, 2005). If the delivery was to a location other than Alaska or Hawaii, the GSA shipment time was added to the required transit time for Privately Owned Vehicles

(POV) as reported in the Global POV Contract (GPC) managed by the Surface Deployment and Distribution Command (SDDC) from the port of Los Angeles (SDDC, 2005). Shipment times for John Deere and Kawasaki models to locations other than Alaska and Hawaii were derived using the previously mentioned GPC times to the specific location being considered. For Alaska and Hawaii, local purchase was used. Interpolation was used to more accurately reflect point value awards when required based on actual delivery times to the different locations. When used, numbers were rounded to the closest whole number.

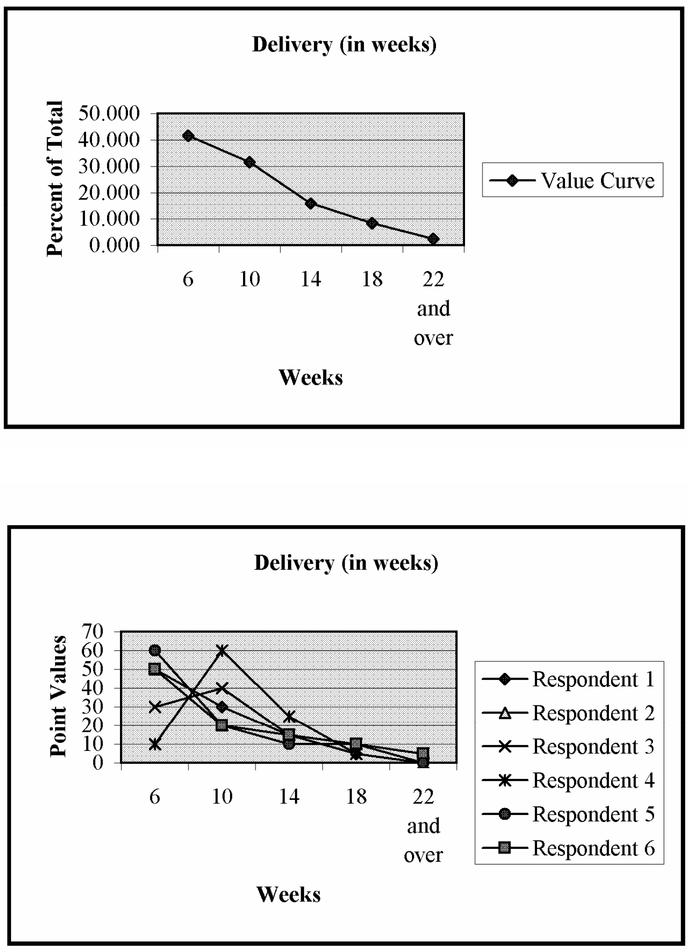
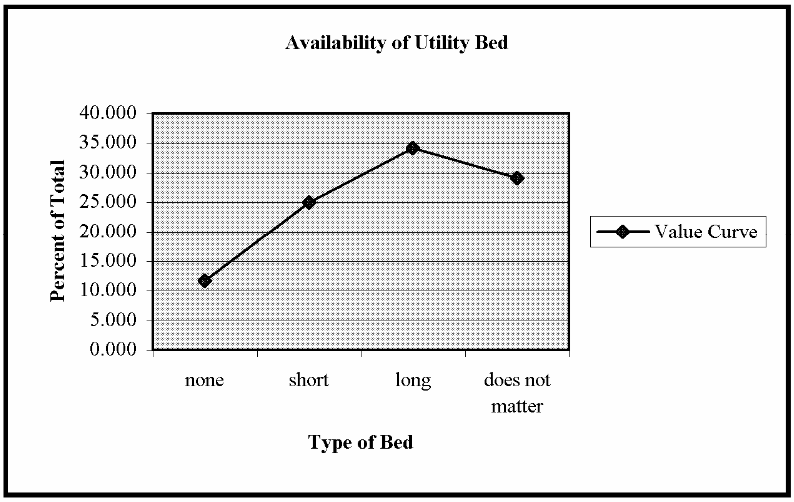


Figure 17: Delivery Charts

Availability of Utility Bed. Availability of a utility bed refers to whether or not the vehicle being considered has a utility bed option and is further divided by the length of the bed offered. Information obtained for this category came from the manufacturer's websites.



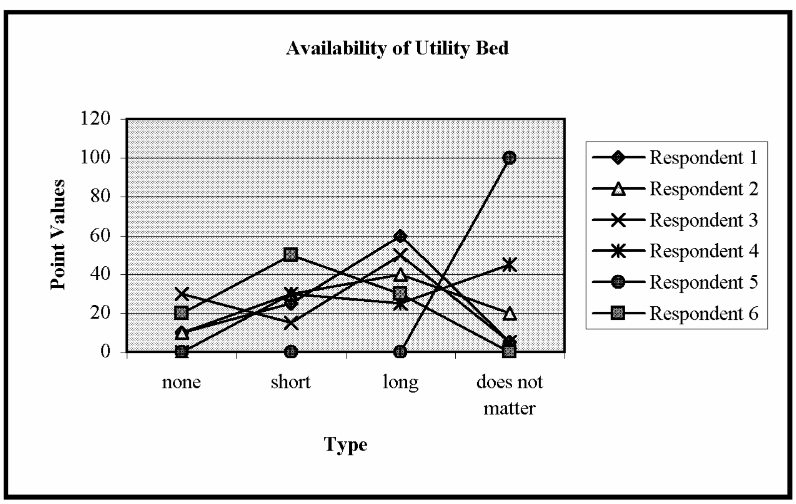
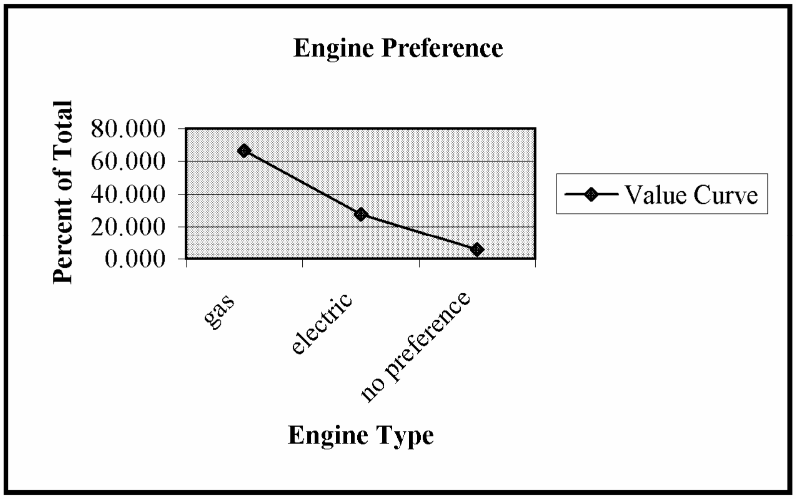


Figure 18: Availability of Utility Bed Charts

Engine Preference. This category refers to the type of engine the vehicle comes with from the manufacturer. The two options found in the commercial marketplace are gas and electric. When examining the individual respondent's graph, it is important to note that respondent two and six provided equal value curves to engine preference. This caused only one value curve line to be visible in the chart.



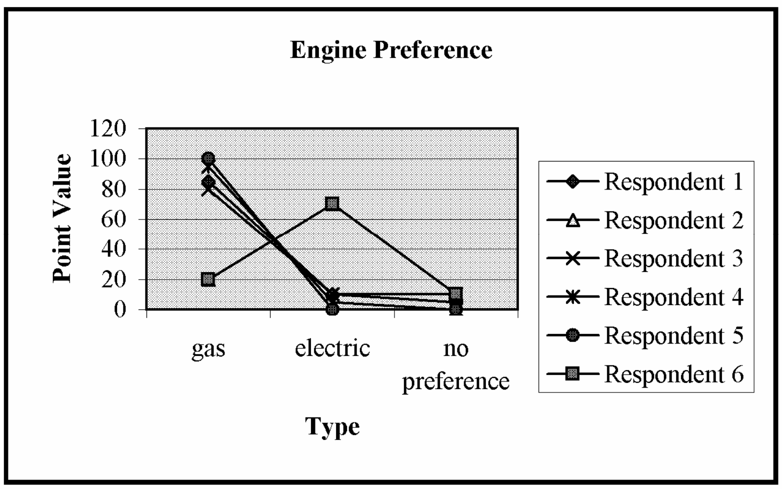
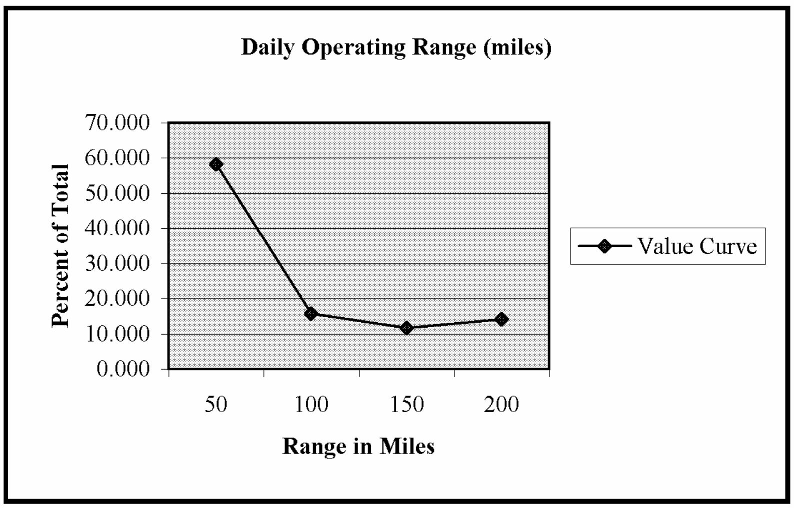


Figure 19: Engine Preference Charts

Daily Operating Range. The daily operating range refers to the maximum distance the vehicle can travel on a single charge or tank of gas. The GEM's maximum operating range of approximately 30 miles was obtained from the manufacturer's website

(GEM, 2005). Operating ranges for the John Deere Gator and Kawasaki Mule were obtained using data from the manufacturer's website. Specific values included a gas tank capacity of 5.3 gallons for the John Deere and 4.1 gallons for the Kawasaki. The gasoline utilization rate of .6 gallon per hour was used for both vehicles as reported by the manufacturer's vehicle specifications (Deere, 2005; Kawasaki, 2005).



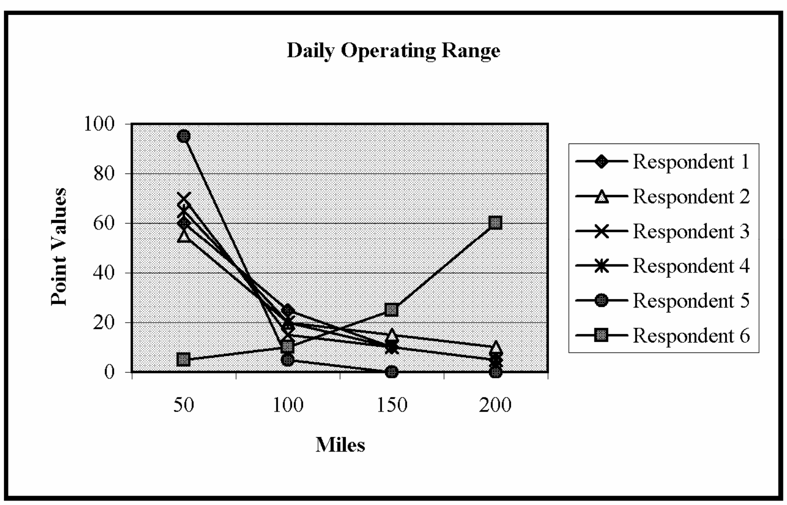
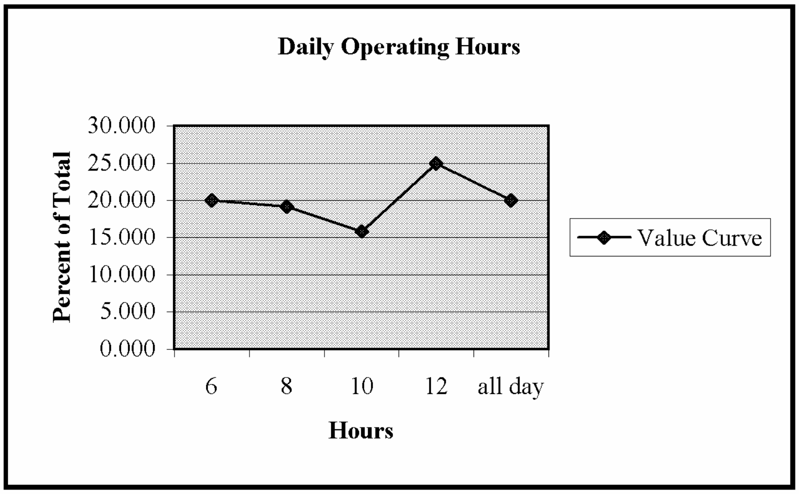


Figure 20: Daily Operating Range Charts

Daily Operating Hours. The daily operating hours refers to the amount of time the vehicle may be used continuously on a single charge or tank of gasoline. While the actual operating time each vehicle may be used is dependant upon the distance traveled per trip, the times used in this research are based on continuous use to allow for meaningful comparison across vehicles. The GEM's operating hours calculation was derived by dividing the maximum distance per charge, 30 miles, by the maximum speed, 25 miles per hour, resulting in a daily operating time of 1.2 hours per vehicle charge (Gem, 2005). The John Deere Gator's operating hours was calculated by the gasoline tank capacity, 5.3 gallons, by the gasoline utilization rate of .6 gallons per hour (Deere, 2005). This resulted in a daily operating time of 8.83 hours. The Kawasaki Mule's operating time was figured in the same manner using a 4.1 gallon tank and a .6 gallon per hour utilization rate which results in a daily operating time of 6.83 hours per tank of gasoline (Kawasaki, 2005). Interpolation was used for both the John Deere and Kawasaki times rounding them to the closest whole number, nine and seven respectively.



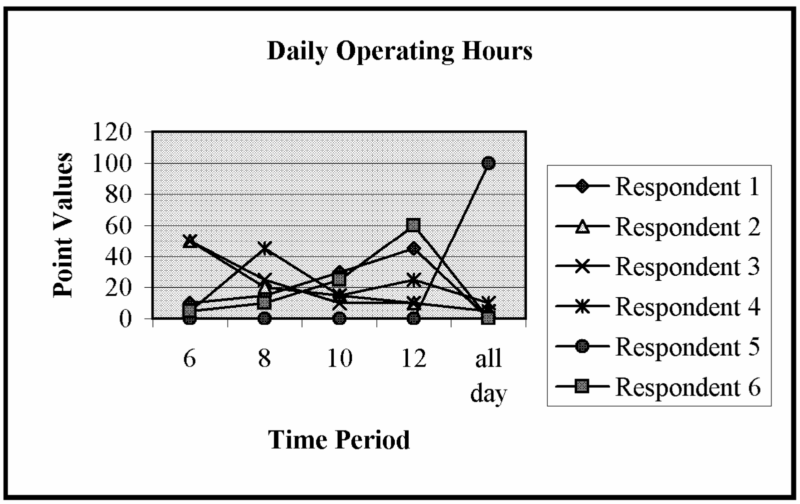
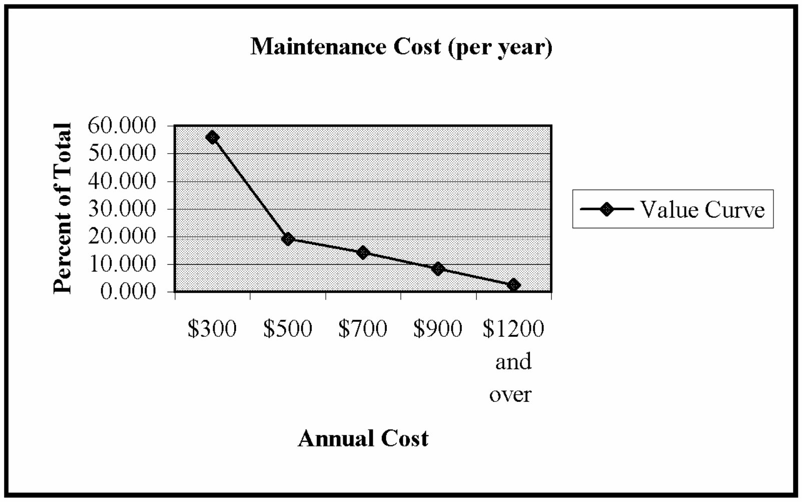


Figure 21: Daily Operating Hours Charts

<u>Maintenance Costs (per year)</u>. Maintenance costs refer to the amount the unit will spend in scheduled and unscheduled repairs and service for the vehicle over the course of a year. The price range, \$300 to over \$1,200, is intended to cover the spectrum of annual maintenance costs.



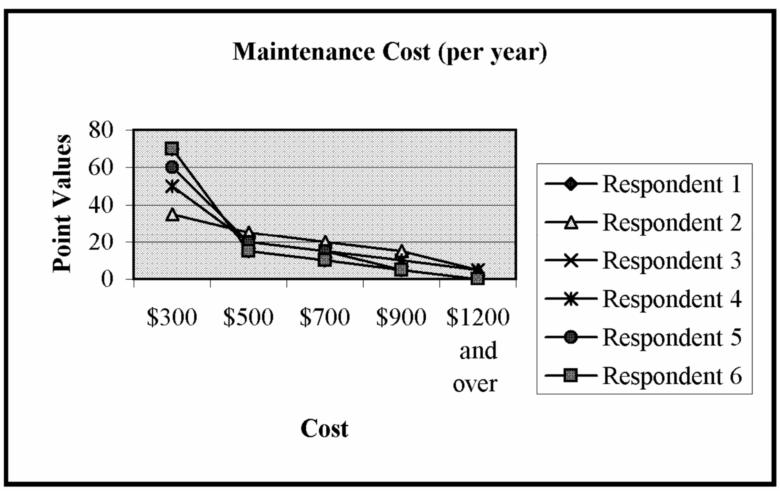
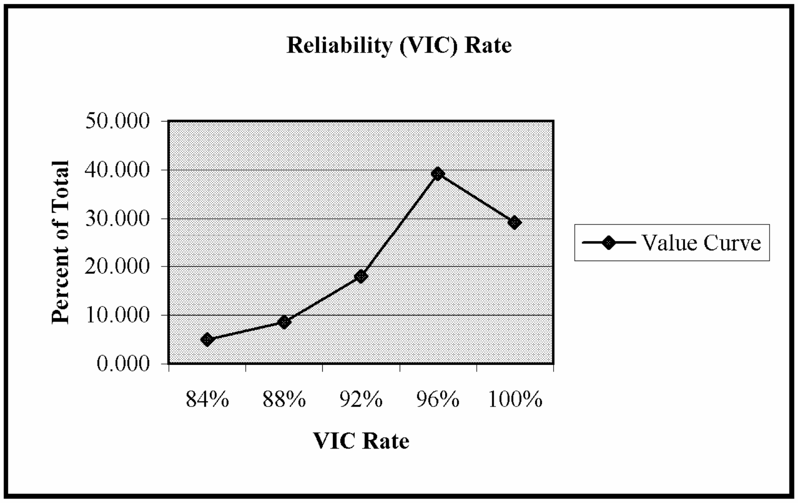


Figure 22: Maintenance Cost Charts

Reliability (VIC) Rate. Reliability, or VIC rate, is intended to show the percentage the vehicle is in service and available for use by the organization. Specific percentage rates were derived to cover the spectrum of those commonly found in Vehicle Maintenance flights.



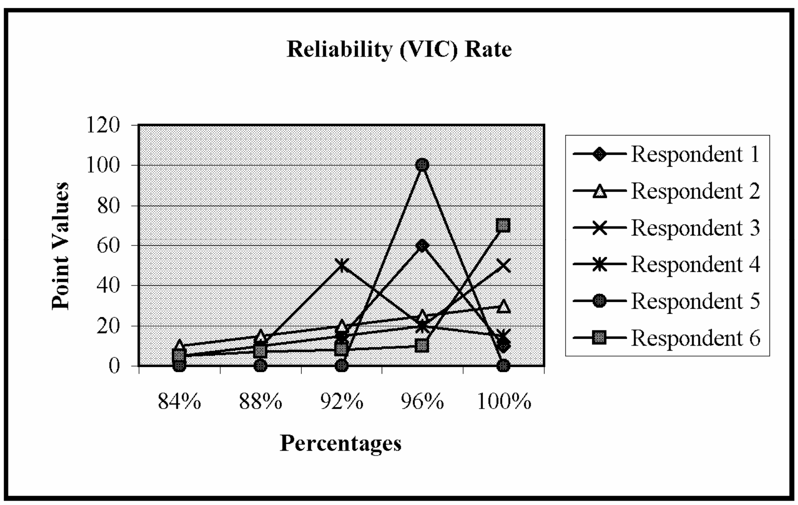


Figure 23: Reliability Rate Charts

Maintenance Costs and Reliability Rates

Despite an exhaustive research effort, maintenance costs detailing annual expenditures or vehicle in commission rates were unavailable. This lack of data; therefore, prohibits their inclusion into the AHP computation. The lack of data available from military organizations who currently posses these assets can be explained by the definition of the vehicles themselves and the resulting management philosophy. LSVs and OGMVCs, as previously mentioned, are procured as equipment items with a requirement to maintain them in accordance with the manufacturer's recommendations. Due to their categorization as equipment items, monthly maintenance records, to include costs of repairs and service as well as vehicle in commission rates, are not required to be kept. Maintenance actions are normally performed by an off-base company with payment coming from the organization's government purchase card. While records of all purchases made from a unit's account do exist, the researcher was unable to find a unit able to produce the documentation detailing amounts spent on routine and unscheduled maintenance.

Despite the lack of data available for these two categories, their importance in the buying decision still needs to be accounted for. To maintain their factor weight importance, zeros will be entered for the three vehicle's points in the Maintenance Cost and Reliability Rate categories. This will keep the remaining six factor's weight in proportion as if the data were available and the factors used.

Summation of Questionnaires and Optimal Vehicle Decision by Respondent

As previously discussed, a two part questionnaire was sent to each of nine PACAF LRS commanders. Results were received from six of the nine squadrons with one respondent completing only half of the questionnaire, omitting the Factor Weights tab. A summation of the questionnaire and application of the results are presented for each respondent below. The methodology follows the AHP as detailed in Chapter Three.

Respondent One. Factor weight information from respondent one indicates that Job Suitability, Maintenance Costs and Reliability Rates are the three most important factors to be considered when purchasing a vehicle (Appendix C). Collectively, these three attributes account for 46.39% of the total weight for all eight factors. This factor weight information, as well as that of the remaining five attributes, was used to weight the points assigned to the various options under each vehicle factor culminating in a vehicle decision using the AHP. The results indicate that based on the preferences of respondent one, the Kawasaki Mule is the best suited vehicle for that particular location given their priorities (Appendix C). It is important to note; however, that the John Deere Gator was only one one-thousandth of a point behind the Kawasaki Mule, making them essentially equally well suited for respondent one's mission (Appendix C).

Respondent Two. Analysis of respondent two's factor weight matrix reveals Job Suitability, Reliability and Maintenance Costs to be the three most significant factors impacting their decision towards purchase of a vehicle (Appendix D). Collectively, the three factors account for 49.34% of the total weight for all factors. In a similar process as described for respondent one, the weighted factor weights were multiplied with their respective individual attribute points to produce an overall score for the three vehicles. The results indicate that the Kawasaki Mule is the best suited vehicle given respondent two's overall priorities (Appendix D).

Respondent Three. The three most significant factors to respondent three when buying a vehicle are Job Suitability, Reliability and Maintenance Costs. Together, these three top factors account for 52.87% of the total weight for all factors. The resulting calculations indicate that the Kawasaki Mule is the best suited vehicle for the given locations priorities (Appendix E).

Respondent Four. Factor weight information from respondent four indicated that Delivery Time, Procurement Cost, and Fuel Efficiency are the three most important aspects to consider when purchasing a vehicle (Appendix F). Collectively, the three factors account for 46.35% of the total weight for all factors. Based on the responses to the questionnaire, two vehicles tied in points for being the best suited for the particular location's needs and priorities. The John Deere Gator and Kawasaki Mule both received .3685 points in the final analysis (Appendix F).

Respondent Five. Analysis of respondent five's factor weight information reveals that the three most important aspects they consider when purchasing a vehicle are Job Suitability, Maintenance Costs, and Procurement Costs (Appendix G). Collectively, the three factors account for 47.32% of the total weight across all factors. Final calculations indicated that the Kawasaki Mule is the most well suited vehicle based on the respondent's priorities (Appendix G).

Respondent Six. Respondent six did not return the factor weight portion of the questionnaire, thus preventing a true location specific determination of the most appropriate vehicle for their use. However, in an effort to still use their individual factor weight point assessments, an average factor weight from across the remaining five respondents was used. The three most important factors from across the respondents were Job Suitability, Maintenance Costs and Reliability (Appendix H). Using the aggregate of the factor weights applied to respondent six's individual factor weight point assessments produces a response giving the John Deere the most points from among the three compared. Therefore, the John Deere Gator is the best suited for respondent six based on the aggregate of priorities from the remaining five respondents applied to respondent six's individual point values (Appendix G).

In reviewing the individual response results, the Kawasaki Mule was chosen as the optimum vehicle four times, the Kawasaki Mule and John Deere Gator tied for most effective vehicle once, and the John Deere Gator being chosen best once. This indicates a strong preference for gasoline based vehicles versus electric when considering an alternative to the general purpose vehicle.

Summation of Questionnaires and Optimal Vehicle Decision for PACAF as a Whole

The five factor weight matrices from part one of the questionnaire are presented in Figure 24 below. Next, the five matrices were averaged together to obtain one overall factor weight matrix (Figure 25). Following the procedures presented in the previous chapter, the final relative factor weights were obtained and are presented in Figure 26 below.

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	6	6	7	7	7	8	7
Procurement Cost	4	5	6	4	4	7	8	7
Maintenance Cost	4	4	5	6	6	8	7	7
Reliability	3	6	4	5	7	7	7	8
Ease of Service	3	6	4	3	5	6	7	7
Fuel Efficiency	3	3	2	3	4	5	6	6
Warranty	2	2	3	3	3	4	5	4
Delivery Time	3	3	3	2	3	4	6	5

Respondent 1

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	7	6	7	8	8	8	7
Procurement Cost	3	5	4	3	6	6	6	7
Maintenance Cost	4	6	5	5	7	7	7	7
Reliability	3	7	5	5	8	8	8	7
Ease of Service	2	4	3	2	5	7	7	7
Fuel Efficiency	2	4	3	2	3	5	4	6
Warranty	2	4	3	2	3	6	5	7
Delivery Time	3	3	3	3	3	4	3	5

Respondent 2

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	9	9	9	9	9	9	7
Procurement Cost	1	5	3	3	8	4	8	7
Maintenance Cost	1	7	5	4	8	7	8	6
Reliability	1	7	6	5	9	7	9	8
Ease of Service	1	2	2	1	5	2	8	7
Fuel Efficiency	1	6	3	3	8	5	8	8
Warranty	1	2	2	1	2	2	5	2
Delivery Time	3	3	4	2	3	2	8	5

Respondent 3

Figure 24: Five Factor Weight Matrices

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	7	4	7	7	3	7	2
Procurement Cost	3	5	7	8	8	3	7	2
Maintenance Cost	6	3	5	9	6	3	7	2
Reliability	3	2	1	5	8	3	7	2
Ease of Service	3	2	4	2	5	3	7	2
Fuel Efficiency	7	7	7	7	7	5	1	1
Warranty	3	3	3	3	3	9	5	2
Delivery Time	8	8	8	8	8	9	8	5

Respondent 4

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	6	7	8	8	6	8	6
Procurement Cost	4	5	4	4	6	5	8	6
Maintenance Cost	3	6	5	9	9	6	9	6
Reliability	2	6	1	5	8	6	8	6
Ease of Service	2	4	1	2	5	4	8	6
Fuel Efficiency	4	5	4	4	6	5	5	6
Warranty	2	2	1	2	2	5	5	6
Delivery Time	4	4	4	4	4	4	4	5

Respondent 5

Figure 24: Five Factor Weight Matrices Continued

Overall	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	7	6	8	8	7	8	6
Procurement Cost	3	5	5	4	6	5	7	6
Maintenance Cost	4	5	5	7	7	6	8	6
Reliability	2	6	3	5	8	6	8	6
Ease of Service	2	4	3	2	5	4	7	6
Fuel Efficiency	3	5	4	4	4	5	5	5
Warranty	2	3	2	2	3	5	5	4
Delivery Time	4	4	4	4	4	5	6	5
totals =	26	38	33	35	45	43	54	44

Figure 25: Overall Factor Matrix

									totals/8
Job Suitability	0.1938	0.1832	0.1939	0.2147	0.1718	0.1528	0.1487	0.1324	0.1739
Procurement Cost	0.1163	0.1309	0.1455	0.1243	0.1410	0.1157	0.1375	0.1324	0.1304
Maintenance Cost	0.1395	0.1361	0.1515	0.1864	0.1586	0.1435	0.1413	0.1279	0.1481
Reliability	0.0930	0.1466	0.1030	0.1412	0.1762	0.1435	0.1450	0.1416	0.1363
Ease of Service	0.0853	0.0942	0.0848	0.0565	0.1101	0.1019	0.1375	0.1324	0.1004
Fuel Efficiency	0.1318	0.1309	0.1152	0.1073	0.0925	0.1157	0.0892	0.1233	0.1132
Warranty	0.0775	0.0681	0.0727	0.0621	0.0573	0.1204	0.0929	0.0959	0.0809
Delivery Time	0.1628	0.1099	0.1333	0.1073	0.0925	0.1065	0.1078	0.1142	0.1168

Figure 26: Final Relative Weights

Commanders considered Job Suitability, which is comprised of availability of utility bed, engine type, daily operating range, and daily operating hours, as the single most important aspect when considering a vehicle purchase receiving a 17.39% factor weight. Routine and unscheduled maintenance costs were also important to commanders as the Maintenance Cost (per year) factor was rated second most important at 14.81%. Keeping with the same priorities and interests, Reliability (VIC) Rate was the third most important factor to be considered have a 13.63% weight. Therefore, the top three factors comprise 45.83% of the total factor weight when considering which vehicle to purchase.

Part two of the questionnaire is presented in Figure 27 below. The matrices indicate how each respondent assigned points to the various options under each vehicle factor. Additionally, they present both the average point value for each option from across the six respondents and the possible points to be awarded if a vehicle falls into that option's criterion. Next, using information from the manufacturer's websites, points were assigned to each vehicle, in each attribute category, based on how the vehicle's specifications or performance compared to the desired values of the commanders (Figure 28). It is important to mention that a vehicle will not be given fewer points for overachieving an outcome in a category. For example, under the daily operating range category, commanders assign more points to achieving the capability of fifty miles per day than they do to the capability of traveling one hundred miles or higher. It is recognized that commanders determined, on average, fifty miles may be all that is required for one day's operation. However, exceeding that milestone will be viewed as a benefit and the vehicle will be awarded the highest point value in that category for which its specifications qualify. This situation was applied to the values in the Daily Operating Range, Daily Operating Hours, and Fuel Efficiency categories.

Procurement Cost

Respondent	1	2	3	4	5	6	Total Divided by 6	Points
$6,000	10	70	70	20	60	70	50.00	10.00
$9,000	25	15	15	30	20	15	20.00	4.00
$12,000	60	10	10	50	15	10	25.83	5.17
$15,000	5	5	5	0	5	5	4.17	0.83
total =	100	100	100	100	100	100	100.00	20.00

Maintenance Cost (per year)

Respondent	1	2	3	4	5	6	Total Divided by 6	Points
$300	70	35	50	60	50	70	55.83	11.17
$500	15	25	20	20	20	15	19.17	3.83
$700	10	20	15	15	15	10	14.17	2.83
$900	5	15	10	5	10	5	8.33	1.67
$1200 and over	0	5	5	0	5	0	2.50	0.50
total =	100	100	100	100	100	100	100.00	20.00

Reliability (VIC) Rate

Respondent	1	2	3	4	5	6	Total Divided by 6	Points
84%	5	10	5	0	5	5	5.00	1.00
88%	10	15	10	0	10	7	8.67	1.73
92%	15	20	15	0	50	8	18.00	3.60
96%	60	25	20	100	20	10	39.17	7.83
100%	10	30	50	0	15	70	29.17	5.83
total =	100	100	100	100	100	100	100.00	20.00

Ease of Service
Availability of Parts

Respondent	1	2	3	4	5	6	Total Divided by 6	Points
immediate area	45	70	60	90	25	40	55.00	11.00
surrounding community	25	20	30	10	50	35	28.33	5.67
Mail order	10	10	10	0	25	25	13.33	2.67
total =	80	100	100	100	100	100	96.67	19.33

Figure 27: Point Assignment by Respondent and Attribute

Fuel Efficiency (per mile)

Respondent	1	2	3	4	5	6	Total Divided by 6	Points
$0.01	10	50	35	0	0	50	24.17	4.83
$0.05	20	20	25	0	80	20	27.50	5.50
$0.09	50	15	20	50	20	15	28.33	5.67
$0.13	15	10	15	40	0	10	15.00	3.00
$0.17	5	5	5	10	0	5	5.00	1.00
total =	100	100	100	100	100	100	100.00	20.00

Warranty (in years)

Respondent	1	2	3	4	5	6	Total Divided by 6	Points
1	20	10	15	85	80	10	36.67	7.33
2	30	15	25	10	15	20	19.17	3.83
3	50	75	60	5	5	70	44.17	8.83
total =	100	100	100	100	100	100	100.00	20.00

Delivery (in weeks)

Respondent	1	2	3	4	5	6	Total Divided by 6	Points
6	50	50	30	60	10	50	41.67	8.33
10	30	20	40	20	60	20	31.67	6.33
14	15	15	15	10	25	15	15.83	3.17
18	5	10	10	10	5	10	8.33	1.67
22 and over	0	5	5	0	0	5	2.50	0.50
total =	100	100	100	100	100	100	100.00	20.00

Job Suitability

Availability of Utility Bed

Respondent	1	2	3	4	5	6	Total Divided by 6	Points
none	10	10	30	0	0	20	11.67	2.33
short	25	30	15	0	30	50	25.00	5.00
long	60	40	50	0	25	30	34.17	6.83
does not matter	5	20	5	100	45	0	29.17	5.83
total =	100	100	100	100	100	100	100.00	20.00

Figure 27: Point Assignment by Respondent and Attribute Continued

Engine Preference

Respondent	1	2	3	4	5	6	Total Divided by 6	Points
gas	85	20	80	100	95	20	66.67	13.33
electric	10	70	10	0	5	70	27.50	5.50
no preference	5	10	10	0	0	10	5.83	1.17
total =	100	100	100	100	100	100	100.00	20.00

Daily Operating Range (miles)

Respondent	1	2	3	4	5	6	Total Divided by 6	Points
50	60	55	70	95	65	5	58.33	11.67
100	25	20	15	5	20	10	15.83	3.17
150	10	15	10	0	10	25	11.67	2.33
200	5	10	5	0	5	60	14.17	2.83
total =	100	100	100	100	100	100	100.00	20.00

Daily Operating Hours

Respondent	1	2	3	4	5	6	Total Divided by 6	Points
6	10	50	50	0	5	5	20.00	4.00
8	15	20	25	0	45	10	19.17	3.83
10	30	15	10	0	15	25	15.83	3.17
12	45	10	10	0	25	60	25.00	5.00
all day	0	5	5	100	10	0	20.00	4.00
total =	100	100	100	100	100	100	100.00	20.00

Figure 27: Point Assignment by Respondent and Attribute Continued

Procurement Cost

	Gem	Gator	Mule
GEM	1	8	8
Gator	10	1	10
Mule	10	10	1
Totals =	21	19	19

			Row totals/3
0.0476	0.4211	0.4211	0.2966
0.4762	0.0526	0.5263	0.3517
0.4762	0.5263	0.0526	0.3517

Maintenance Cost

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Engine Preference

	Gem	Gator	Mule
Gem	1	5.5	5.5
Gator	13.3334	1	13.3334
Mule	13.3334	13.3334	1
Totals =	27.6668	19.8334	19.8334

			Row totals/3
0.0361	0.2773	0.2773	0.1969
0.4819	0.0504	0.6723	0.4015
0.4819	0.6723	0.0504	0.4015

Reliability (VIC) Rate

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Ease of Service/Parts

	Gem	Gator	Mule
GEM	1	2.6666	2.6666
Gator	5.6666	1	5.6666
Mule	5.6666	5.6666	1
Totals =	12.3332	9.3332	9.3332

			Row totals/3
0.0811	0.2857	0.2857	0.2175
0.4595	0.1071	0.6071	0.3912
0.4595	0.6071	0.1071	0.3912

Fuel Efficiency

	Gem	Gator	Mule
GEM	1	5.5	5.5
Gator	5.5	1	5.5
Mule	5.5	5.5	1
Totals =	12	12	12

			Row totals/3
0.0833	0.4583	0.4583	0.3333
0.4583	0.0833	0.4583	0.3333
0.4583	0.4583	0.0833	0.3333

Figure 28: Normalized Points by Vehicle Type

Warranty

	Gem	Gator	Mule
GEM	1	7.334	7.334
Gator	7.334	1	7.334
Mule	7.334	7.334	1
Totals =	15.668	15.668	15.668

			Row totals/3
0.0638	0.4681	0.4681	0.3333
0.4681	0.0638	0.4681	0.3333
0.4681	0.4681	0.0638	0.3333

Delivery in weeks

	Gem	Gator	Mule
GEM	1	4.75	4.75
Gator	8.3334	1	8.3334
Mule	8.3334	8.3334	1
Totals =	17.6668	14.0834	14.0834

			Row totals/3
0.0566	0.3373	0.3373	0.2437
0.4717	0.0710	0.5917	0.3781
0.4717	0.5917	0.0710	0.3781

Availability of Utility

	Gem	Gator	Mule
GEM	1	6.8334	6.8334
Gator	6.8334	1	6.8334
Mule	6.8334	6.8334	1
Totals =	14.6668	14.6668	14.6668

			Row totals/3
0.0682	0.4659	0.4659	0.3333
0.4659	0.0682	0.4659	0.3333
0.4659	0.4659	0.0682	0.3333

Daily Operating Range

	Gem	Gator	Mule
GEM	1	0	0
Gator	11.6666	1	11.6666
Mule	11.6666	11.6666	1
Totals =	24.3332	12.6666	12.6666

			Row totals/3
0.0411	0.0000	0.0000	0.0137
0.4795	0.0789	0.9211	0.4932
0.4795	0.9211	0.0789	0.4932

Daily Operating Hours

	Gem	Gator	Mule
GEM	1	0	0
Gator	4	1	4
Mule	4	4	1
Totals =	9	5	5

			Row totals/3
0.1111	0.0000	0.0000	0.0370
0.4444	0.2000	0.8000	0.4815
0.4444	0.8000	0.2000	0.4815

Figure 28: Normalized Points by Vehicle Type Continued

As previously mentioned, actual data for annual maintenance costs and reliability rates for the three vehicles being considered were unavailable. To keep the factor weighting in line with the commanders specifications, a zero point value was entered into both matrices to obtain vehicle point scores. To complete the AHP, the point totals (Figure 29) were multiplied by their overall factor weight (Figure 26) to produce a matrix containing the weighted point values for each vehicle in each of the eight main categories as indicated in Figure 30. Finally, the rows were summed to obtain the final rating for each of the three vehicles (Figure 30).

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Utility Bed
GEM	0.2966	0.3333	0.3333	0.2175	0.3333	0.3333	0.2437	0.3333
J. D.	0.3517	0.3333	0.3333	0.3912	0.3333	0.3333	0.3781	0.3333
Kawasaki	0.3517	0.3333	0.3333	0.3912	0.3333	0.3333	0.3781	0.3333

	Engine Preference	Daily Operating Range	Daily Operating Hours	Averaged Job Suitability
GEM	0.1969	0.0137	0.0370	0.1452
J. D.	0.4015	0.4932	0.4815	0.4274
Kawasaki	0.4015	0.4932	0.4815	0.4274

Figure 29: Summation of Point Totals

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Job Suitability	Grand Total
GEM	0.0387	0.0494	0.0454	0.0218	0.0377	0.0270	0.0285	0.0253	0.2737
J. D.	0.0459	0.0494	0.0454	0.0393	0.0377	0.0270	0.0442	0.0743	0.3631
Kawasaki	0.0459	0.0494	0.0454	0.0393	0.0377	0.0270	0.0442	0.0743	0.3631

Figure 30: Weighted Point Totals and Result Totals

Based on PACAF LRS commander's input, either the John Deere Gator or the Kawasaki Mule would best serve the aggregate demands of its users. Both vehicles have very similar characteristics and performance resulting in an equal rating at the command preference level.

Chapter Summary

This chapter answered the three investigative questions as discussed in Chapter One. Next, the eleven vehicle attributes used in this research were discussed, followed by a summation of each respondent's results and selection of the most appropriate alternative to the general purpose vehicle by each responding location. The chapter concluded with the results for PACAF as a whole, addressing both the relative importance of each attribute and selection of the best vehicle for the command.

V. Conclusions and Recommendations

This chapter reviews the results and major issues covered in the research, followed by a discussion on the importance of the research findings. The chapter concludes with recommendations for future research related to this topic.

A review of the individual and group responses from the questionnaire reveals that there are several factors more important than the initial purchase price of a vehicle. Foremost, commanders want a vehicle that is well suited for the particular mission of the unit. A combination of engine type, daily operating range and hours, and availability of a utility bed formed the job suitability factor, which was ranked most important by four of five squadron commanders. Following this practical application towards vehicle attributes, commanders are also very concerned with the cost to maintain the vehicle along with its availability for use. Maintenance cost and reliability rates ranked second or third in all but one response, further emphasizing their importance in the overall decision process. The resulting conclusion indicates that commanders want a vehicle that can perform its purpose at a relatively low cost while minimizing out-of-service times due to maintenance problems. Through the use of the AHP, the John Deere Gator and the Kawasaki Mule performed best during the course of this analysis.

This research has detailed an important problem in the management of vehicles as equipment items. It has shown that annual maintenance costs and vehicle reliability rates are two of the most important factors squadron commanders would consider when making equipment item vehicle purchases. However, due to current policy, tracking maintenance costs and reliability rates per vehicle type is not being accomplished. This lack of information limits the ability of commanders to make a fully informed buying decision which potentially results in suboptimal purchases that, in the long term, could result in unnecessary additional costs to the unit.

One possible example of this situation occurring can be seen in the squadron commander's preference for the initial purchase price of the vehicle. Four of the six respondents indicated a continually decreasing preference to increasingly expensive vehicles. However, two respondents indicated an increasing preference for a more expensive vehicle purchase price from $6,000 to $12,000 as demonstrated in Figure 13. This demonstrates two things. First, it appears that $12,000 is the maximum amount squadron commanders are willing to pay for an equipment item classified vehicle. Second, if we assume that the commanders who showed an increasing preference for a more expensive vehicle are doing so for an anticipated return on their investment in the way of increased quality, it underscores the need for life cycle maintenance costs and reliability rates for the vehicles being considered. The commander purchasing a $12,000 equipment item vehicle may be purchasing a higher quality product; however, without annual maintenance cost and reliability information this determination can not be made. Further, it is plausible that the annual maintenance costs and reliability rates for a $6,000 and $12,000 vehicle may be the same. If this were true, the purchase of the more expensive vehicle would simply be costing the unit an additional $6,000 in unit funds without returning a benefit for increased cost.

Another important finding of this research can be seen in the respondents' preferences towards vehicle engine types. Four of the six respondents indicated a very strong preference towards gas engine powered vehicles as opposed to vehicles with an electric motor. Further, analysis of the two locations indicating an electric engine preference reveals that both locations have prior electric vehicle experience or education. This familiarization may make them more likely to include electric vehicles in their fleets.

Finally, the daily operating range question generated an interesting result. Five of the six respondents indicated a decreasing preference for an increasing longer operating range. One possible explanation for this may be that it demonstrates the intended use of equipment item vehicles within the workplace. It appears that commanders envision their use for short distance trips. This would result in increased availability of the traditional general purpose vehicle fleet to perform functions more suited to that vehicle's capability.

The research has indicated that commanders have many options when considering the purchase of an LSV or OGMVC. Deciding upon which vehicle to purchase may depend on many factors specific to the base that is considering the purchase. For example, a cold climate base would probably be more inclined to purchase a vehicle that can control for environmental factors while a base with many hills may be inclined to purchase a vehicle that does especially well in uphill driving. It is important to note that these specific factors will shape the priorities in deciding upon a vehicle for that location and may result in different vehicle attributes being used in the AHP than those used during this research effort.

Recommendations for Future Research

A key result of this research was the identification of pertinent vehicle attributes and creation of a decision building model that can be easily tailored to a unit's unique mission. The attributes were based partly on industry defined factors that, in some instances, may not be as important or as applicable to the military unit. Future research should focus on identifying, through a survey, what specific attributes are important to the military commander. Additionally, obtaining actual maintenance and vehicle in commission records for the vehicles being considered would produce a more accurate analysis and judgment of the vehicles.

Appendix A: Vehicle Specifications

Global Electric Motorcar (GEM)

Weights and Measures:

- Curb Weight: 1078 pounds Length: 99 inches
- GVW: 1600 pounds Height: 68 inches
- Width: 55 inches Turning Radius: 12 feet 6 inches
- Wheelbase: 72 inches

Powertrain

- Motor: 72-volt shunt GE motor
- Transmission: Front-wheel-drive Dana Spicer speed reducer with integral differential
- Speed Controller: GE solid-state custom controller
- Battery Pack: Six Trojan 12-volt deep-cycle batteries (optional Deka Gel - maintenance free)
- Onboard Charger: Proprietary 72-volt DC using 110-volt AC input.

Chassis

- Tires: 10-inch two-ply street and turf-rated tires
- Brakes: Four-wheel automotive-style hydraulic brakes and parking brake
- Front Suspension: Dual a-arm independent suspension with coil over shocks
- Rear Suspension: Trailing arm with two coil spring/shock units
- Steering: Automotive rack-and-pinion with permanently sealed tie-rod ends
- Frame: Aluminum welded space frame using custom aluminum-alloy extrusions

Body

- Seating: Seats two occupants
- Bench seat using a molded foam cushion covered by marine-grade
- UV-stable vinyl coverings
- Passenger Restraints: Automotive-design three-point safety belts
- Lighting: Quartz-halogen headlamps, front and rear turn signals, high-mount rear brake and taillamps with a 20 second safety delay after vehicle is turned off.
- Windshield: Laminated, tinted automotive safety glass with wiper
- Body: Structural composite and thermoplastic panels
- Horn: Standard
- Floor Mat: Standard
- Safety Handles: Dual upper hand (optional) and lower seat rail
- Reflector: Rear and side
- Mirror: Rearview and dual exterior (driver’s side standard, passenger side optional)

Performance

- Speed: Dual Controllable Low: 0-15 mph High: 0-25 mph
- Range: Up to 30 miles

Kawasaki Mule

Weights and Measurements

- Wheelbase: 70.0 in.
- Overall length: 107.1 in.
- Overall width: 52.6 in.
- Overall height: 70.9 in.
- Ground clearance: 6.7 in.

Powertrain

- Engine: Four-stroke single-cylinder
- Displacement: 401cc
- Bore x stroke: 82 x 76mm
- Carburetor: Nikki 6C1026
- Cooling: Fan assisted, air cooled
- Ignition: Magneto and transistor

Chassis

- Drive train: Continuously variable transmission with high and low range plus reverse
- Final drive: Shaft-driven selectable four-wheel drive, dual-mode rear differential
- Front suspension: MacPherson strut
- Rear suspension: Unit swing-axle

Body

- Front and rear tires: Tubeless 24x9-10 and 24x11-10
- Brakes: Four-wheel hydraulic drums, triple-sealed
- Dry weight: 974.2 lbs.
- Fuel capacity: 4.1 gal.
- Instruments/lighting: Oil temperature meter, hour meter, gourd-style headlights, taillight and stoplight

Performance

- Turning radius: 10.8 ft.
- Load capacity: 926 lbs.
- Bed capacity: 400 lbs.
- Towing capacity: 1,100 lbs.

John Deere Gator

Weights and Measurements
- Wheelbase: 65.5 in.
- Overall width: 49.0 in.
- Overall height: 44 in.

Powertrain
- Engine: Four-stroke single-cylinder
- Cooling: Air
- Ignition: Magneto solid state

Chassis
- Drive train: Continuously variable transmission
- Front suspension: Ind., spring-over-shock, single A-arm
- Rear suspension: Two-high-flotation low pressure tires

Body
- Front tires: 18x8.5-8, 4PR
- Rear tires: 20x10-8, 2PR
- Brakes: Wet disk and transaxle
- Wet weight: 653 lbs.

Performance
- Turning radius: 19.9 feet
- Load capacity: 800 lbs.
- Bed capacity: 400 lbs.
- Towing capacity: 600 lbs.

Appendix B: Questionnaire

Squadron CCs: Please rate the importance of each vehicle attribute below against each of the other attributes using the following scale:

1	absolutely not preferred	6	weakly preferred
2	very strongly not preferred	7	strongly preferred
3	strongly not preferred	8	very strongly preferred
4	weakly not preferred	9	absolutely preferred
5	equivalent		

For example: If job suitability is determined to be weakly preferred to procurement cost a 6 would be placed in the block as indicated below. If job suitability were to be very strongly preferred to fuel efficiency an 8 would be placed in the corresponding cell as indicated below.

Example of filled in sheet:

B

A	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	6	6	7	7	8	8	7
Procurement Cost		5	6	4	4	7	8	7
Maintenance Cost			5	6	6	8	7	7
Reliability				5	7	7	7	8
Ease of Service					5	6	7	7
Fuel Efficiency						5	6	6
Warranty							5	4
Delivery Time								5

In summary, the above chart shows that Job Suitability (A) is weakly preferred to Procurement Cost (B), weakly preferred to Maintenance Cost (B), strongly preferred to Reliability (B), strongly preferred to Ease of Service (B), etc. The purpose of this analysis will allow me to understand which factors are more important and how much more important one factor is over another.

Using the above as an exmple, please complete the below chart based on which attributes are most important to you as a commander.

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5							
Procurement Cost		5						
Maintenance Cost			5					
Reliability				5				
Ease of Service					5			
Fuel Efficiency						5		
Warranty							5	
Delivery Time								5

Squadron CCs: In an effort to understand your preferences and their respective weights, please distribute a total of 100 points across the possibilities for each vehicle attribute. Additionally, please consider the possibility that a lower procurement cost may be related to an increased maintenance cost and reduced VIC rates. Likewise, a very high VIC rate may equate to increased maintenance costs.

Example:

Procurement Cost	Point Values*
$6,000	60
$9,000	20
$12,000	15
$15,000	5
total =	*100*

* When distributing points, please do not repeat the same value in any one attribute i.e. 70, 10, 10, 10. The lowest value any option can receive is five points. This example indicates a much stronger preference for a lower initial procurement cost.

Procurement Cost	Point Values
$6,000	
$9,000	
$12,000	
$15,000	
total =	0

Maintenance Cost (per year)	Point Values
$300	
$500	
$700	
$900	
$1200 and over	
total =	0

Reliability (VIC) rate	Point Values
84%	
88%	
92%	
96%	
100%	
total =	0

Vehicle Management Managers: In an effort to understand your preferences and their respective weights, please distribute a total of 100 points across the possibilities for each vehicle attribute.

Example:

Job Suitability

Availability of utility bed	Point Values*
none	60
short	20
long	15
does not matter	5
total =	*100*

* When distributing points, please do not repeat the same value in any one attribute i.e. 70, 10, 10, 10. The lowest value any option can receive is five points. This example indicates a much stronger preference for no utility bed on the LSV.

Job Suitability

Availability of utility bed	Point Values
none	
short	
long	
does not matter	
total =	0

Engine Preference	Point Values
gas	
electric	
no preference	
total =	0

Daily Operating Range (miles)	Point Values
50	
100	
150	
200	
total =	0

Daily Operating Hours	Point Values
6	
8	
10	
12	
all day	
total =	0

Ease of Service

Availability of parts in:	Point Values
immediate area	
surrounding community	
Mail order	
total =	0

Fuel Efficiency (per mile)	**Point Values**
$0.01	
$0.05	
$0.09	
$0.13	
$0.17	
total =	0

Warranty (in years)	**Point Values**
1	
2	
3	
total =	0

Delivery (in weeks)	**Point Values**
6	
10	
14	
18	
22 and over	
total =	0

Appendix C: Respondent One's Data

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	6	6	7	7	7	8	7
Procurement Cost	4	5	6	4	4	7	8	7
Maintenance Cost	4	4	5	6	6	8	7	7
Reliability	3	6	4	5	7	7	7	8
Ease of Service	3	6	4	3	5	6	7	7
Fuel Efficiency	3	3	2	3	4	5	6	6
Warranty	2	2	3	3	3	4	5	4
Delivery Time	3	3	3	2	3	4	6	5
Column Totals	27	35	33	33	39	48	54	51

Factor Weight Matrix

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Totals Divided by 8
Job Suitability	0.1852	0.1714	0.1818	0.2121	0.1795	0.1458	0.1481	0.1373	0.1702
Procurement Cost	0.1481	0.1429	0.1818	0.1212	0.1026	0.1458	0.1481	0.1373	0.1410
Maintenance Cost	0.1481	0.1143	0.1515	0.1818	0.1538	0.1667	0.1296	0.1373	0.1479
Reliability	0.1111	0.1714	0.1212	0.1515	0.1795	0.1458	0.1296	0.1569	0.1459
Ease of Service	0.1111	0.1714	0.1212	0.0909	0.1282	0.1250	0.1296	0.1373	0.1268
Fuel Efficiency	0.1111	0.0857	0.0606	0.0909	0.1026	0.1042	0.1111	0.1176	0.0980
Warranty	0.0741	0.0571	0.0909	0.0909	0.0769	0.0833	0.0926	0.0784	0.0805
Delivery Time	0.1111	0.0857	0.0909	0.0606	0.0769	0.0833	0.1111	0.0980	0.0897

Final Relative Weights

Procurement Cost

	Respondent Values	Category Points
$6,000	10	2
$9,000	25	5
$12,000	60	12
$15,000	5	1
total =	100	20

Maintenance Cost

	Respondent Values	Category Points
$300	70	14
$500	15	3
$700	10	2
$900	5	1
$1200 and over	0	0
total =	100	20

Reliabilty (VIC) Rate

	Respondent Values	Category Points
84%	5	1
88%	10	2
92%	15	3
96%	60	12
100%	10	2
total =	100	20

Availability of Utility Bed

	Respondent Values	Category Points
none	10	2
short	25	5
long	60	12
does not matter	5	1
total =	100	20

Engine Preference

	Respondent Values	Category Points
gas	85	17
electric	10	2
no preference	5	1
total =	100	20

Daily Operating Range

	Respondent Values	Category Points
50	60	12
100	25	5
150	10	2
200	5	1
total =	100	20

Daily Operating Hours

	Respondent Values	Category Points
6	10	2
8	15	3
10	30	6
12	45	9
all day	0	0
total =	100	20

Ease of Service

	Respondent Values	Category Points
immediate area	45	9
surrounding community	25	5
Mail order	10	2
total =	100	20

Point Assignment by Attribute

Fuel Efficiency

	Respondent Values	Category Points
$0.01	10	2
$0.05	20	4
$0.09	50	10
$0.13	15	3
$0.17	5	1
total =	100	20

Warranty (in years)

	Respondent Values	Category Points
1	20	4
2	30	6
3	50	10
total =	100	20

Delivery in Weeks

	Respondent Values	Category Points
6	50	10
10	30	6
14	15	3
18	5	1
22 and over	0	0
total =	100	20

Point Assignment by Attribute Continued

Procurement Cost

	Gem	Gator	Mule
GEM	1	3	3
Gator	2	1	2
Mule	2	2	1
Totals =	5	6	6

			Row totals/3
0.2000	0.5000	0.5000	0.4000
0.4000	0.1667	0.3333	0.3000
0.4000	0.3333	0.1667	0.3000

Maintenance Cost

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Engine Preference

	Gem	Gator	Mule
Gem	1	2	2
Gator	17	1	17
Mule	17	17	1
Totals =	35	20	20

			Row totals/3
0.0286	0.1000	0.1000	0.0762
0.4857	0.0500	0.8500	0.4619
0.4857	0.8500	0.0500	0.4619

Reliability (VIC) Rate

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Ease of Service/Parts

	Gem	Gator	Mule
GEM	1	2	2
Gator	5	1	5
Mule	5	5	1
Totals =	11	8	8

			Row totals/3
0.0909	0.2500	0.2500	0.1970
0.4545	0.1250	0.6250	0.4015
0.4545	0.6250	0.1250	0.4015

Fuel Efficiency

	Gem	Gator	Mule
GEM	1	2.5	2.5
Gator	3.5	1	3.5
Mule	3.5	3.5	1
Totals =	8	7	7

			Row totals/3
0.1250	0.3571	0.3571	0.2798
0.4375	0.1429	0.5000	0.3601
0.4375	0.5000	0.1429	0.3601

Normalized Points by Vehicle Type

Warranty

	Gem	Gator	Mule
GEM	1	4	4
Gator	4	1	4
Mule	4	4	1
Totals =	9	9	9

			Row totals/3
0.1111	0.4444	0.4444	0.3333
0.4444	0.1111	0.4444	0.3333
0.4444	0.4444	0.1111	0.3333

Delivery in weeks

	Gem	Gator	Mule
GEM	1	10	10
Gator	10	1	10
Mule	10	10	1
Totals =	21	21	21

			Row totals/3
0.0476	0.4762	0.4762	0.3333
0.4762	0.0476	0.4762	0.3333
0.4762	0.4762	0.0476	0.3333

Availability of Utility

	Gem	Gator	Mule
GEM	1	12	12
Gator	12	1	12
Mule	12	12	1
Totals =	25	25	25

			Row totals/3
0.0400	0.4800	0.4800	0.3333
0.4800	0.0400	0.4800	0.3333
0.4800	0.4800	0.0400	0.3333

Daily Operating Range

	Gem	Gator	Mule
GEM	1	0	0
Gator	1	1	1
Mule	2	2	1
Totals =	4	3	2

			Row totals/3
0.2500	0.0000	0.0000	0.0833
0.2500	0.3333	0.5000	0.3611
0.5000	0.6667	0.5000	0.5556

Daily Operating Hours

	Gem	Gator	Mule
GEM	1	0	0
Gator	4.5	1	4.5
Mule	2.5	2.5	1
Totals =	8	3.5	5.5

			Row totals/3
0.1250	0.0000	0.0000	0.0417
0.5625	0.2857	0.8182	0.5555
0.3125	0.7143	0.1818	0.4029

Normalized Points by Vehicle Type Continued

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Utility Bed
GEM	0.4000	0.3333	0.3333	0.1970	0.2798	0.3333	0.3333	0.3333
J. D.	0.3000	0.3333	0.3333	0.4015	0.3601	0.3333	0.3333	0.3333
Kawasaki	0.3000	0.3333	0.3333	0.4015	0.3601	0.3333	0.3333	0.3333

	Engine Preference	Daily Operating Range	Daily Operating Hours	Averaged Job Suitability
GEM	0.0762	0.0833	0.0417	0.1336
J. D.	0.4619	0.3611	0.5555	0.4280
Kawasaki	0.4619	0.5556	0.4029	0.4384

Summation of Point Totals

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Job Suitability	Grand Total
GEM	0.0564	0.0493	0.0486	0.0250	0.0274	0.0268	0.0299	0.0227	0.2862
J. D.	0.0423	0.0493	0.0486	0.0509	0.0353	0.0268	0.0299	0.0728	0.3560
Kawasaki	0.0423	0.0493	0.0486	0.0509	0.0353	0.0268	0.0299	0.0746	0.3578

Weighted Point Totals and Result Totals

Appendix D: Respondent Two's Data

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	7	6	7	8	8	8	7
Procurement Cost	3	5	4	3	6	6	6	7
Maintenance Cost	4	6	5	5	7	7	7	7
Reliability	3	7	5	5	8	8	8	7
Ease of Service	2	4	3	2	5	7	7	7
Fuel Efficiency	2	4	3	2	3	5	4	6
Warranty	2	4	3	2	3	6	5	7
Delivery Time	3	3	3	3	3	4	3	5
Column Totals	24	40	32	29	43	51	48	53

Factor Weight Matrix

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Totals Divided by 8
Job Suitability	0.2083	0.1750	0.1875	0.2414	0.1860	0.1569	0.1667	0.1321	0.1817
Procurement Cost	0.1250	0.1250	0.1250	0.1034	0.1395	0.1176	0.1250	0.1321	0.1241
Maintenance Cost	0.1667	0.1500	0.1563	0.1724	0.1628	0.1373	0.1458	0.1321	0.1529
Reliability	0.1250	0.1750	0.1563	0.1724	0.1860	0.1569	0.1667	0.1321	0.1588
Ease of Service	0.0833	0.1000	0.0938	0.0690	0.1163	0.1373	0.1458	0.1321	0.1097
Fuel Efficiency	0.0833	0.1000	0.0938	0.0690	0.0698	0.0980	0.0833	0.1132	0.0888
Warranty	0.0833	0.1000	0.0938	0.0690	0.0698	0.1176	0.1042	0.1321	0.0962
Delivery Time	0.1250	0.0750	0.0938	0.1034	0.0698	0.0784	0.0625	0.0943	0.0878

Final Relative Weights

Procurement Cost

	Respondent Values	Category Points
$6,000	70	14
$9,000	15	3
$12,000	10	2
$15,000	5	1
total =	100	20

Maintenance Cost

	Respondent Values	Category Points
$300	35	7
$500	25	5
$700	20	4
$900	15	3
$1200 and over	5	1
total =	100	20

Reliabilty (VIC) Rate

	Respondent Values	Category Points
84%	10	2
88%	15	3
92%	20	4
96%	25	5
100%	30	6
total =	100	20

Availability of Utility Bed

	Respondent Values	Category Points
none	10	2
short	30	6
long	40	8
does not matter	20	4
total =	100	20

Engine Preference

	Respondent Values	Category Points
gas	20	4
electric	70	14
no preference	10	2
total =	100	20

Daily Operating Range

	Respondent Values	Category Points
50	55	11
100	20	4
150	15	3
200	10	2
total =	100	20

Daily Operating Hours

	Respondent Values	Category Points
6	50	10
8	20	4
10	15	3
12	10	2
all day	5	1
total =	100	20

Ease of Service

	Respondent Values	Category Points
immediate area	70	14
surrounding community	20	4
Mail order	10	2
total =	100	20

Point Assignment by Attribute

Fuel Efficiency

	Respondent Values	Category Points
$0.01	50	10
$0.05	20	4
$0.09	15	3
$0.13	10	2
$0.17	5	1
total =	100	10

Warranty (in years)

	Respondent Values	Category Points
1	10	2
2	15	3
3	75	15
total =	100	1

Delivery in Weeks

	Respondent Values	Category Points
6	50	10
10	20	0
14	15	0
18	10	0
22 and over	5	0
total =	100	11

Point Assignment by Attribute Continued

Procurement Cost

	Gem	Gator	Mule
GEM	1	10.3333	10.3333
Gator	14	1	14
Mule	14	14	1
Totals =	29	25.3333	25.3333

			Row totals/3
0.0345	0.4079	0.4079	0.2834
0.4828	0.0395	0.5526	0.3583
0.4828	0.5526	0.0395	0.3583

Maintenance Cost

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Engine Preference

	Gem	Gator	Mule
Gem	1	14	14
Gator	4	1	4
Mule	4	4	1
Totals =	9	19	19

			Row totals/3
0.1111	0.7368	0.7368	0.5283
0.4444	0.0526	0.2105	0.2359
0.4444	0.2105	0.0526	0.2359

Reliability (VIC) Rate

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Ease of Service/Parts

	Gem	Gator	Mule
GEM	1	14	14
Gator	4	1	4
Mule	4	4	1
Totals =	9	19	19

			Row totals/3
0.1111	0.7368	0.7368	0.5283
0.4444	0.0526	0.2105	0.2359
0.4444	0.2105	0.0526	0.2359

Fuel Efficiency

	Gem	Gator	Mule
GEM	1	8.5	8.5
Gator	5.5	1	5.5
Mule	5.5	5.5	1
Totals =	12	15	15

			Row totals/3
0.0833	0.5667	0.5667	0.4056
0.4583	0.0667	0.3667	0.2972
0.4583	0.3667	0.0667	0.2972

Normalized Points by Vehicle Type

Warranty

	Gem	Gator	Mule
GEM	1	2	2
Gator	2	1	2
Mule	2	2	1
Totals =	5	5	5

			Row totals/3
0.2000	0.4000	0.4000	0.3333
0.4000	0.2000	0.4000	0.3333
0.4000	0.4000	0.2000	0.3333

Delivery in weeks

	Gem	Gator	Mule
GEM	1	10	10
Gator	10	1	10
Mule	10	10	1
Totals =	21	21	21

			Row totals/3
0.0476	0.4762	0.4762	0.3333
0.4762	0.0476	0.4762	0.3333
0.4762	0.4762	0.0476	0.3333

Availability of Utility

	Gem	Gator	Mule
GEM	1	8	8
Gator	8	1	8
Mule	8	8	1
Totals =	17	17	17

			Row totals/3
0.0588	0.4706	0.4706	0.3333
0.4706	0.0588	0.4706	0.3333
0.4706	0.4706	0.0588	0.3333

Daily Operating Range

	Gem	Gator	Mule
GEM	1	0	0
Gator	3	1	3
Mule	7	7	1
Totals =	11	8	4

			Row totals/3
0.0909	0.0000	0.0000	0.0303
0.2727	0.1250	0.7500	0.3826
0.6364	0.8750	0.2500	0.5871

Daily Operating Hours

	Gem	Gator	Mule
GEM	1	0	0
Gator	3.5	1	3.5
Mule	7	7	1
Totals =	11.5	8	4.5

			Row totals/3
0.0870	0.0000	0.0000	0.0290
0.3043	0.1250	0.7778	0.4024
0.6087	0.8750	0.2222	0.5686

Normalized Points by Vehicle Type Continued

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Utility Bed
GEM	0.2834	0.3333	0.3333	0.2275	0.4056	0.3333	0.3333	0.3333
J. D.	0.3583	0.3333	0.3333	0.3862	0.2972	0.3333	0.3333	0.3333
Kawasaki	0.3583	0.3333	0.3333	0.3862	0.2972	0.3333	0.3333	0.3333

	Engine Preference	Daily Operating Range	Daily Operating Hours	Averaged Job Suitability
GEM	0.5283	0.0303	0.0290	0.2302
J. D.	0.2359	0.3826	0.4024	0.3385
Kawasaki	0.2359	0.5871	0.5686	0.4312

Summation of Point Totals

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Job Suitability	Grand Total
GEM	0.0352	0.0510	0.0529	0.0250	0.0360	0.0321	0.0293	0.0418	0.3032
J. D.	0.0445	0.0510	0.0529	0.0424	0.0264	0.0321	0.0293	0.0615	0.3400
Kawasaki	0.0445	0.0510	0.0529	0.0424	0.0264	0.0321	0.0293	0.0784	0.3568

Weighted Point Totals and Result Totals

Appendix E: Respondent Three's Data

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	7	4	7	7	3	7	2
Procurement Cost	3	5	7	8	8	3	7	2
Maintenance Cost	6	3	5	9	6	3	7	2
Reliability	3	2	1	5	8	3	7	2
Ease of Service	3	2	4	2	5	3	7	2
Fuel Efficiency	7	7	7	7	7	5	1	1
Warranty	3	3	3	3	3	9	5	2
Delivery Time	8	8	8	8	8	9	8	5
Column Totals	38	37	39	49	52	38	49	18

Factor Weight Matrix

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Totals Divided by 8
Job Suitability	0.1316	0.1892	0.1026	0.1429	0.1346	0.0789	0.1429	0.1111	0.1292
Procurement Cost	0.0789	0.1351	0.1795	0.1633	0.1538	0.0789	0.1429	0.1111	0.1304
Maintenance Cost	0.1579	0.0811	0.1282	0.1837	0.1154	0.0789	0.1429	0.1111	0.1249
Reliability	0.0789	0.0541	0.0256	0.1020	0.1538	0.0789	0.1429	0.1111	0.0934
Ease of Service	0.0789	0.0541	0.1026	0.0408	0.0962	0.0789	0.1429	0.1111	0.0882
Fuel Efficiency	0.1842	0.1892	0.1795	0.1429	0.1346	0.1316	0.0204	0.0556	0.1297
Warranty	0.0789	0.0811	0.0769	0.0612	0.0577	0.2368	0.1020	0.1111	0.1007
Delivery Time	0.2105	0.2162	0.2051	0.1633	0.1538	0.2368	0.1633	0.2778	0.2034

Final Relative Weights

Procurement Cost

	Respondent Values	Category Points
$6,000	70	14
$9,000	15	3
$12,000	10	2
$15,000	5	1
total =	100	20

Maintenance Cost

	Respondent Values	Category Points
$300	50	10
$500	20	4
$700	15	3
$900	10	2
$1200 and over	5	1
total =	100	20

Reliabilty (VIC) Rate

	Respondent Values	Category Points
84%	5	1
88%	10	2
92%	15	3
96%	20	4
100%	50	10
total =	100	20

Availability of Utility Bed

	Respondent Values	Category Points
none	30	6
short	15	3
long	50	10
does not matter	5	1
total =	100	20

Engine Preference

	Respondent Values	Category Points
gas	80	16
electric	10	2
no preference	10	2
total =	100	20

Daily Operating Range

	Respondent Values	Category Points
50	70	14
100	15	3
150	10	2
200	5	1
total =	100	20

Daily Operating Hours

	Respondent Values	Category Points
6	50	10
8	25	5
10	10	2
12	10	2
all day	5	1
total =	100	20

Ease of Service

	Respondent Values	Category Points
immediate area	60	12
surrounding community	30	6
Mail order	10	2
total =	100	20

Point Assignment by Attribute

Fuel Efficiency

	Respondent Values	Category Points
$0.01	35	7
$0.05	25	5
$0.09	20	4
$0.13	15	3
$0.17	5	1
total =	100	20

Warranty (in years)

	Respondent Values	Category Points
1	15	3
2	25	5
3	60	12
total =	100	20

Delivery in Weeks

	Respondent Values	Category Points
6	30	6
10	40	8
14	15	3
18	10	2
22 and over	5	1
total =	100	20

Point Assignment by Attribute Continued

Procurement Cost

	Gem	Gator	Mule
GEM	1	10.3333	10.3333
Gator	14	1	14
Mule	14	14	1
Totals =	29	25.3333	25.3333

			Row totals/3
0.0345	0.4079	0.4079	0.2834
0.4828	0.0395	0.5526	0.3583
0.4828	0.5526	0.0395	0.3583

Maintenance Cost

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Engine Preference

	Gem	Gator	Mule
Gem	1	2	2
Gator	16	1	16
Mule	16	16	1
Totals =	33	19	19

			Row totals/3
0.0303	0.1053	0.1053	0.0803
0.4848	0.0526	0.8421	0.4599
0.4848	0.8421	0.0526	0.4599

Reliability (VIC) Rate

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Ease of Service/Parts

	Gem	Gator	Mule
GEM	1	2	2
Gator	6	1	6
Mule	6	6	1
Totals =	13	9	9

			Row totals/3
0.0769	0.2222	0.2222	0.1738
0.4615	0.1111	0.6667	0.4131
0.4615	0.6667	0.1111	0.4131

Fuel Efficiency

	Gem	Gator	Mule
GEM	1	2	2
Gator	6	1	6
Mule	6	6	1
Totals =	13	9	9

			Row totals/3
0.0769	0.2222	0.2222	0.1738
0.4615	0.1111	0.6667	0.4131
0.4615	0.6667	0.1111	0.4131

Normalized Points by Vehicle Type

Warranty

	Gem	Gator	Mule
GEM	1	3	3
Gator	3	1	3
Mule	3	3	1
Totals =	7	7	7

			Row totals/3
0.1429	0.4286	0.4286	0.3333
0.4286	0.1429	0.4286	0.3333
0.4286	0.4286	0.1429	0.3333

Delivery in weeks

	Gem	Gator	Mule
GEM	1	5.5	5.5
Gator	6	1	6
Mule	6	6	1
Totals =	13	12.5	12.5

			Row totals/3
0.0769	0.4400	0.4400	0.3190
0.4615	0.0800	0.4800	0.3405
0.4615	0.4800	0.0800	0.3405

Availability of Utility

	Gem	Gator	Mule
GEM	1	10	10
Gator	10	1	10
Mule	10	10	1
Totals =	21	21	21

			Row totals/3
0.0476	0.4762	0.4762	0.3333
0.4762	0.0476	0.4762	0.3333
0.4762	0.4762	0.0476	0.3333

Daily Operating Range

	Gem	Gator	Mule
GEM	1	0	0
Gator	1	1	1
Mule	2	2	1
Totals =	4	3	2

			Row totals/3
0.2500	0.0000	0.0000	0.0833
0.2500	0.3333	0.5000	0.3611
0.5000	0.6667	0.5000	0.5556

Daily Operating Hours

	Gem	Gator	Mule
GEM	1	0	0
Gator	3.5	1	3.5
Mule	7.5	7.5	1
Totals =	12	8.5	4.5

			Row totals/3
0.0833	0.0000	0.0000	0.0278
0.2917	0.1176	0.7778	0.3957
0.6250	0.8824	0.2222	0.5765

Normalized Points by Vehicle Type Continued

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Utility Bed
GEM	0.2834	0.3333	0.3333	0.1738	0.3611	0.3333	0.3190	0.3333
J. D.	0.3583	0.3333	0.3333	0.4131	0.3194	0.3333	0.3405	0.3333
Kawasaki	0.3583	0.3333	0.3333	0.4131	0.3194	0.3333	0.3405	0.3333

	Engine Preference	Daily Operating Range	Daily Operating Hours	Averaged Job Suitability
GEM	0.0803	0.0833	0.0278	0.1312
J. D.	0.4599	0.3611	0.3957	0.3875
Kawasaki	0.4599	0.5556	0.5765	0.4813

Summation of Point Totals

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Job Suitability	Grand Total
GEM	0.0324	0.0465	0.0524	0.0137	0.0445	0.0177	0.0324	0.0304	0.2701
J. D.	0.0410	0.0465	0.0524	0.0326	0.0394	0.0177	0.0346	0.0899	0.3541
Kawasaki	0.0410	0.0465	0.0524	0.0326	0.0394	0.0177	0.0346	0.1116	0.3758

Weighted Point Totals and Result Totals

Appendix F: Respondent Four's Data

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	7	4	7	7	3	7	2
Procurement Cost	3	5	7	8	8	3	7	2
Maintenance Cost	6	3	5	9	6	3	7	2
Reliability	3	2	1	5	8	3	7	2
Ease of Service	3	2	4	2	5	3	7	2
Fuel Efficiency	7	7	7	7	7	5	1	1
Warranty	3	3	3	3	3	9	5	2
Delivery Time	8	8	8	8	8	9	8	5
Column Totals	38	37	39	49	52	38	49	18

Factor Weight Matrix

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Totals Divided by 8
Job Suitability	0.1316	0.1892	0.1026	0.1429	0.1346	0.0789	0.1429	0.1111	0.1292
Procurement Cost	0.0789	0.1351	0.1795	0.1633	0.1538	0.0789	0.1429	0.1111	0.1304
Maintenance Cost	0.1579	0.0811	0.1282	0.1837	0.1154	0.0789	0.1429	0.1111	0.1249
Reliability	0.0789	0.0541	0.0256	0.1020	0.1538	0.0789	0.1429	0.1111	0.0934
Ease of Service	0.0789	0.0541	0.1026	0.0408	0.0962	0.0789	0.1429	0.1111	0.0882
Fuel Efficiency	0.1842	0.1892	0.1795	0.1429	0.1346	0.1316	0.0204	0.0556	0.1297
Warranty	0.0789	0.0811	0.0769	0.0612	0.0577	0.2368	0.1020	0.1111	0.1007
Delivery Time	0.2105	0.2162	0.2051	0.1633	0.1538	0.2368	0.1633	0.2778	0.2034

Final Relative Weights

Procurement Cost

	Respondent Values	Category Points
$6,000	20	4
$9,000	30	6
$12,000	50	10
$15,000	0	0
total =	100	20

Maintenance Cost

	Respondent Values	Category Points
$300	60	12
$500	20	4
$700	15	3
$900	5	1
$1200 and over	0	0
total =	100	20

Reliabilty (VIC) Rate

	Respondent Values	Category Points
84%	0	0
88%	0	0
92%	0	0
96%	100	20
100%	0	0
total =	100	20

Availability of Utility Bed

	Respondent Values	Category Points
none	0	0
short	0	0
long	0	0
does not matter	100	20
total =	100	20

Engine Preference

	Respondent Values	Category Points
gas	100	20
electric	0	0
no preference	0	0
total =	100	20

Daily Operating Range

	Respondent Values	Category Points
50	95	19
100	5	1
150	0	0
200	0	0
total =	100	20

Daily Operating Hours

	Respondent Values	Category Points
6	0	0
8	0	0
10	0	0
12	0	0
all day	100	20
total =	100	20

Ease of Service

	Respondent Values	Category Points
immediate area	90	18
surrounding community	10	2
Mail order	0	0
total =	100	20

Point Assignment by Attribute

Fuel Efficiency

	Respondent Values	Category Points
$0.01	0	0
$0.05	0	0
$0.09	50	10
$0.13	40	8
$0.17	10	2
total =	100	20

Warranty (in years)

	Respondent Values	Category Points
1	85	17
2	10	2
3	5	1
total =	100	20

Delivery in Weeks

	Respondent Values	Category Points
6	60	12
10	20	4
14	10	2
18	10	2
22 and over	0	0
total =	100	20

Point Assignment by Attribute Continued

Procurement Cost

	Gem	Gator	Mule
GEM	1	9.3333	9.3333
Gator	12	1	12
Mule	12	12	1
Totals =	25	22.3333	22.3333

			Row totals/3
0.0400	0.4179	0.4179	0.2919
0.4800	0.0448	0.5373	0.3540
0.4800	0.5373	0.0448	0.3540

Maintenance Cost

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Engine Preference

	Gem	Gator	Mule
Gem	1	1	1
Gator	19	1	19
Mule	19	19	1
Totals =	39	21	21

			Row totals/3
0.0256	0.0476	0.0476	0.0403
0.4872	0.0476	0.9048	0.4799
0.4872	0.9048	0.0476	0.4799

Reliability (VIC) Rate

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Ease of Service/Parts

	Gem	Gator	Mule
GEM	1	5	5
Gator	10	1	10
Mule	10	10	1
Totals =	21	16	16

			Row totals/3
0.0476	0.3125	0.3125	0.2242
0.4762	0.0625	0.6250	0.3879
0.4762	0.6250	0.0625	0.3879

Fuel Efficiency

	Gem	Gator	Mule
GEM	1	4	4
Gator	12	1	12
Mule	12	12	1
Totals =	25	17	17

			Row totals/3
0.0400	0.2353	0.2353	0.1702
0.4800	0.0588	0.7059	0.4149
0.4800	0.7059	0.0588	0.4149

Normalized Points by Vehicle Type

Warranty

	Gem	Gator	Mule
GEM	1	16	16
Gator	16	1	16
Mule	16	16	1
Totals =	33	33	33

			Row totals/3
0.0303	0.4848	0.4848	0.3333
0.4848	0.0303	0.4848	0.3333
0.4848	0.4848	0.0303	0.3333

Delivery in weeks

	Gem	Gator	Mule
GEM	1	8.5	8.5
Gator	2	1	2
Mule	2	2	1
Totals =	5	11.5	11.5

			Row totals/3
0.2000	0.7391	0.7391	0.5594
0.4000	0.0870	0.1739	0.2203
0.4000	0.1739	0.0870	0.2203

Availability of Utility

	Gem	Gator	Mule
GEM	1	6	6
Gator	5	1	5
Mule	5	5	1
Totals =	11	12	12

			Row totals/3
0.0909	0.5000	0.5000	0.3636
0.4545	0.0833	0.4167	0.3182
0.4545	0.4167	0.0833	0.3182

Daily Operating Range

	Gem	Gator	Mule
GEM	1	0	0
Gator	1	1	1
Mule	2	2	1
Totals =	4	3	2

			Row totals/3
0.2500	0.0000	0.0000	0.0833
0.2500	0.3333	0.5000	0.3611
0.5000	0.6667	0.5000	0.5556

Daily Operating Hours

	Gem	Gator	Mule
GEM	1	0	0
Gator	6	1	6
Mule	5	5	1
Totals =	12	6	7

			Row totals/3
0.0833	0.0000	0.0000	0.0278
0.5000	0.1667	0.8571	0.5079
0.4167	0.8333	0.1429	0.4643

Normalized Points by Vehicle Type

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Utility Bed
GEM	0.3589	0.3333	0.3333	0.0667	0.3333	0.3333	0.1383	0.3333
J. D.	0.3206	0.3333	0.3333	0.4667	0.3333	0.3333	0.4308	0.3333
Kawasaki	0.3206	0.3333	0.3333	0.4667	0.3333	0.3333	0.4308	0.3333

	Engine Preference	Daily Operating Range	Daily Operating Hours	Averaged Job Suitability
GEM	0.0081	0.3333	0.3333	0.2520
J. D.	0.4959	0.3333	0.3333	0.3740
Kawasaki	0.4959	0.3333	0.3333	0.3740

Summation of Point Totals

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Job Suitability	Grand Total
GEM	0.0468	0.0416	0.0311	0.0059	0.0432	0.0336	0.0281	0.0326	0.2630
J. D.	0.0418	0.0416	0.0311	0.0412	0.0432	0.0336	0.0876	0.0483	0.3685
Kawasaki	0.0418	0.0416	0.0311	0.0412	0.0432	0.0336	0.0876	0.0483	0.3685

Weighted Point Totals and Result Totals

Appendix G: Respondent Five's Data

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	6	7	8	8	6	8	6
Procurement Cost	4	5	4	4	6	5	8	6
Maintenance Cost	3	6	5	9	9	6	9	6
Reliability	2	6	1	5	8	6	8	6
Ease of Service	2	4	1	2	5	4	8	6
Fuel Efficiency	4	5	4	4	6	5	5	6
Warranty	2	2	1	2	2	5	5	6
Delivery Time	4	4	4	4	4	4	4	5
Column Totals	26	38	27	38	48	41	55	47

Factor Weight Matrix

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Totals Divided by 8
Job Suitability	0.1923	0.1579	0.2593	0.2105	0.1667	0.1463	0.1455	0.1277	0.1758
Procurement Cost	0.1538	0.1316	0.1481	0.1053	0.1250	0.1220	0.1455	0.1277	0.1324
Maintenance Cost	0.1154	0.1579	0.1852	0.2368	0.1875	0.1463	0.1636	0.1277	0.1651
Reliability	0.0769	0.1579	0.0370	0.1316	0.1667	0.1463	0.1455	0.1277	0.1237
Ease of Service	0.0769	0.1053	0.0370	0.0526	0.1042	0.0976	0.1455	0.1277	0.0933
Fuel Efficiency	0.1538	0.1316	0.1481	0.1053	0.1250	0.1220	0.0909	0.1277	0.1255
Warranty	0.0769	0.0526	0.0370	0.0526	0.0417	0.1220	0.0909	0.1277	0.0752
Delivery Time	0.1538	0.1053	0.1481	0.1053	0.0833	0.0976	0.0727	0.1064	0.1091

Final Relative Weights

Procurement Cost

	Respondent Values	Category Points
$6,000	60	12
$9,000	20	4
$12,000	15	3
$15,000	5	1
total =	100	20

Maintenance Cost

	Respondent Values	Category Points
$300	50	10
$500	20	4
$700	15	3
$900	10	2
$1200 and over	5	1
total =	100	20

Reliabilty (VIC) Rate

	Respondent Values	Category Points
84%	5	1
88%	10	2
92%	50	10
96%	20	4
100%	15	3
total =	100	20

Availability of Utility Bed

	Respondent Values	Category Points
none	0	0
short	30	6
long	25	5
does not matter	45	9
total =	100	20

Engine Preference

	Respondent Values	Category Points
gas	95	19
electric	5	1
no preference	0	0
total =	100	20

Daily Operating Range

	Respondent Values	Category Points
50	65	13
100	20	4
150	10	2
200	5	1
total =	100	20

Daily Operating Hours

	Respondent Values	Category Points
6	5	1
8	45	9
10	15	3
12	25	5
all day	10	2
total =	100	20

Ease of Service

	Respondent Values	Category Points
immediate area	25	5
surrounding community	50	10
Mail order	25	5
total =	100	20

Point Assignment by Attribute

Fuel Efficiency

	Respondent Values	Category Points
$0.01	0	0
$0.05	80	16
$0.09	20	4
$0.13	0	0
$0.17	0	0
total =	100	20

Warranty (in years)

	Respondent Values	Category Points
1	80	1
2	15	0
3	5	0
total =	100	1

Delivery in Weeks

	Respondent Values	Category Points
6	10	2
10	60	12
14	25	5
18	5	1
22 and over	0	0
total =	100	20

Point Assignment by Attribute Continued

Procurement Cost

	Gem	Gator	Mule
GEM	1	4.6666	4.6666
Gator	4	1	4
Mule	4	4	1
Totals =	9	9.6666	9.6666

			Row totals/3
0.1111	0.4828	0.4828	0.3589
0.4444	0.1034	0.4138	0.3206
0.4444	0.4138	0.1034	0.3206

Maintenance Cost

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Engine Preference

	Gem	Gator	Mule
Gem	1	0	0
Gator	20	1	20
Mule	20	20	1
Totals =	41	21	21

			Row totals/3
0.0244	0.0000	0.0000	0.0081
0.4878	0.0476	0.9524	0.4959
0.4878	0.9524	0.0476	0.4959

Reliability (VIC) Rate

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Ease of Service/Parts

	Gem	Gator	Mule
GEM	1	0	0
Gator	2	1	2
Mule	2	2	1
Totals =	5	3	3

			Row totals/3
0.2000	0.0000	0.0000	0.0667
0.4000	0.3333	0.6667	0.4667
0.4000	0.6667	0.3333	0.4667

Fuel Efficiency

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Normalized Points by Vehicle Type

Warranty

	Gem	Gator	Mule
GEM	1	17	17
Gator	17	1	17
Mule	17	17	1
Totals =	35	35	35

			Row totals/3
0.0286	0.4857	0.4857	0.3333
0.4857	0.0286	0.4857	0.3333
0.4857	0.4857	0.0286	0.3333

Delivery in weeks

	Gem	Gator	Mule
GEM	1	3	3
Gator	12	1	12
Mule	12	12	1
Totals =	25	16	16

			Row totals/3
0.0400	0.1875	0.1875	0.1383
0.4800	0.0625	0.7500	0.4308
0.4800	0.7500	0.0625	0.4308

Availability of Utility

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Daily Operating Range

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Daily Operating Hours

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Normalized Points by Vehicle Type Continued

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Utility Bed
GEM	0.2919	0.3333	0.3333	0.2242	0.1702	0.3333	0.5594	0.3636
J. D.	0.3540	0.3333	0.3333	0.3879	0.4149	0.3333	0.2203	0.3182
Kawasaki	0.3540	0.3333	0.3333	0.3879	0.4149	0.3333	0.2203	0.3182

	Engine Preference	Daily Operating Range	Daily Operating Hours	Averaged Job Suitability
GEM	0.0403	0.0833	0.0278	0.1288
J. D.	0.4799	0.3611	0.5079	0.4168
Kawasaki	0.4799	0.5556	0.4643	0.4545

Summation of Point Totals

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Job Suitability	Grand Total
GEM	0.0386	0.0550	0.0412	0.0209	0.0214	0.0251	0.0610	0.0226	0.2859
J. D.	0.0469	0.0550	0.0412	0.0362	0.0521	0.0251	0.0240	0.0733	0.3537
Kawasaki	0.0469	0.0550	0.0412	0.0362	0.0521	0.0251	0.0240	0.0799	0.3604

Weighted Point Totals and Result Totals

Appendix H: Respondent Six's Data

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time
Job Suitability	5	7	6	8	8	7	8	6
Procurement Cost	3	5	5	4	6	5	7	6
Maintenance Cost	4	5	5	7	7	6	8	6
Reliability	2	6	3	5	8	6	8	6
Ease of Service	2	4	3	2	5	4	7	6
Fuel Efficiency	3	5	4	4	4	5	5	5
Warranty	2	3	2	2	3	5	5	4
Delivery Time	4	4	4	4	4	5	6	5
Column Totals	26	38	33	35	45	43	54	44

Factor Weight Matrix

	Job Suitability	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Totals Divided by 8
Job Suitability	0.1938	0.1832	0.1939	0.2147	0.1718	0.1528	0.1487	0.1324	0.1739
Procurement Cost	0.1163	0.1309	0.1455	0.1243	0.1410	0.1157	0.1375	0.1324	0.1304
Maintenance Cost	0.1395	0.1361	0.1515	0.1864	0.1586	0.1435	0.1413	0.1279	0.1481
Reliability	0.0930	0.1466	0.1030	0.1412	0.1762	0.1435	0.1450	0.1416	0.1363
Ease of Service	0.0853	0.0942	0.0848	0.0565	0.1101	0.1019	0.1375	0.1324	0.1004
Fuel Efficiency	0.1318	0.1309	0.1152	0.1073	0.0925	0.1157	0.0892	0.1233	0.1132
Warranty	0.0775	0.0681	0.0727	0.0621	0.0573	0.1204	0.0929	0.0959	0.0809
Delivery Time	0.1628	0.1099	0.1333	0.1073	0.0925	0.1065	0.1078	0.1142	0.1168

Final Relative Weights

Procurement Cost

	Respondent Values	Category Points
$6,000	60	12
$9,000	20	4
$12,000	15	3
$15,000	5	1
total =	100	20

Maintenance Cost

	Respondent Values	Category Points
$300	50	10
$500	20	4
$700	15	3
$900	10	2
$1200 and over	5	1
total =	100	20

Reliabilty (VIC) Rate

	Respondent Values	Category Points
84%	5	1
88%	10	2
92%	50	10
96%	20	4
100%	15	3
total =	100	20

Availability of Utility Bed

	Respondent Values	Category Points
none	0	0
short	30	6
long	25	5
does not matter	45	9
total =	100	20

Engine Preference

	Respondent Values	Category Points
gas	95	19
electric	5	1
no preference	0	0
total =	100	20

Daily Operating Range

	Respondent Values	Category Points
50	65	13
100	20	4
150	10	2
200	5	1
total =	100	20

Daily Operating Hours

	Respondent Values	Category Points
6	5	1
8	45	9
10	15	3
12	25	5
all day	10	2
total =	100	20

Ease of Service

	Respondent Values	Category Points
immediate area	25	5
surrounding community	50	10
Mail order	25	5
total =	100	20

Point Assignment by Attribute

Fuel Efficiency

	Respondent Values	Category Points
\$0.01	0	0
\$0.05	80	16
\$0.09	20	4
\$0.13	0	0
\$0.17	0	0
total =	100	20

Warranty (in years)

	Respondent Values	Category Points
1	80	16
2	15	3
3	5	1
total =	100	20

Delivery in Weeks

	Respondent Values	Category Points
6	10	2
10	60	12
14	25	5
18	5	1
22 and over	0	0
total =	100	20

Point Assignment by Attribute Continued

Procurement Cost

	Gem	Gator	Mule
GEM	1	10.3333	10.3333
Gator	14	1	14
Mule	14	14	1
Totals =	29	25.3333	25.3333

			Row totals/3
0.0345	0.4079	0.4079	0.2834
0.4828	0.0395	0.5526	0.3583
0.4828	0.5526	0.0395	0.3583

Maintenance Cost

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Engine Preference

	Gem	Gator	Mule
Gem	1	14	14
Gator	4	1	4
Mule	4	4	1
Totals =	9	19	19

			Row totals/3
0.1111	0.7368	0.7368	0.5283
0.4444	0.0526	0.2105	0.2359
0.4444	0.2105	0.0526	0.2359

Reliability (VIC) Rate

	Gem	Gator	Mule
GEM	1	0	0
Gator	0	1	0
Mule	0	0	1
Totals =	1	1	1

			Row totals/3
1.0000	0.0000	0.0000	0.3333
0.0000	1.0000	0.0000	0.3333
0.0000	0.0000	1.0000	0.3333

Ease of Service/Parts

	Gem	Gator	Mule
GEM	1	5	5
Gator	7	1	7
Mule	7	7	1
Totals =	15	13	13

			Row totals/3
0.0667	0.3846	0.3846	0.2786
0.4667	0.0769	0.5385	0.3607
0.4667	0.5385	0.0769	0.3607

Fuel Efficiency

	Gem	Gator	Mule
GEM	1	8.5	8.5
Gator	5.5	1	5.5
Mule	5.5	5.5	1
Totals =	12	15	15

			Row totals/3
0.0833	0.5667	0.5667	0.4056
0.4583	0.0667	0.3667	0.2972
0.4583	0.3667	0.0667	0.2972

Normalized Points by Vehicle Type

Warranty

	Gem	Gator	Mule
GEM	1	2	2
Gator	2	1	2
Mule	2	2	1
Totals =	5	5	5

			Row totals/3
0.2000	0.4000	0.4000	0.3333
0.4000	0.2000	0.4000	0.3333
0.4000	0.4000	0.2000	0.3333

Delivery in weeks

	Gem	Gator	Mule
GEM	1	10	10
Gator	10	1	10
Mule	10	10	1
Totals =	21	21	21

			Row totals/3
0.0476	0.4762	0.4762	0.3333
0.4762	0.0476	0.4762	0.3333
0.4762	0.4762	0.0476	0.3333

Availability of Utility Bed

	Gem	Gator	Mule
GEM	1	10	10
Gator	6	1	6
Mule	6	6	1
Totals =	13	17	17

			Row totals/3
0.0769	0.5882	0.5882	0.4178
0.4615	0.0588	0.3529	0.2911
0.4615	0.3529	0.0588	0.2911

Daily Operating Range

	Gem	Gator	Mule
GEM	1	0	0
Gator	12	1	12
Mule	5	5	1
Totals =	18	6	13

			Row totals/3
0.0556	0.0000	0.0000	0.0185
0.6667	0.1667	0.9231	0.5855
0.2778	0.8333	0.0769	0.3960

Daily Operating Hours

	Gem	Gator	Mule
GEM	1	0	0
Gator	3.5	1	3.5
Mule	1.5	1.5	1
Totals =	6	2.5	4.5

			Row totals/3
0.1667	0.0000	0.0000	0.0556
0.5833	0.4000	0.7778	0.5870
0.2500	0.6000	0.2222	0.3574

Normalized Points by Vehicle Type Continued

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Utility Bed
GEM	0.2834	0.3333	0.3333	0.2786	0.4056	0.3333	0.3333	0.4178
J. D.	0.3583	0.3333	0.3333	0.3607	0.2972	0.3333	0.3333	0.2911
Kawasaki	0.3583	0.3333	0.3333	0.3607	0.2972	0.3333	0.3333	0.2911

	Engine Preference	Daily Operating Range	Daily Operating Hours	Averaged Job Suitability
GEM	0.5283	0.0185	0.0556	0.2550
J. D.	0.2359	0.5855	0.5870	0.4249
Kawasaki	0.2359	0.3960	0.3574	0.3201

Summation of Point Totals

	Procurement Cost	Maintenance Cost	Reliability	Ease of Service	Fuel Efficiency	Warranty	Delivery Time	Job Suitability	Grand Total
GEM	0.0386	0.0550	0.0412	0.0209	0.0214	0.0251	0.0610	0.0226	0.2859
J. D.	0.0469	0.0550	0.0412	0.0362	0.0521	0.0251	0.0240	0.0733	0.3537
Kawasaki	0.0469	0.0550	0.0412	0.0362	0.0521	0.0251	0.0240	0.0799	0.3604

Weighted Point Totals and Result Totals

Bibliography

Adams, Marilyn R. "Fleet buying: not for the timid," *Purchasing*, 108: 44-52 (February 1990).

Battin, Jeffrey L. Bender, Thomas J. *A Methodology for Project Selection using Economic Analysis and the Analytic Hierarchy Process.* MS Thesis, AFIT/GSM/LSY/92-2. School of Systems and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, September 1992 (AD-A258202).

Black, Tom. "Buying fleet vehicles: Options are standard" *American City and County,* 114: 38-48 (March 1999).

CNN. "Meet the Bushmobile." Excerpt from article. n. pag. http://www.cnn.com/2004/US/South/02/03/offbeat.g8.ap/. 15 June 2004.

Department of the Air Force. "*Vehicle Funding"* Report to 2004 VMAG, HQ USAF, Washington DC. 2004.

Department of the Air Force. *Transportation: Vehicle Operations.* AFI 24-301. Washington: HQ USAF, 1 November 2001.

Department of the Air Force. *Transportation: Vehicle Operation.* Pacific Air Forces Supplement to AFI 24-301. Washington: HQ USAF, 6 June 2003.

Department of the Air Force. *Transportation: Vehicle Management.* AFI 24-302. Washington: HQ USAF, 1 February 2005

Department of Energy. "DOE Studies Neighborhood Electric Vehicle Use." Excerpt from article. n. pag. http://avt.inel.gov/pdf/press_release/2001nev_study.pdf. 15 June 2004.

Department of Energy. "Neighborhood Electric Vehicles." n. pag. http://www.eere.energy.gov/cleancities/atv/tech/nev.html. 20 June 2004a.

Department of Energy. "Vehicle Buyer's Guide for Consumers." n. pag. http://www.eere.energy.gov/cleancities/vbg/progs/search_class.cgi?6. 15 June 2004b.

Department of Energy. "U.S. Gasoline and Diesel Fuel Prices." n. pag. http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp. 5 January 2005.

Department of Transportation. *National Highway Traffic Safety Administration Federal Motor Vehicle Safety Standards.* June 1998.

GSA Advantage. "GEM Passenger NEV." n. pag. https://www.gsaadvantage.gov/advgsa/advantage/main/start_page.do. 7 January 2005.

Global Electric Motorcars. "Frequently Asked Questions." n. pag. http://www.gemcar.com/asp/faq.asp?id=17. 18 June 2004.

HQ PACAF. "Electric Utility Rates for PACAF Units." Electronic Message. 084700Z, 23 September 2004.

"Hyundai Consumer Survey Reveals Escalating Influence of 'Value' on Car Buying Decisions," *PR Newswire*, (April 17, 2003).

Insurance Institute for Highway Safety. "Use of Low Speed Vehicles on Public Roads." Article. n. pag. http://www.hwysafety.org/safety%5Ffacts/state%5Flaws/htm. 4 August 20044.

John Deere. "Product Information." n. pag. http://www.deere.com/en_US/deerecom/usa_canada.html. 15 August 2004.

Kawasaki. "Product Information." n. pag. http://www.kawasaki.com/uv/. 15 August 2004.

Luethke, Gary A. *An Application of the Analytic Hierarchy Process to Evaluate Candidate Locations for Building Military Housing.* MS Thesis, AFIT/GOR/ENS/87-10. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, December 1987 (AD-A189780).

Saaty, Thomas L. *The Analytic Hierarchy Process.* New York: McGraw Hill Book Company, 1980.

Saaty, Thomas L. *Decision Making for Leaders.* Belmont CA: Lifetime Learning Publications, 1982.

Surface Deployment and Distribution Command. "Shipping your POV." n. pag. http://www.mtmc.army.mil/. 5 January 2005.

Tabucannon, Mario T. *Multiple Criteria Decision Making in Industry.* New York: Elsevier Science Publishing Inc., 1988.

Vita

Captain Andrew H. Pate graduated from Southwest Texas State University, San Marcos, Texas, in May 1997 with a Bachelor of Science in Criminal Justice. After earning his commission, Captain Pate was assigned to the 623d Air Mobility Support Squadron, Ramstein AB, Germany as a Transportation Officer. While at Ramstein, he served as a Duty Officer and Senior Controller in the Air Terminal Operations Center, and the OIC Combat Readiness. While stationed at Ramstein, Captain Pate earned a Master of Human Relations from the University of Oklahoma. In June 2000, Captain Pate was transferred to the 37th Transportation Squadron, Lackland AFB, Texas where he performed duties as Flight Commander of Combat Readiness, Flight Commander of Air Operations Terminal, and Deputy Commander for the 37th Transportation Squadron. Additionally, Capt Pate served as the Executive Officer for the 37th Mission Support Group, Lackland AFB, Texas. In August 2003, he entered the Graduate Logistics Management program at the Air Force Institute of Technology, Wright-Patterson AFB, OH. Upon graduation, Captain Pate will be assigned to Headquarters Pacific Air Forces, Hickam AFB, Hawaii.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From – To)*
21-03-2005	**Master's Thesis**	May 2004 – Mar 2005

4. TITLE AND SUBTITLE
DETERMINING PACAF TRANSPORTATION ALTERNATIVES TO THE GENERAL PURPOSE VEHICLE

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Pate, Andrew H., Captain, USAF

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)
Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/EN)
2950 Hobson Street, Building 642
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GLM/ENS/05-20

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
PACAF/LGRW
Attn: Lt Col Peter Miyares
25 E. Street, Suite I 326 DSN: 449-8557
Hickam AFB, HI 96853-5427 e-mail: peter.miyares@hickam.af.mil

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Vehicle fleets under gird the mission of Air Force bases. Under funding for vehicle replacement requirements raised concerns and has led to purchasing alternative vehicles classified as equipment items to supplement budget shortfalls. In order to effectively use funds and meet mission requirements, Pacific Air Force (PACAF) commanders need an adjustable multifactor decision tool that will allow them to make an informed purchasing decision from among appropriately classified equipment item vehicles.

This research will discuss existing regulatory restrictions to alternative transportation purchases, consider available alternative vehicles, and determine the attributes important to vehicle purchases. A review of current Air Force Instruction on vehicles and purchases, as well as researching commercially available alternative vehicles, and conducting an investigative questionnaire resulted in the development of a multifactor weighted decision making model.

Through application of the Analytic Hierarchy Process based on responses to the investigative questionnaire, an optimum alternative vehicle for PACAF was discovered. This research concludes with the development and application of a multifactor weighted decision making tool appropriate for assisting with alternative vehicle choices. Further, the research concludes that either the John Deere Gator or Kawasaki Mule are the optimum alternative vehicle choices for PACAF units.

15. SUBJECT TERMS
Analytic Hierarchy Process, Low Speed Vehicle, Neighborhood Electric Vehicle, Fleet Buying Decision

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Marvin A. Arostegui, Lt Col., USAF (ENS)
					19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	121	(937) 255-6565, ext 4333 marvin.arostegui@afit.edu

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18