Fire Apparatus Replacement/Refurbishment Determination

By:
Mark A. Wolf
Greenville Fire Department
Greenville, Ohio

An applied research project submitted to the Ohio Fire Executive Program

June 2003

ABSTRACT

Due to high capital costs, fire apparatus replacement and refurbishing decisions should be based on an objective decision making process. This research determined that currently, many fire apparatus replacement and refurbishing decisions are based on subjective decisions including individual sentiment about the apparatus. Many large communities have a fire apparatus replacement program, many small community fire departments do not.

The purpose of this research project was to examine the variables that effect the replacement and refurbishing decisions and to produce a model for use in making objective decisions.

Descriptive research was used to answer the following questions:

1. When should a fire apparatus be considered for replacement?
2. Is a decision making aid, matrix or model available to assist with the decision making process in the determination of when to replace a fire apparatus and is refurbishment of the apparatus an option?
3. If no usable model exists, what are the logical variables that should exist and how should they be weighted?
4. If a model is developed and weight assigned to the various components, what would the outcome be if the Greenville Fire Department aerial platform is assessed?

The procedures used to complete this research consisted of a literature review, interviews and a telephone survey.

The result of this research project was the generation of model to assess the need to replace fire apparatus. A scoring system recommends actions from keeping an apparatus in-service to recommending the retirement of the apparatus. Included is a determination if the apparatus is or is not a candidate for refurbishment.

The recommendations of this research project are:

1. To increase the awareness of the huge financial implications the decisions concerning when to replace fire apparatus have on a community.
2. To overcome long standing fire service tradition and values in the fire apparatus decision making process.
3. To spend funds for increased safety and efficiency to increase output in capability.
4. To increase the sophistication of the manner in which decisions are made for the replacement and refurbishing of fire apparatus using data and a model.
5. To field test and verify the model developed for validation.
6. To further develop the model as additional data becomes available.

TABLE OF CONTENTS

ABSTRACT....................2
TABLE OF CONTENTS....................4
INTRODUCTION....................5
RESEARCH QUESTIONS....................6
BACKGROUND AND SIGNIFICANCE....................7
LITERATURE REVIEW....................9
PROCEDURES....................23
RESULTS....................25
RECOMMENDATIONS....................35
REFERENCES....................37
APPENDIX A....................40
APPENDIX B....................44
APPENDIX C....................46
APPENDIX D....................48

INTRODUCTION

The provision of reliable firefighting apparatus is one of the most important capital assets of a local government. The fire apparatus fleet must be maintained in the highest state of readiness to respond to emergencies. The fleet of fire apparatus should also be looked at from an efficiency and safety perspective. Modern fire apparatus could utilize manpower more efficiently due to user friendly controls and ergonomic design. In addition, newer construction standards increase the safe use of the apparatus (National Fire Protection Association 1901 Standard for Automotive Fire Apparatus 2003 Edition - Draft, 2003).

Engine Company apparatus costing in excess of $300,000 and Ladder Company apparatus costing over $700,000 are not unusual today. For example, the New Madison Fire Department, New Madison, Ohio purchased a triple combination pumper (Appendix A - Figure 1) for $317,000.00 (J. Frech, personal communication, April 22, 2003) in 2002. Capital costs as high as these could place a tremendous burden upon a municipality's capital expenditure budget. As stated in National Fire Protection Association [NFPA] 1901 Standard for Automotive Fire Apparatus 1999 Edition (1999, p.75), “fire apparatus is a major purchase and should not be done in a haphazard manner.” Therefore, thoughtful study should be performed to plan for the purchase and long-term use of these apparatus to minimize the economic impact on a governing body.

The problem is determining when to replace a fire apparatus. Different levels of use and preventative maintenance as well as the possibility of obsolescence of the apparatus, introduced a few variables that need to be considered. In the United States, traditional values may lend to an organization making unnecessary purchases (Mallet, 1982). An additional problem is in making objective decisions when considering at what point to replace or refurbish fire apparatus (Heller, 1983). One avenue that could be considered in the planning and budgeting process is the refurbishment of apparatus instead of purchasing new (National Fire Protection Association 1912 Standard for Fire Apparatus Refurbishing 2001 Edition, 2001). Refurbishment is the life extension of the fire apparatus by having repaired and rebuilding the apparatus to one degree or another.

The purpose of this study was to research the principles of when fire apparatus should be replaced and the availability of decision making models that could assist in making objective and critical decisions. If sound decisions are not made in relation to replacing fire apparatus, communities could incur higher than necessary capital operating costs.

RESEARCH QUESTIONS

1. When should a fire apparatus be considered for replacement?
2. Is a decision making aid, matrix or model available to assist with the decision making process in the determination of when to replace a fire apparatus and is refurbishment of the apparatus an option?
3. If no usable model exists, what are the logical variables that should exist and how should they be weighted?
4. If a model is developed and weight assigned to the various components, what would the outcome be if the Greenville Fire Department aerial platform is assessed?

BACKGROUND AND SIGNIFICANCE

Fire apparatus have been in use in one form or another since the dawn of civilization (McCall, 1976). For example, McCall writes that about 200 B.C. a pair of brass force pumps were connected to a discharge tube on a portable engine and operated manually for the purposes of fire suppression. McCall records that this basic concept of discharging water for fire suppression is still in use today. The basic components of fire apparatus is the chassis with associated bodywork, the propulsion system of the apparatus, the fire pump and its energy source. The principle components of fire apparatus are the fire pump, booster equipment (water or chemical extinguishing tanks), hose carrying capacity, ground ladder equipment and an aerial device (Mallet, 1982). When several of these five functional types have been combined on one apparatus, a combination ensues. For example, the most widely used apparatus is considered a triple-combination pumper (Appendix A - Figure 2) as it is equipped with a pump, carries hose and has booster equipment (water tank). The apparatus that has a pump, booster equipment, hose, ladders and an aerial device is termed a quintuple combination (quint) (Appendix A - Figure 3) (Mallet, 1982).

Hand drawn manually operated pumps were first patented in 1721 by Richard Newsham (Goodenough, 1985). McCall (1976) recorded that steam operated fire pumps were developed in the 1850s and were produced until the late 1910s. Most of this steam operated fire apparatus was horse drawn, however, some self-propelled steam fire apparatus was built. For example, in 1908 Amoskeog built a self-propelled steam fire apparatus that was used until 1940 (McCall, 1975). McCall recorded that the next significant development in fire apparatus was the internal combustion engine. The first recorded use of an internal combustion engine used to propel fire apparatus was in 1906 at the Radnor Fire Company in Wayne, Pennsylvania. During the period, 1912 to 1916, many horse drawn steam fire pumpers were converted to motorized apparatus with the horses being replaced with a gasoline powered engine for propulsion (McCall, 1976). McCall (1976) noted that the speed of the changes occurring during this period occurred with such speed that a buyer could purchase steam powered apparatus that was propelled by horses, electrical motors and gasoline engines as well as motorized pumpers from the same manufacturer. McCall further recorded that many developments in fire apparatus technology seen today were in fact developed many years ago an not embraced quickly by the fire service. For example, Mack Trucks produced the first fully enclosed triple combination pumper in 1935 (Appendix A - Figure 4) (McCall, 1976). Fully enclosed cabs were not required by the National Fire Protection Association 1901 Standard for Automotive Fire Apparatus until the 1991 Edition (National Fire Protection Association 1901 Standard for Automotive Fire Apparatus 2003 Edition (2003, draft). The first fire apparatus that used a diesel engine for propulsion was manufactured in 1939 (Appendix A - Figure 5), however, the diesel engine was not widely used until the 1960s (McCall, 1976). Calderone and Lerch (1984) argued that in the tradition bound fire service, innovations and improvements could take decades to gain widespread acceptance. Their example of this is the reluctance to change to metal aerial ladders instead of wood in the 1940s (Appendix A - Figure 6 & Figure 7). Goodenough (1985) reported that innovations in design of fire apparatus were greeted with scepticism as early as just after the Revolutionary War. Goodenough further described the rivalries between the fire companies characterized by their roughness, heroism, brawling, parades and pride. These characteristics set in motion a tradition of independence between the various fire companies (Goodenough, 1985). Highly decorated apparatus distinctive to an individual fire company was common and this tradition has carried through to the twentieth century (Goodenough). Mallet (1982) argued that due to strong local customs in the fire service, peculiarities (traditions) die hard.

Several authors (Saunders and Ku, Senter and Craven) researched argued that fire departments use age as the determining factor in the replacement of fire apparatus. At or before twenty years of age, most are replaced and are still in good mechanical condition (Wolf, 2001). Wolf further argued that when in satisfactory mechanical condition, the total refurbishment of fire apparatus was a viable option for many communities to extend the life of fire apparatus to reduce the cost of fire protection to a community. For a real example, in the Greenville, Ohio Fire Department, the aerial apparatus must be considered for replacement within the next five to ten years. The probability of increasing maintenance costs and obsolescence of the apparatus are the primary factors for the replacement of this apparatus. It is expected that the cost of replacing this apparatus could be in excess of $1,000,000. With proper planning and a tool to determine use and cost effectiveness, the community could save taxpayer money if it is determined to be cost effective to refurbish this apparatus to include up-to-date technology, instead of purchasing a new aerial apparatus.

LITERATURE REVIEW

Craven (1995), Craven (1997) and Peters (1994) argued that the life span of fire apparatus depended on the level of use, local conditions, environment and the scope of preventative maintenance. For example, Cravens and Peters both argued that moderate to heavy use of pumping apparatus limited the useful life to ten to fifteen years. Conversely, Cravens and Peters argued that the useful life span of pumping apparatus subjected to light use could be estimated at twenty years.

Senter (1999) examined variables that may affect useful life span and identified steps that may improve apparatus life span. These variables included apparatus utilization, local environment, local operating conditions and most importantly, the scope of preventative maintenance.

Fire apparatus was recommended for replacement at fifteen to twenty year intervals by the American Insurance Association [AIA] Special Interest Bulletin No. 39 (1975). The AIA bulletin included the factors of obsolescence due to inadequate braking, slow acceleration, inadequate protection of driver and men, a structurally weakened chassis due to overloading, increasing cost of maintenance, low efficiency, low dependability and difficulty in obtaining replacement parts as factors to replace the apparatus within the specified interval.

A National Bureau of Standards report, Sequencing the Purchase and Retirement of Fire Engines (Saunders and Ku, 1974), listed a twenty year life span for fire apparatus. No data was presented in the report to justify their position. However, the report suggested placing “front-line” apparatus in reserve status or in slower responding stations after a ten year life span.

According to Green and Knorr (1989) in Managing Public Equipment, considerable debate about which variable determines the optimal replacement point for vehicles exists. Green and Knorr further related that equipment managers could track vehicle productivity data such as age, use, fuel consumed and downtime to determine the point at which a vehicle would be replaced. Green and Knorr also argued that the length of time over which the average total units' cost was

lowest was the optimal economic life of the equipment. After this point was reached, they argued that it should be replaced. Their optimal economic life was determined by using what they termed, "life cycle" costing. Life cycle costing used the units' total costs including depreciation, operations and maintenance costs, downtime, use rates, obsolescence (parts availability), operator training costs, parts inventory and the value of money. Green & Knorr used the experience of the City of Alberta, Canada to illustrate their position. Calculations for a sedan were graphed and the point of lowest economic cost was determined (Chart 1). They argued that this vehicle should be replaced at five years. They further argued that any cost incurred after the lowest economic point was reached, was a penalty cost which could be avoided if the vehicle was replaced. Green & Knorr argued that the life cycle costing for public works capital investment including equipment purchases was the most economical manner in which to maintain the infrastructure of a community.

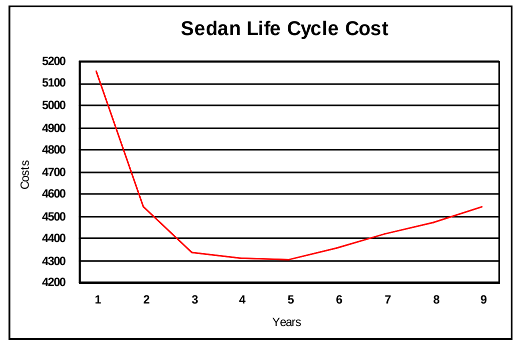

Chart 1. Sedan life cycle costs.

From *Managing Public Equipment*, by H. Green and R. Knorr, 1989, Copyright 1989 by the American Public Works Association.

In the National Fire Protection Association [NFPA] 1911 Standard for Service Tests of Fire Pump Systems on Fire Apparatus 2002 Edition (2002), service tests are to be conducted on an annual frequency or after major repairs to insure the equipment met its performance criteria. In the Fire Suppression Rating Schedule (Insurance Services Office, 1980), the insurance industry scored pump capacity on meeting criteria for the regular and systematic pump tests. Both of these documents did not list age as a limiting factor for meeting performance criteria.

Craven (1995) discussed the impact of maintenance costs and its impact on total costs as an apparatus aged. As it aged, parts wore out and needed replacement. A pro-active preventative maintenance program could hold costs to an acceptable level. Craven also proposed the total lifetime operating cost of a vehicle should determine when it should be taken out-of-service. For example, he argued that when a predetermined cost per mile is reached, the apparatus should be removed from active use. Craven considered this process as "life cycle costing." In life cycle costing, Craven used three "lives:" Service Life, which is the amount of time the vehicle could render service to the community; Technological Life, which represented obsolescence compared to a new vehicle built using the latest technology in manufacturing and operational aspects; and finally and most importantly, the Economic Life as being what impact the vehicle had on capital and operating budgets. These costs included operations, maintenance, downtime, obsolescence, operator training, parts and depreciation. Craven also related that proper records must be kept to perform an analysis of the vehicle to determine the total cost and best financial avenue. Craven suggested using the present cost, future cost based on history, the cost of a new vehicle and a physical inspection and diagnosis. Craven then suggested using a decision tree to replace, refurbish or rehabilitate the apparatus.

Craven (1997) related that equipment reliability was a huge issue. Craven illustrated the need for the fire apparatus to be in a constant state of readiness due to the nature of the fire service.

A National Bureau of Standards report, Sequencing the Purchase and Retirement of Fire

Engines (Saunders and Ku, 1974), was written to describe methods of determining an "optimum" manner of sequencing the purchasing and retiring of fire engines. Although this report was directed at fleet replacement decisions using mathematical models, some points addressed issues with costs associated with maintaining older equipment. The report stated, "One class of equipment replacement problems balances the cost of failure against the cost of planned replacements (Saunders and Ku, 1974, p. 12)." In addition, the report stated, "A third class of equipment maintenance problems deals with the replacement of items that deteriorate (Saunders and Ku, 1974, p. 15)." It further stated, "....models to solve this problem typically trade-off the increasing operational and maintenance cost (and decreasing resale value) of an aging item against the cost of a new purchase (Saunders and Ku, 1974, p. 15)."

This research has indicated that increased maintenance cost is normal on older fire apparatus. Cost history and projected costs for the future must be considered as a factor in determining when to replace or refurbish a fire apparatus. In addition, reliability of the apparatus must be considered.

In National Fire Protection Association [NFPA] 1911 Standard for Service Tests of Fire Pump Systems on Fire Apparatus 1997 Edition (1997), regular and systematic pump tests have shown that existing defects could be found, where in the day-to-day light pump use normally encountered, they could remain hidden until the pump is called upon to pump at capacity. This standard further described the following: "Fire pump testing methods were first published by the National Board of Fire Underwriters in 1910. Prior tests were characterized as more spectacular than exact (NFPA 1911, 1997, p. 21)." The basic service test for fire pumps as it is now known, was developed by the International Association of Fire Engineers in 1913 (NFPA 1911, 1997).

In 1981, the publishing rights to the National Board of Fire Underwriters "Fire Department Pumper Tests and Fire Stream Tables" was transferred to the National Fire Protection Association. Soon after, some slight modifications were made to improve safety, to recognize large diameter hose, removed language that dealt with positive displacement pumps and modified the test descriptions to correlate with the NFPA standard format (NFPA 1911, 1997). It is interesting to note that other than the changes listed, the essential components of the test have remained the same.

In National Fire Protection Association [NFPA] 1914 Standard for Testing Aerial Devices 1997 Edition (1997), the testing was performed to insure a minimum degree of safety. It is notable that age of the apparatus was not mentioned in this document.

In Hickey (1993), his examples of credit for pump tests for the Fire Suppression Grading Schedule underscored the need for cities to conduct annual service tests of pumps and to maintain the mechanical performance of each piece of apparatus. Hickey argued that the major components of fire apparatus are the pump and aerial ladder and routine testing to meet minimum performance standards is necessary to ensure the equipment would perform to the criteria specified for the apparatus. Hickey argues that the original Fire Suppression Grading Schedule was based on determining deficiencies from the numerical criterion set forth. This document was based upon the original developed in 1916. This document gave high deficiency points to apparatus over twenty years old. This document was used until it underwent a major revision in 1974. Hickey related the new Fire Suppression Grading Schedule published in 1980 assigned credits, not deficiency points. Furthermore, the ISO Fire Suppression Rating Schedule (ISO, 1980) gave credit to all pump tests that met the criteria in the Underwriters publication

"Fire Department Test and Fire Stream Tables (1911) ."

Several authors listed specific ages for the replacement of fire apparatus. The American Insurance Association [AIA] Special Interest Bulletin No. 39, Fire Department Apparatus - Replacement Of, Revised 1975) argued that in general apparatus fifteen to twenty years old should be replaced. Craven (1997) argued that after twenty years obsolescence make the apparatus less desirable to use even if mechanically functional. Craven also stated, "Increasingly, apparatus is being designed to improve its functional performance." Senter (1999) argued that apparatus with moderate to heavy use should be replaced after ten to fifteen years and apparatus with light use should be replaced after twenty years of use. In addition, Senter argued that after a period, heavily used apparatus could be moved from "front line" service to a "reserve" use prior to usual retirement. Green and Knorr (1989) described an important consideration for the replacement of equipment based only on use and/or age when it is used as emergency equipment (fire apparatus).

Roum (2001) argued that depot level maintenance, which is the repair, overhaul, modification, engineering and logistical support, must be sustained for the military systems including aircraft. In a speech before a congressional committee, he stated, "NAVAIR Jacksonville (a depot maintenance facility) is currently conducting an analysis of alternatives for the P-3 Orion aircraft when it achieves its designed fatigue life in 2005 (Roam, 2001, p. 10)." Critical components in aircraft have a "designed fatigue life" that is based upon engineering data with a safety factor built in (Roam, 2001). As material condition and reliability degrade, depot level maintenance must be performed to keep the system in-service. Depot level maintenance for the military is parallel to the refurbishment of fire apparatus.

In Green and Knorr (1989), it is argued that low downtime and high parts availability are critical factors for emergency equipment. Their text, in contrast to Craven (1997), listed obsolescence as the availability of parts for repairs as well as technologically improved equipment. Craven (1997) listed obsolescence as it related only to technology.

Heller (1983) suggested performing a simple cost analysis in making an objective determination in deciding whether to extend the life of fire apparatus. First, the useful life of the apparatus must be determined without any action being taken to extend the useful life. Next, he used straight-line depreciation for simplicity with the useful life divided by the purchase price. Heller assumed the value of the apparatus to be zero at the end of the vehicles' life. Heller then determined today's value, again based on straight-line depreciation. Heller then added the cost of refurbishment and divided this value by the extended useful life to determine the cost per year for the apparatus. This value was then compared with the cost of a new similar apparatus divided by its useful life. An objective comparison was then made. Heller further stated that the closer the numbers, the more critical the decision. In Wolf (2001), he used a cost analysis worksheet using straight-line depreciation similar to Heller's method to estimate the cost for a refurbishment of a triple combination pumper (Appendix A - Figure 9). It is interesting to note that the year 2000 refurbishment was the second for this apparatus. Wolf and Heller (1983), argue that a cost benefit/analysis must be completed to determine the economic value of the refurbishment process.

In Green and Knorr (1989), significant data was presented on the equipment replacement process they called "Life-Cycle Cost Analysis." This work described variables such as the hours of operation, age, use, fuel consumed and downtime used to track vehicle productivity. It was also related that considerable debate exists about which variable determines the optimal replacement point. Analysis of economic life was described in detail in their work. This process determined the length of time over which the average total unit cost is lowest. The total unit cost was determined by calculating all costs associated with ownership including depreciation, operations, maintenance, downtime and use rates, obsolescence, operator training time and costs, parts inventory and the value of money. Economic replacement followed three premises. First, as a unit ages, average maintenance and operational costs increase. Second, as a unit grows older, investment costs decrease.

Third, there is a point in the unit's life at which the total average cost is minimum. This is argued as the optimum economic life point. It is further argued that the objective of life-cycle costing for equipment replacement is to replace units when maintenance and associated downtime costs increase (see Chart 1).

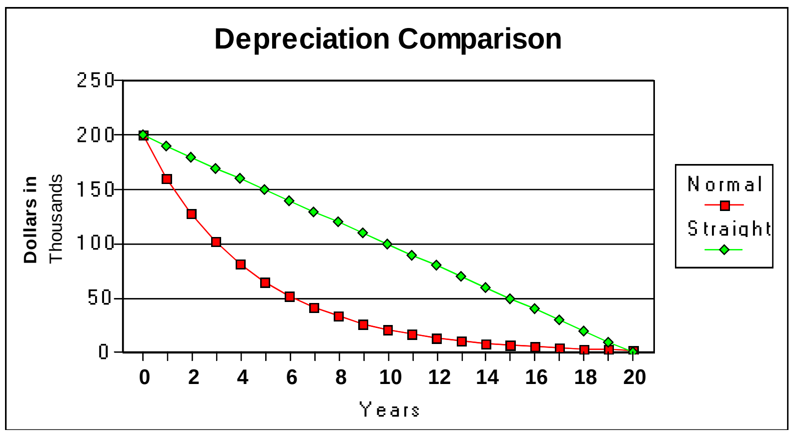

Chart 2. Comparison of depreciation using values and calculations expressed by Green and Knorr (1989), Heller (1983) and Wolf (2001).

From Managing Public Equipment by H. Green and R. Knorr copyright by the American Public Works Association 1989, Rehab? Find the Bottom Line by J. Heller , copyright 1983 and (2001). New or Refurbished - That is the Question by M. Wolf, M. copyright 2001 by the Ohio Fire Chiefs' Association.

Green (1989), Heller (1983) and Wolf (2001) argued that deprecation should be a factor in determining the economic life of equipment. Heller (1983) and Wolf (2001) detailed, for simplification purposes, a straight line method of calculating depreciation. Green argues that in "Life Cycle Cost Analysis," depreciation should be projected linearly. Green further argues that resale value (depreciation) is adjusted with the assumption of a 20% loss of value annually. Green (1989) further argues that the actual depreciation rate will not be known until the unit is disposed of. For comparison, Chart 2 illustrates the depreciation rates of a fire apparatus projected as straight-line rate as argued by Heller (1983) and Wolf (2001) and the 20% per annum rates argued by Green and Knorr (1989).

National Fire Protection Association 1500 Standard for Fire Department Safety and Health Program 2002 Edition (2002) states, "When fire apparatus is refurbished, it shall be specified and ordered to meet the applicable requirements of NFPA 1912, *Standard for Fire Apparatus Refurbishing* (p. 14)." National Fire Protection Association [NFPA] 1912 Standard for Fire Apparatus Refurbishing 2001 Edition (2001) discusses construction and engineering standards and directly discusses the decision making process that needs to be undertaken for the refurbishment of fire apparatus. NFPA 1912 (2001) discusses two levels of refurbishment. Level I refurbishment is when the apparatus or components refurbished are brought up to the current edition of NFPA 1901. Level II refurbishment is when the apparatus or components refurbished meet the applicable chapters of the NFPA 1901 in effect at the time of original manufacture. National Fire Protection Association [NFPA] 1901 Standard for Automotive Fire Apparatus 1999 Edition (1999) states that when major renovations are made, the apparatus should be brought into line with the standard as much as possible. With the passage of the National Traffic and Motor Vehicle Safety Act of 1966, it is unlawful to deliver fire apparatus not in compliance (NFPA 1901, 1999). A new draft of National Fire Protection Association 1901 Standard for Automotive Fire Apparatus that will be voted on late in 2003 includes a new section titled "Appendix D - Guidelines for First Line and Reserve Apparatus" that includes several recommendations concerning the upgrading (refurbishing) of fire apparatus. First and foremost, this document recommends that fire departments should seriously consider the value and risk of keeping pre-1991 fire apparatus in front-line service due to the significant safety improvements found in the 1991 edition of NFPA 1901. The 1991 edition of NFPA 1901 is referred to as the "benchmark" from which new and improved apparatus have evolved (NFPA 1901, 2003 draft). Furthermore, this document suggests that apparatus manufactured prior to 1979 be upgraded or removed from service. Section 3 of Annex D contains a list of features that refurbished fire apparatus should have included during the upgrade (reference list in Appendix A).

Heller (1983) provides information that when a glider kit program is undertaken, the unit will be titled the year when the rework is undertaken. He further maintains that this may be a cost effective alternative when a unit is damaged early in its useful life span. In addition, John Rideout (personal communication, February 14 , 2003) stated that when a Glider Kit is completed on an apparatus, a new title has to be issued, all current manufacturing standards must be met, and may be cost prohibited. Appendix D of NFPA 1901 (2003) recommends a thorough cost benefit analysis be completed as some refurbishments may exceed the current value of an apparatus.

In Wolf (2001), it was argued that the extent of a refurbish can vary wildly. He suggested starting at the bottom (chassis) and working up with the use of a decision tree matrix based on the vehicle components. The matrix presented is used in the decision making process when considering refurbishment as an alternative to purchasing a new apparatus (Appendix A - Figure 8). The matrix considers the elements that need to be considered; it does not provide any objective criteria as to which is the better alternative, buy new or refurbish. Saunders and Ku (1974) compared the factors of depreciation and cost effectiveness of life extension.

In the appendix of NFPA 1912 (2001), it is suggested that use of the standard will create information checklists that will identify areas on the vehicle that should be addressed when considering refurbishing. A sample “Apparatus Refurbishing Specification Form” is contained in the standard; however, a checklist or model is not provided as part of this document.

Heller (1983) discussed the sentimental attachment some fire departments have with a particular piece of fire apparatus. Heller argues that this is not a time to be sentimental; fiscal responsibility should rule. John Rideout (personal communication, February 14 , 2003) stated that in his experience in refurbishing fire apparatus, many fire departments (mostly small and independent) make unwise financial decisions concerning the refurbishment on fire apparatus for sentimental reasons. While conducting the telephone survey for this report, many respondents reported that sentiment towards a particular fire apparatus is the largest single factor that many independent organizations base their decisions on for the refurbishment of fire apparatus (J. Rideout, Rich Spires, Mel Nyman, Bob Billings, personal communications and interviews, February 14-16 , 2003).

Literature Review Summary

The fire service as an institution has been organized for many years. Over these years it became, at times, very traditionally bound and resistant to change. After many years of slow evolution, fire apparatus changed significantly just after the beginning of the 20th century. Even with many important innovations in fire apparatus being developed, the fire service did not embrace the changes in technology with the speed at which they were introduced. This failure, along with the normal cycle time of up to twenty years or more for the replacement of fire apparatus, caused the technological advantage of improved fire apparatus not to be utilized as quickly as it could be. Calderone and Learch (1984) argued that in the tradition bound fire service, decades may elapse before new technology is embraced. This factor, along with the normal cycle time of a ten to over a twenty year life span could be the cause of obsolete fire apparatus being utilized instead of technologically improved fire apparatus.

It is clear that fire apparatus does not have a finite life span. The life span of fire apparatus will depend on variables such as the level of use, local conditions and scope of preventative maintenance. For example, heavy use of fire apparatus may limit its usefulness to ten years or less. In contrast, low use fire apparatus might be mechanically sound after twenty years or more of use. One detail that many authors researched agreed upon was that the scope of preventative maintenance is a critical factor in the long-term use of fire apparatus.

The replacement intervals noted in the literature research that list a finite time for replacement could not be validated by facts. New and better construction methods of fire apparatus along with new technology contained in construction standards such as NFPA 1901, have made the fire apparatus manufactured now safer as well as more efficient.

The economic value and life of fire apparatus is surrounded by much debate. Clearly the research has shown that a point is present for each fire apparatus in which it would be economically feasible to replace the apparatus than pay for increasing maintenance costs. For example, the economic life concept introduced by Green and Knorr (1989) is of exceptional value. The lowest point of a unit's cost is calculated by affixing an economic value on operational costs, maintenance costs, downtime, use rates, obsolescence, operator training costs, part inventory, depreciation and the value of money. Their argument, that after the point of lowest economic cost has been reached, a penalty cost will be encountered that can be avoided with the replacement of the unit.

All fire apparatus should meet the recognized standards of performance testing. The two primary testing standards are the National Fire Protection Association 1911 Standard for Service Tests of Fire Pump Systems and National Fire Protection Association 1914 Standard for Testing Fire Department Aerial Devices. It was also noted that the fire insurance industry requires these tests to be completed for recognition in the Fire Suppression Rating Schedule.

The reliability of fire apparatus to perform at all times under all conditions was a common theme presented by the authors reviewed. Saunders and Ku (1974) argued that the cost of failure must be balanced with the cost of replacements.

The United States military have highly sophisticated methods of determining when to perform "depot maintenance" on its airplanes and ships. It is worthy to note that this level of sophistication could not be found in any fire service literature. Engineering data and extensive record keeping and analysis is used to extend the life of many military systems.

Two methods were found which could be utilized to determine the value of fire apparatus into the future. The difference between using straight line deprecation (Wolf, 2001) and a normal 20% per year loss of value (Green and Knorr, 1989) is significant (Chart 2). It has also been noted that the actual value cannot be determined until the unit is sold (Green an Knorr, 1989).

National Fire Protection Association Standards 1500 (Fire Department Safety and Health Program), 1901 (Automotive Fire Apparatus, 1912 (Fire Apparatus Refurbishing) should be referenced for all decision making processes related to fire apparatus. Recently, significant increases were made in the area for safety of fire department personnel operating and riding in fire apparatus.

The refurbishment of existing apparatus is an option to replacement. The level of a refurbishment will vary. A level I refurbishment will restore an apparatus to the standards in place at the time of original manufacture. A level II refurbishment will bring the apparatus into line with the standards of the current edition of NFPA 1901. A new draft of NFPA 1901 will be voted upon in 2003 that includes specific recommendations on what should and should not be done with older fire apparatus. The basic thrust of this document is to increase the safety to fire department personnel. Table 1 in Appendix A lists the recommended features from NFPA 1901 (2003, draft) that be considered during the refurbishment process.

PROCEDURES

This research project utilized several research methodologies. These methodologies examined when a fire apparatus should be considered for replacement or refurbishment and were decision making aids available for the refurbishment vs. new considerations. The procedures used included a literature review, a telephone survey, and personal interviews.

Literature Review

The literature review targeted trade journals, magazines, textbooks, technical standards and other works that contained information on fire apparatus, fire apparatus replacement and refurbishment practices, fire apparatus testing standards, and fire apparatus construction standards. In addition, comparison literature from the United States Military was researched. Applicable sources were summarized and included in the Literature Review section of this report.

Telephone Survey

A survey of seven questions was developed to solicit information from fire apparatus manufacturers and refurbishment shops. Research conducted in the Fire Apparatus Manufactures Association (FAMA) Buyers' Guide (FAMA, 2003) concluded that thirty five manufactures of aerials and pumpers exist in the United States. Eleven manufactures were contacted for the telephone survey, representing 31½% of the listed manufacturers of aerials and pumpers. The manufacturers selected for the telephone survey was conducted at random from the list of thirty five manufactures of aerials and pumpers. The persons contacted at the respective manufacturer for the survey managed the refurbishment process for the manufacturer. Manufacturers were chosen for the telephone survey because they work extensively with the development of bids and specifications for new and refurbished fire apparatus. Responses for the survey were tabulated and are contained in Appendix B, Table 2.

The questions for the telephone survey were developed to solicit information needed to compile data for how decisions are made in the refurbishing process of fire apparatus. A complete list of the telephone survey questions are in Appendix B.

Personal Interviews and Communications

Several personal interviews and communications were made with representatives of several fire apparatus manufacturers for this research report. The author felt that they were experts as they deal with the specification and refurbishment of fire apparatus on a daily basis.

Definitions of Terms

Refurbishment. The partial or complete remanufacture of a fire apparatus.

Triple combination pumper. A fire fighting apparatus containing a pump, hose carrying capacity and a water tank

Quintuple combination. A fire fighting apparatus containing a pump, hose carrying capacity, water tank, ground ladder storage and an aerial ladder devise.

Assumptions

The procedures used in this research project were based on three basic assumptions. First, it was assumed that all authors referenced in the literature review completed unbiased and objective research. Second, it was assumed that all respondents to the personal interviews answered all questions fairly and objectively. Third, it was assumed that all respondents to the telephone survey answered all questions fairly and objectively.

RESULTS

1. **When should a fire apparatus be considered for replacement?** No clear cut answer could be found during the research efforts. While many authors (Wolf, 2001; Craven, 1995; Heller, 1983,Saunders and Ku, 1974) discussed several common issues regarding when fire apparatus should be replaced, no common consensus could be

determined. Tradition and personal sentiment seemed to play a large part of many decisions related to the purchase of fire apparatus (J. Rideout, Rich Spires, Mel Nyman, Bob Billings, personal communications and interviews, February 14-16 , 2003). The need for reliable fire apparatus needs to be addressed as the functioning of the fire apparatus for emergencies use is extremely time sensitive.

2. **Is a decision making aid, matrix or model available to assist with the decision making process in the determination of when to replace a fire apparatus and is refurbishment of the apparatus an option?**

An in-depth, objective decision making aid, matrix, or model is not readily available. The only decision making model for fire apparatus located (Wolf, 2001), listed the components that needed consideration. However, this model did not contain an objective process in making decisions. National Fire Protection Association 1912 Standard for Fire Apparatus Refurbishing 2001 Edition (2001) contained a detailed list of items for consideration and a sample specification form for refurbishment; however, the standard did not present an objective system for assisting with the decision making process. The information gathered from personal communications (J. Rideout, Rich Spires, Mel Nyman, Bob Billings, personal communications and interviews, February 14-16 , 2003) related that most decisions concerning refurbishment of fire apparatus were subjective and based on personal sentiment.

3. **If no usable model exists, what are the logical variables that should exist and how should they be weighted?**

A list of variables and associated weighting that could be considered for evaluating any quintuple fire apparatus are as follows:

1. Mechanicals (weight 25%)
    1. Chassis & drive train
        1. Engine & transmission
        2. Suspension
        3. Steering gear & brake system
        4. Tires/wheels
    2. Pump and related equipment
        1. Transfer case
        2. Pump

        3. Valves & piping
        4. Booster tank
        5. Annual pump tests
    3. Aerial device
        1. Aerial meets specifications of NFPA 1901 Chapter 18
        2. Annual tests

2. Electrical System (weight 5%)
    1. Alternator
    2. Wiring & batteries
    3. Warning lighting & siren system
    4. Electronic controls

3. Cab & Body (weight 10%)
    1. Cab & hose body condition
    2. Compartment & hose storage volume/layout
    3. Ground ladders
    4. Fit & finish

4. Obsolescence (weight 10%)
    1. Compare with new apparatus with latest “improvements”
    2. Parts availability into future

5. Ergonomics (15%)
    1. Apparatus efficiency
    2. Apparatus safe to operate
    3. Enclosed seating positions
    4. Training

6. Economics (weight 35%)
    1. Input of purchasing price, depreciated value, operational and maintenance costs to create an “Economic Factor Score”

<u>Assumptions for Scoring</u>

Assumptions for scoring are:

1. The model was designed for and assumed that a trained, qualified and experienced fire apparatus technician performed the scoring.
2. The model was designed for use on any quintuple combination (pump, hose capacity, booster tank, ground ladders and aerial device) apparatus.
3. The model addressed the variables discovered in the literature review, interviews and

assigned weight based upon the relative importance of the items.

4. A graduated scale is used for scoring. A “0" would be for an unsafe or unacceptable condition. A “10" would be scored for a faultless or new condition. A “5" would be scored for a component that is in good condition, but has seen average use, wear and tear. The minimum total score possible is zero. The maximum total score possible is 200.
5. The final total score is assessed using the following scale:

   <80 - Consider apparatus replacement, most likely is not a candidate for refurbishment.

   80 - 100 - Monitor condition frequently, is a poor candidate for refurbishment.

   101 - 120 - Monitor condition closely, is a fair candidate for refurbishment.

   121 - 140 - Apply normal preventative maintenance and reassess in the future, is a good candidate for refurbishment.

   141 - 200 - Apply standard preventative maintenance and assess when a factor is identified that necessitates reassessment.
6. The considerations for scoring in the detailed sections are:

Mechanicals

Engine - General condition, fluid leakage, power available satisfactory, condition of auxiliary units (i.e. radiator, water pump, etc.), condition of belts and hoses.

Transmission - General condition, fluid leaks, clutch condition (if equipped), shift smooth, transmission match engine torque. In addition, consider benefits of a automatic vs. a manual transmission.

Suspension and Steering - Gross vehicle weight rating adequate for loaded apparatus, turning angle adequate, power steering or power assist unit adequate, angle of approach minimum of 8^{N}.

Brakes - Anti-lock brake equipped, moisture ejector present, air dryer present, pressure valve present to prevent brake lock-up from auxiliary accessories, equipped with quick build-up air reservoir, paring brake holds on 20^{N} grade, apparatus stoped within 35' at 20 miles per hour.

Tires - Proper load capacity, wear.

Fire Pump - Powered properly, heat exchanger and cooler provided, operator panel marked and illuminated, equipped with pressure control system, gauges and instrumentation adequate.

Valves and Piping - Hose threads terminate in NST (national standard), all intake and discharge piping equipped with bleeder valves, intake valves can be closed within three seconds, discharge valves three inches and greater equipped with slow close valves, no discharges greater than 2½" located at operators panel.

Booster Tank - General condition, leaks present, corrosion.

Pumping Tests - Apparatus passes annual NFPA 1911 Standard for Service Tests of Fire Pumps on Fire Apparatus.

Aerial and Ground Ladder Tests - Apparatus aerial ladder and ground ladders pass annual testing as specified in National Fire Protection Association 1914 Standard for Testing Fire Department Aerial Devices 2002 Edition (2002) National Fire Protection Association 1932 Standard for Use, Maintenance, and Service Testing of Fire Department Ground Ladders 1999 Edition (1999).

Electrical System

Alternator - Proper amperage output for application.

Wiring - General condition, sized properly, positive and sound mechanical and electrical connections, equipped with over current devices.

Warning Lights/Siren - Equipped with upper and lower level warning lights, equipped with responding and blocking modes for warning lights, proper flash rates (75 per minute/devise & 150 per minute at measurement point), audible warning devise mount as far forward and as low as possible.

Controls - Pump interlock and indicator equipped, electrical load manager equipped, switches and relays in good condition.

Cab & Body

Cab, Hose Body & Compartmentation - General condition, corrosion, windows, windshield wipers, highway lighting and marker lights, all enclosed compartments ventilated, all enclosed compartments illuminated, pump and plumbing access adequate, compartments weather resistant, equipment containment provided for.

Storage Volume - Hose storage volume adequate, compartment storage volume adequate.

Ground Ladders - Ground ladders proper size/type for application, ground ladder storage system proper configuration.

Fit and Finish - Paint/coating condition, corrosion.

Obsolescence - Compare with new technology, is present apparatus adequate and compatible or can it be upgraded, will replacement parts be available in future.

Ergonomics

Efficiency - Door/compartment handles at proper height, head height in cab at 37" minimum, driver seat adjustable, mirrors adequate and adjustable, instruments visible to driver, heating and/or cooling system adequate.

Safety - Work lighting present, compartment open light present in cab, equipped with seat belt at all riding positions, noise level in cab #90db, cab equipment secured, adequate steps and handrails, stepping, standing and walking surfaces non-slip, equipped with reflective trim.

Seating Positions - Seating positions fully enclosed.

Training - Ability to quickly train operators on use.

Economics

The economic score is derived from a mathematical model:

$$100 - (D + e + f + m + p) = V$$

$$V \times 70\% = S$$

D = Depreciated value

e = Engine hours x 0.001

f = Fuel cost x 0.0001

m = Mileage x 0.0005

p = Preventative and repairs cost x 0.01

V = Economic value transferred to the assessment score sheet

S = Evaluated score (70% of economic value)

The total economic value possible for a new apparatus is 100. The mathematical model subtracts from this value figuring depreciation, mileage, engine hours, repairs, preventative maintenance cost and fuel cost.

The following factors are considered in the mathematical model:

1. Ratio of value when new to the value at time of the assessment using a 20% per year depreciation rate.
2. Ratio of the vehicles mileage. The total vehicle mileage represents the use level of the apparatus.
3. Ratio of the engine hours. The total engine hours represents the use level and wear and tear of the apparatus drive train. During pumping operations, two of the three major components of the drive train (engine and transmission) are operating, resulting in a representation of the use of the drive train.
4. Ratio of the life time costs of repairs and preventative maintenance costs of operating the apparatus.
5. Ratio of life time fuel costs of operating the apparatus.

A sample apparatus scoring worksheet is presented Figure 10 in Appendix C. The data is transferred from this worksheet to a computerized spreadsheet that performs the calculations to obtain the final score.

4. **If a model is developed and weight assigned to the various components, what would**

the outcome be if the Greenville Fire Department aerial platform is assessed?

The assessment and scoring of the Greenville Fire Department quintuple combination apparatus was completed and is contained in Figure 11 and Figure 12 in Appendix D. This apparatus scored a 100.8 points out of a possible 200 points which is rated as: Monitor condition frequently, is a poor candidate for refurbishment. Rational for the scoring of this apparatus is as follows:

Mechanicals (weight 25%)

1. Chassis & drive train
    1. Engine & transmission - Above average condition, normal wear and tear
    2. Suspension - Above average condition, normal wear and tear
    3. Steering gear & brake system - Good condition, normal wear and tear
    4. Tires/wheels - Poor condition - all rear tires need replaced
2. Pump and related equipment
    1. Pump - Excellent condition, rebuilt less than five years previous
    2. Transfer case - Above average condition, normal wear and tear
    3. Valves & piping - Good condition, normal wear and tear
    4. Booster tank - Good condition, normal wear and tear
    5. Annual pump tests - Passed all pumping tests
3. Aerial device
    1. Aerial meets specifications of NFPA 1901 Chapter 18 - Needs modernized - obsolete control system
    2. Annual tests - Passed all ladder tests

2. Electrical System (weight 5%)
    1. Alternator - Above average condition, normal wear and tear
    2. Wiring & batteries - Above average condition, normal wear and tear

3. Warning lighting & siren system - Needs brought up to current NFPA 1901 standards
4. Electronic controls - Above average condition, normal wear and tear

3. Cab & Body (weight 10%)
    1. Hose Body - Good condition, normal wear and tear
    2. Compartment & hose storage volume/layout - Above average condition, normal wear and tear
    3. Ground ladders - Poor condition, ladders not banked for efficient deployment and use
    4. Fit & finish - Good condition, normal wear and tear

4. Obsolescence (weight 10%)
    1. Compare with new apparatus with latest “improvements” - Aerial needs upgraded to new technology (electronic controls)
    2. Parts availability into future - No problems noted with recent maintenance and repairs in obtaining parts and materials

5. Ergonomics (15%)
    1. Apparatus efficiency - Rated well
    2. Apparatus safe to operate - Yes, except for enclosed seating positions
    3. Enclosed seating positions - Needs rear seating area of crew compartment enclosed
    4. Training - Average time and skills needed

6. Economics (weight 35%)
    1. Economic Factor Score - Scored a 31.0 out of 100.0 points. Using the 20% per year depreciation rate (Green and Knorr, 1989) gives this apparatus a value of $8,679.72. Although the literature researched

indicated that the 20% per year depreciation rate is valid (Green and Knorr, 1989), it may need to be recalculated due to the low score calculated. For example, by changing the value of the apparatus to a value of $75,000.00 in the model, the economic score changes to 70.2 from 31.0 and the overall score changes to 128.3 (Apply normal preventative maintenance and reassess in the future, is a good candidate for refurbishment) from 100.8 (Monitor condition frequently, is a poor candidate for refurbishment). Recent advertisements for used fire apparatus of quintuple combination apparatus similar to the Greenville Quint (age, aerial type, pump capacity, etc.) were found to be listed at $75,000 to $90,000.

DISCUSSION

The fire service would be better suited to focus on the important aspects related to the performance of fire apparatus rather than making decisions for traditional or sentimental reasons. For example, the need to pass the annual pumping and ladder tests (National Fire Protection Association 1911 Standard for Service Tests of Fire Pump Systems on Fire Apparatus 1997 Edition, 1997 and National Fire Protection Association 1914 Standard for Testing Fire Department Aerial Devices 1997 Edition, 1997) is of greater importance than the sometimes higher traditional values placed on how fire apparatus decisions are made (Calderone and Lerch, 1984).

The model developed combined aspects of importance such as level of use, scope of preventative maintenance, operational and use costs, etc. argued by the authors researched. It is noteworthy that the United States military has a method of using engineering and trend data (Roam, 2001 and Loftus, 1992) to determine how aircraft and ships are maintained; however, the fire service has not embraced a service wide system of assessment even though standards are available for use such as those published by the National Fire Protection Association.

Determining the actual value of a fire apparatus may not fall within the annual depreciation rate as argued by Green and Knorr (1989). However, Green and Knorr also argued that the actual value cannot be determined until the unit is sold. It may be desirable to use a professional fire apparatus appraiser to determine the value for use in the model. The rating for the Greenville Fire Department Aerial changed dramatically when the current value was changed from the 20% per year rate argued by Green and Knorr to a value of similar used fire apparatus being sold at the present time. The revision of the value of the Greenville Fire Department aerial platform in the model changed its status from a poor candidate for refurbishment to an excellent candidate for refurbishment.

The research concluded that use of the model developed could save taxpayer dollars in two primary manners. First, if a fire apparatus is assessed and scores low, it can be taken out-of-service and replaced saving considerable funds on maintenance and repairs. Secondly, if the fire apparatus assessed is a candidate for refurbishment, taxpayers dollars can be saved by extending the life of the unit. The implications to the organization that uses the model is to use the instrument to assist in making decisions regarding the replacement and refurbishing of fire apparatus in an objective unbiased manner, therefore having the potential of saving taxpayer dollars while providing reliable and safe fire apparatus..

RECOMMENDATIONS

It is recommended that the following items be pursued in the future to save taxpayer dollars to increase the effectiveness of fiscal responsibility:

1. Increase awareness on costs issues for fire apparatus purchasing decisions and there effect on a community.
2. Overcome long standing traditional values for fire apparatus decisions. To protect a communities investment, objective decisions rather that subjective decisions need to be made.
3. Spend capital funds on output in capability (i.e. pump, hose carrying capability, booster equipment, ground ladders, and aerial ladder) and safety related issues rather than items of traditional value.
4. Increase sophistication of decision making with a model to reflect the commitment to protect the huge investment necessary to provide reliable fire apparatus to a community. The effect of this would be to reduce or eliminate personal sentiment in the decision making process. During the survey and interviews for this research, no model could be located that is currently used for the decision making process of determining the value of replacement versus refurbishing fire apparatus.
5. Field test the model to verify its applicability and value in assisting with decision making for fire apparatus purchases. The anticipated field test would include the evaluation of

several quintuple combination fire apparatus for comparison to validate the model.

6. Further develop the proposed model to achieve results. This action would increase the accuracy of the model to actual conditions in the sphere of fire apparatus refurbishment decision making.

REFERENCES

American Insurance Association. (ND). *Fire Department Apparatus - Replacement Of* (Special Interest Bulletin No. 39 Revised February, 1975). New York, NY.

Calderone, J. & Lerch, J. (1984). Wheels of the Bravest, A History of FDNY Fire Apparatus 1865-1982. New York, NY: Fire Apparatus Journal Publications.

Craven, R. (1995, November). Apparatus Specifications: A Guide To Saving Time & Money. *Firehouse, 20*(11), 86-88.

Craven, R. (1997). Fire department apparatus and equipment. In A. E. Cote (Ed.), *Fire Protection Handbook, 18*, (pp.10-201 - 10-214). Quincy, MA: National Fire Protection Association.

Fire Apparatus Manufacturers' Association. (2001, May 12). FAMA Buyers' Guide. Retrieved from http://fama.org/BuyersGuide/

Goodenough, S. (1985). *The Fire Engine, An Illustrated History*. Secaucus, NJ: Orbis Publishing.

Green, H. & Knorr, R. (1989). *Managing Public Equipment*. Chicago, IL: American Public Works Association.

Heller, J. (1983). Rehab? Find the Bottom Line. *Fire Service Today*, 14-15.

Hickey, H. (1993). *Fire Suppression Rating Schedule Handbook*. Professional Loss Control Education Foundation.

Insurance Services Office, Inc. (1980). *Fire Suppression Rating Schedule*. Insurance

Services Office, Inc.

Loftus, S. (1992). *OPNAV Instruction 4700.7j, Maintenance Policy for Naval Ships*. Washington DC: Department of the Navy.

Mallet, J. (1982). *Fire Engines of the World*. London: Osprey Publishing Limited.

McCall, W. (1976). *American Fire Engines Since 1900.* Sarasota, FL: Crestline Publishing Co., Inc.

National Fire Protection Association (2002). *NFPA 1500 Standard on Fire Department Safety and Health Program 2002 Edition.* Quincy, MA: National Fire Protection Association.

National Fire Protection Association (1999). *NFPA 1901 Standard for Automotive Fire Apparatus 1999 Edition.* Quincy, MA: National Fire Protection Association.

National Fire Protection Association (2003). *NFPA 1901 Standard for Automotive Fire Apparatus 2003 Edition.* Quincy, MA: National Fire Protection Association. Draft submitted for publication.

National Fire Protection Association (1997). *NFPA 1911 Standard for Service Tests of Fire Pump Systems on Fire Apparatus 1997 Edition.* Quincy, MA: National Fire Protection Association.

National Fire Protection Association (2001). *NFPA 1912 Standard for Fire Apparatus Refurbishing 2001 Edition.* Quincy, MA: National Fire Protection Association.

National Fire Protection Association (1997). *NFPA 1914 Standard for Testing Fire Department Aerial Devices 1997 Edition.* Quincy, MA: National Fire Protection Association.

Peters, William C. (1994). *Fire Apparatus Purchasing Handbook.* Saddle Brook, NJ: Fire Engineering.

Roum, C. (2001). Future Viability of Depot Level Maintenance and Repair. *Proceedings of the Subcommittee on Military Readiness of the House Armed Services Committee.* Washington DC.

Saunders, P. and Ku, R. (1974). Sequencing the Purchase and Retirement of Fire Engines. *NBS Special Publication 411*. Gaithersburg, MD: U. S. National Bureau of Standards.

Senter, E. (1999). *Improving Fire Apparatus Life Span Projections in the Norfolk Department of Fire and Paramedical Services.* Emmittsburg, MD: National Fire Academy, Executive Fire Officer Program.

Wolf, M. (2001). New or Refurbished - That is the Question. *Ohio Fire Chiefs' Journal, 4*(3).