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FOREWORD

Equipment managers in public and private organizations are responsible for all aspects of providing a diversified fleet of motorized equipment. Factors of concern to equipment managers include cost control, preventive maintenance, repair shop productivity, employee training and motivation, equipment replacement decisions, inventory control, commercial drivers license, alternative fuels, environmental safety, privatization, electronically controlled diesel engines, and other related topics. Ten Equipment Management Workshops have been conducted since 1976 to provide a continuing forum for the exchange of new ideas and developments in maintenance and management of equipment fleets.

The 10th Equipment Management Workshop was sponsored by the Transportation Research Board Committee on Equipment Maintenance in cooperation with the Oregon Department of Transportation and the Federal Highway Administration in Portland, Oregon, July 31-August 3, 1994. The proceedings of this Workshop are included in this *Circular* and structured around the following topics:

- Impact of Clean Air Act Amendments on Diesel Fuel.
- Waste Management.
- Alternative Fuels.
- Equipment of the Future.
- Human Resource Management.
- Equipment Maintenance.
- Toward Equipment Standardization.
- Rehabilitation, Purchasing and Leasing.
- International Equipment Technology.
- Reports from Regional Equipment Manager's Meetings.

Equipment research issues identified by the workshop participants are being reviewed and expanded by members of the Committee on Equipment Maintenance for publication as research problem statements in future TRB *Circulars*. Planning is ongoing for the 11th Equipment Management Workshop scheduled for June 1996 in New York State.

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SECTION I IMPACT OF CLEAN AIR ACT AMENDMENTS ON DIESEL FUEL

DIESEL FUEL ISSUES

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ABSTRACT

In recent years, environmental regulations have had a dramatic effect on the formulation of diesel fuel. The trend toward low-environmental impact diesel fuel has resulted in new formulations that not only benefit the environment but can enhance diesel engine performances as well. The sulfur content of highway diesel fuel has been reduced to a maximum of 0.05% by weight nationwide. California has an additional requirement of a maximum of 10% aromatics content that covers most highway and non-highway vehicles. However, fuels with higher aromatics levels can be certified if they demonstrate equivalent emissions. Development of such certified fuels has been the focus of much research by fuel producers.

The introduction of new fuels, coupled with the rapid changes in engine design to meet new emission regulations, has created the need to address several fuel properties to ensure proper performance while protecting certain engine components. Diesel fuel lubricity and its effect on some fuel system injection equipment, such as a rotary distributer pump, is one such issue which is being investigated by several groups. Other issues are also being addressed by joint groups in industry and regulatory agencies. Their goal is to find practical solutions, in each case, in a relatively short time.

To maximize the reduction of diesel exhaust emissions, both engines and fuels have been regulated. On the engine side, elements such as electronic management systems, engine geometry changes, higher injection pressures and timing optimization have been used to reach new emissions goals. On the fuel side, properties such as sulfur and aromatics contents, and also cetane index, have been regulated. Fuel regulations were based on the best technical data available at the time. In some cases, different properties might have been targeted had the results of new research been available.

Additional changes to diesel fuel properties, beyond the regulated ones, have been proposed by engine manufacturers to make meeting future engine emissions regulations more feasible. These changes in fuel properties and those imposed by the regulations, while environmentally beneficial can sometimes, cause performance problems. These problems would need to be investigated rapidly and solved simultaneously with the introduction of new fuels.

This article includes the description of some pertinent fuel properties, a summary of the Federal and California fuel regulations, and a brief review of several fuel related issues, such as lubricity. In some areas, such as diesel fuel dye requirements, rapid changes are in progress. Therefore, developments may replace some information provided at this time.

INTRODUCTION

Conventional diesel fuel and practices associated with its production, handling, and use are well established and have been understood for many years. Recent and rapid changes in this area have created many new challenges. Environmental requirements and demands, much like the ones in the gasoline area, were initiated in the 1980s to regulate and limit the emissions related to the use of diesel fuel. Oxides of nitrogen (NOx) and particulate matter (PM) have been the main focus of the regulations. Compression ignition engines have the advantage of operating more efficiently since they have a higher compression ratio. This, however, translates to higher peak combustion temperatures, which leads to higher NOx levels. Hydrocarbon (HC) and carbon monoxide (CO) emissions, on the other hand, are not as serious issues as they are in gasoline engines.

FUEL PROPERTIES

The American Society for Testing and Materials, ASTM, has specified fuel properties for various grades of diesel fuel (1). Table I contains the specifications for No. 1 and No. 2 diesel fuels. In both cases a new category has been established for the new low sulfur fuels. The following is a brief discussion of the effect of some fuel properties.

Sulfur

Some sulfur in the fuel contributes directly to particulate emissions. Reducing diesel fuel sulfur content, therefore, is an effective way to reduce particulate emissions. Sulfur oxides can also combine with water in the engine to form acids that can attack metals (2).

TABLE 1 ASTM REQUIREMENTS FOR DIESEL FUEL OILS

Property	Grade Low Sulfur No. 1-D	Grade Low Sulfur No. 2-D	Grade No. 1-D	Grade No. 2-D
Flash Point, °C (°F), Min.	38 (100)	52 (125)	38 (100)	52 (125)
Water and Sediment, % Vol, Max.	0.05	0.05	0.05	0.05
Distillation Temperature, °C (°F) 90% % Vol Recovered				
Min.	-	282 (540)	-	282 (540)
Max.	288 (550)	338 (640)	288 (550)	338 (640)
Kinamatic Viscosity, mm²/s at 40°C (104°F)				
Min.	1.3	1.9	1.3	19
Max.	2.4	4.1	2.4	4.1
ASH. % Mass, Max.	0.01	0.01	0.01	0.01
Sulfur, % Mass, Max.	0.05	0.05	0.50	0.50
Copper Strip Corrosion Rating Max. 3 Hr at 50°C (122°F)	No. 3	No. 3	No. 3	No. 3
Cetane Number, Min.	40	40	40	40
One of the Following Properties Must be Met				
(1) Cetane Index, Min.	40	40	-	-
(2) Aromatic, % Vol, Max.	35	35	-	-
Cloud Point, °C (°F), Max.	-	-	-	-

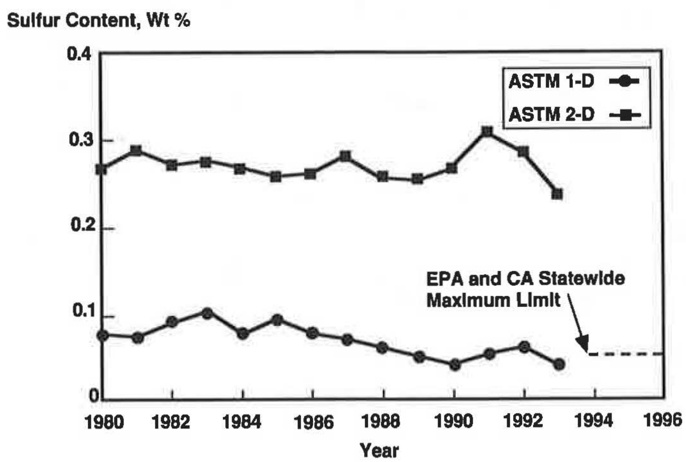

FIGURE 1 U.S. diesel fuel sulfur content trends.

These acids contribute to wear and deposit formation. There is ongoing pressure on fuel suppliers to reduce the fuel's sulfur content. The trend for diesel fuel sulfur content in the U.S. is presented in Figure 1 (3). There had not been a substantial change in the trend until the introduction of the low sulfur fuels in 1993.

Cetane Number

This property is a measure of the ignition quality of the fuel. In a gasoline engine, it is necessary to avoid autoignition prior to spark ignition to have a well-managed combustion process. The diesel engine, however, depends on the fuel to autoignite in the absence of spark plugs. Cetane number affects cold starting and smoke. Engine manufacturers and fuel producers have been engaged in research to determine the cost effectiveness of raising the ASTM cetane number requirement, affecting both emissions and performance. Figure 2 provides the yearly cetane number averages of the U.S. fuels (3). Note that in most cases these values are well above the ASTM required minimum of 40.

Aromatics

Aromatics are the more compact and less reactive hydrocarbon fractions of diesel fuel (4). They resist

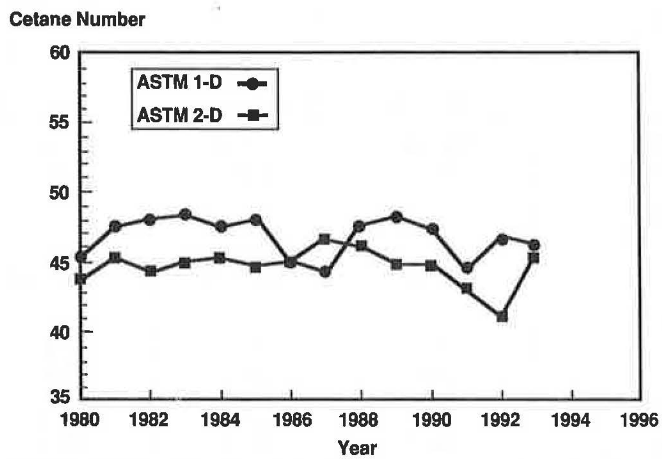

FIGURE 2 U.S. diesel fuel cetane number trends.

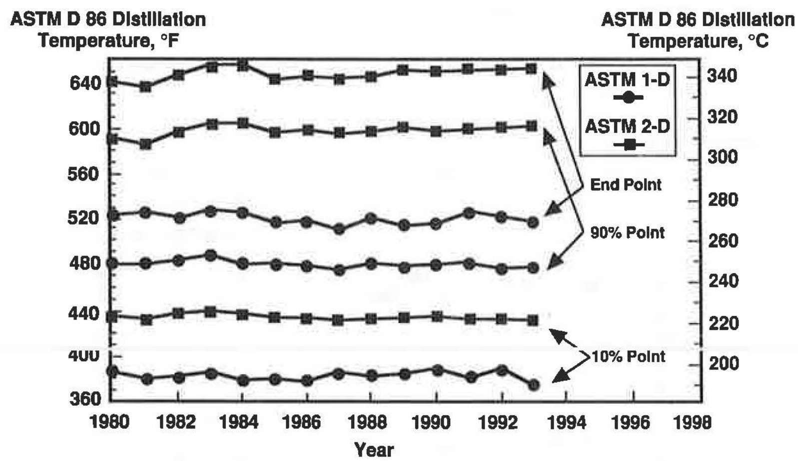

FIGURE 3 U.S. diesel fuel distillation trends.

ignition, which results in a fuel with a lower cetane number. It is generally believed that higher aromatics-containing fuels contribute to higher NOx and PM emissions. Federal regulations include aromatic control and California mandates a substantial reduction.

Distillation

Diesel fuel is a mixture of hydrocarbons with a range of heating value, density, flash point and volatility. One convenient way to characterize the fuel is to determine the boiling point of each fraction of these hydrocarbons. The ASTM specification, in its current form, includes the 90% distillation point of the fuel. Some engine manufacturers have asked for an endpoint specification to prevent the exposure of the engine to heavy oils. The average distillation trend for U.S. diesel fuels is presented in Figure 3 (3). No significant change has occurred in the last few years.

Viscosity

Proper injection system lubrication and optimum fuel atomization require the fuel to have a viscosity between 1.3 and 2.4 mm^2/s at 40^o C for No. 1 fuel, and 1.9 and 4.1 for No.2 fuel (1). Poor combustion results from high viscosity fuel because the fuel droplets are too large. If the viscosity is too low, the fuel will not travel far enough in the combustion chamber (2). This will result in poor mixing and power loss.

Cloud Point

Wax formation in the engine's fuel handling system can lead to filter plugging. This process is a function of fuel composition and temperature. Therefore, no universal value can be specified for this property. Cloud point specifications are based on geographic location and time of the year. Fuel purchased in the winter in a warm region of the country should not be used in colder regions. In areas where refineries cannot produce a No. 2 fuel with a low enough cloud point, blending with No. 1 fuel or additives can be used.

REGULATIONS

Federal regulations required all highway diesel fuel to be limited to a maximum sulfur content of 0.05% by weight starting October 1993. Such fuels also are limited to a minimum cetane index of 40 or a maximum aromatics content of 35% by volume. Cetane index is a calculated value that tends to increase as fuel aromatics decrease. It was selected as a parameter to control fuel aromatics. Cetane number was not chosen because it can be raised with cetane improver additives with no effect on aromatics.

California regulations have the additional requirement of a maximum aromatics content of 10% by volume. The California Air Resources Board's (CARB's) decision to lower the aromatics content of the fuel was based on the best information available at the time. This included data generated in a cooperative study sponsored by the Coordinating Research Council, CRC (5). CARB's emphasis on aromatics at the time might have been altered to recognize the effect of fuel cetane number had the results of the next phase of the CRC program been available (6). This phase of the program concluded that cetane number was effective in reducing HC, CO, NOx, and PM emissions.

Alternative Formulation Fuels

Lowering the aromatics content of diesel fuel from well over 30% by volume to below 10%, requires major capital investments and increased operating costs to most California refineries for severe hydrotreating processes. This is a significant financial burden during a period in which capital funds are needed to make changes required for producing reformulated gasoline, and for complying with a range of other environmental regulations.

CARB has allowed fuel producers the option of producing a less-costly alternative formulation fuel with a higher aromatics content, if equivalent emissions can be demonstrated (7). A candidate fuel to be tested for emissions equivalency must meet the ASTM D 975 diesel fuel specifications. In addition, the following five fuel properties must be determined:

- Sulfur content (not to exceed 500 ppm);
- Total aromatic hydrocarbon content;
- Polycyclic aromatic hydrocarbon content;
- Nitrogen content; and
- Cetane Number.

Once the fuel is certified "equivalent" in a 1991 Detroit Diesel Corporation (DDC) Series 60 engine using a transient emissions cycle, a producer can market the equivalent fuel if the above first four certified properties are not exceeded. The cetane number is a minimum requirement. No further testing is required and any processing and blending scheme can be used to produce the fuel. Table II is a list of five fuels Chevron tested as equivalent candidates (8). Three resulted in successful certifications, including one that became the first CARB certified California alternative diesel fuel. Other fuel producers have certified a number of fuels since then, however, formulations for some of these fuels have been kept confidential.

PERFORMANCE ISSUES

Rapidly changing fuel properties required by environmental regulations can affect fuel handling practices and engine performance. A property that reduces emissions or improves performance in one area may have adverse effects in other areas. Examples of some performance related issues are described in this section.

Elastomer Compatibility

Coincident with the use of low sulfur fuel, some diesel vehicles developed fuel leaks. The leaks occurred at points where elastomers (O-rings) were used to seal joints in the fuel system. The most common incidents were injector fuel pump leaks. According to a task force report prepared for the Governor of California (9), it is estimated that about 2 percent of the heavy duty diesel vehicles were affected.

TABLE 2 FUEL CERTIFICATION ATTEMPT

Fuel Name	Aromatics, Wt % (SFC)	Cetane Number	Sulfur, Wt ppm	Test Result
E2	18.5	50	54	Failed
A2	19	58	54	Passed
D2	16	55	44	Failed
F2	19	59	196	Passed
G2	15	55	202	Passed

Leaks were not limited to any specific engine, fuel supplier or geographic area. They did, however, seem to be related to nitrile rubber (Buna N) seals that had seen long service at high load and high temperature (9). Two possible explanations are being investigated:

- Many new fuels contain less aromatics. Some have suggested that the change from a higher to a lower aromatics content fuel causes seals to shrink. Under this theory, aged seals, which do not have the elasticity to adapt to this change, can fail.
- Some new fuels may be more susceptible to oxidation. The resulting oxidation products (peroxides) might attack the seal material and prematurely age it.

It should be noted that this seal leak issue is not related to diesel fuel lubricity. There is no known relationship between the fuel properties that affect lubricity and those that affect seal leaking.

Lubricity

Diesel injection equipment manufacturers, diesel users, and diesel suppliers have expressed concern regarding the lubricity characteristics of No. 2-D low sulfur diesel mandated in 1993. One reason for their concern is that fuel lubricity problems occurred in Sweden in 1991 when a very severely hydrotreated low sulfur and low aromatics content diesel was mandated. Another reason for their concern is that marginal diesel lubricity may take some time to result in equipment failure.

Diesel fuel functions as a lubricant in certain parts of diesel injection equipment such as rotary distributor pumps and injectors. Both low viscosity and lack of sufficient trace components such as oxygen- and nitrogen-containing compounds and certain aromatics types can be responsible for equipment wear (10).

If the refinery hydrotreating process used to reduce sulfur and aromatics levels is severe enough, the levels of some trace components are reduced. This may also reduce the lubricity properties of diesel fuel. It is not established, however, what hydrotreating severity corresponds to reduced lubricity that affects the operation of a diesel engine's fuel system components such as pumps and injectors. Lubricity associated with severe hydrotreating, known as boundary lubrication, is not necessarily related to diesel fuel viscosity. For example, if two fuels have the same viscosity, and one gives lower friction, wear or scuffing, then it is said to have better lubricity (11). Lubricity is not related to 0-ring seal leakage.

Diesel fuel contamination with excessive sediment and water can also be responsible for equipment wear and failure. People often mistake these effects, as well as lack of proper diesel fuel viscosity, with the effects of inadequate diesel fuel lubricity. Recent research has shown that lower sulfur alone is not related to lower lubricity (12). In fact, low sulfur fuel has been successfully produced and sold in Southern California since 1985.

It has been shown that the lubricity of a poor diesel fuel can be restored if blended with 10 to 20 percent of a good lubricity diesel fuel. It has also been demonstrated that potential diesel lubricity problems can be corrected by the use of lubricity-enhancing additives. However, excessive quantities of additives or improper additives may cause other problems, such as sediment formation in diesel fuel and gum formation in crankcase oils, resulting in plugging of fuel and oil filters. The practice of adding used crankcase oil to diesel fuel can also lower diesel lubricity. Some diesel engine manufacturers warn against this practice in their engines.

More recently, other technical groups and societies such as SAE (Society of Automotive Engineers), ASTM (American Society for Testing and Materials), and ISO (International Organization of Standardization) have begun to address the lubricity issue. The ISO group, in cooperation with the Coordinating European Council (CEC), is defining laboratory bench tests to evaluate the lubricity characteristics of diesel fuels and additives. The goal of the ISO program is to generate sufficient data from these test methods, and from fuel injection equipment performance tests, to select a single test method as the universal method for determining diesel fuel lubricity. This group also aims to produce sufficient information to define a minimum lubricity level to protect fuel delivery system components. ASTM will be able to consider a No. 2-D low sulfur diesel lubricity specification for inclusion in D 975, the Standard Specification for Diesel Fuel Oils, when a single test method has been selected.

Dye Requirement

This requirement has no beneficial effect on emissions reduction or engine performance. It is strictly a government policing tool to deter the illegal use of high sulfur content and non-taxed fuel. Federal regulations prohibit the use of high sulfur fuel for highway application. The Environmental Protection Agency (EPA) initially required the fuel producers to add blue dye to all diesel fuel with a sulfur content above 0.05% by weight. The Internal Revenue Service (IRS), on the other hand, had required addition of 10 pounds per thousand barrels (ptb) of an active blue dye to high sulfur fuels and 5.6 ptb of an active red dye to low sulfur fuels which are exempt from the highway transportation tax. IRS's initial concentration requirements were based on the desire to detect such fuels even after they have been diluted five times.

Many groups have studied and discussed many concerns with respect to these dye requirements. The Federal Aviation Administration (FAA), for example, has expressed concern about misfueling potentials since red and blue dyes are used in certain aviation gasoline products. Fuel suppliers have pointed out problems with established quality monitoring methods, toxicity, dye carry over to jet fuel using a common pipeline, etc., if higher-than-necessary concentrations of these dyes are used. The current decision by EPA and IRS is to use a single dye, red, for both requirements. The concentration level has been set at 3.9 ptb of the solid dye standard Solvent Red 26. Depending on the type of product, this translates to using 8 to 15 ptb of the dye product as received (13). Several concerned parties including many fuel suppliers believe this level is unnecessarily high.

CONCLUSIONS

The primary driving force to alter diesel fuel formulation and properties is the need to reduce exhaust emissions. Major changes have been mandated at the Federal and state levels in a short time. These changes, most often, have been effective. Occasionally, however, further studies and additional time would have resulted in more efficient ways to reduce emission. Continued cooperation between the regulatory agencies and the industry is needed to balance the environmental needs of the society with cost-effective and practical means of producing fuels.

Engine manufacturers are also facing similar challenges to modify their products to comply with aggressive clean air regulations. Engine designs and fuel formulations obviously affect each other along the way to reaching a common goal of improving the environment. The current high level of discussions between the Engine Manufacturers Association (EMA) and the American Petroleum Institute (API) keeps the communication channels open. Through this cooperative effort, a more balanced set of engines and fuels regulations will result. The end user, who depends on both products, will benefit by operating a lower-emissions vehicle without sacrificing operational or performance advantages.

REFERENCES

1. ASTM Method D 975, "Standard Specification for Diesel Fuel Oils," Annual Book of ASTM Standards, Volume 05.01, 1994.
2. "Diesel Fuels," Chevron Research Company, 1988.
3. National Institute for Petroleum and Energy Research (NIPER), "Diesel Fuel Oils, 1993," October 1993.
4. Jessel, A. J., "Reformulated Chevron Special Diesel. How it Improves Performance and Reduces Emissions," Chevron Research and Technology Company, 1990.
5. Ullman, T. L., "Investigation of the Effects of Fuel Composition on Heavy-Duty Diesel Engine Emissions," SAE Technical Paper 892072, September 25-28, 1989.
6. Ullman, T. L., Mason, R.L., Montalvo, D.A., "Effects of Fuel Aromatics, Cetane Number, and Cetane Improver on Emissions from a 1991 Prototype Heavy-Duty Diesel Engine," SAE Technical Paper 902171, October 22-25, 1990.
7. California Air Resources Board (CARB), "Amendments to Title 13, California Code of Regulations, Section 2282: Final Regulation Order," December 26, 1991.
8. Nikanjam, M., "Development of the First CARB Certified California Alternative Diesel Fuel," SAE Technical Paper 930728, March 1-5, 1993.
9. "Report of the Diesel Fuel Task Force," Governor of California Diesel Fuel Task Force, February 18, 1994.

10. "Lubricity of No. 2-D Low Sulfur Diesel Fuel," Chevron, Technical Bulletin, April 15, 1994
11. Nikanjam, M., and Henderson, P. T., "Lubricity of Low Aromatics Diesel Fuel," SAE Technical Paper 920825, February 24-28, 1992.
12. Nikanjam, M., and Henderson, P. T., "Lubricity of Low Sulfur Diesel Fuels," SAE Technical Paper 932740, October 18-21, 1993.
13. William F. McDonald Co., "Customer Alert," June 30, 1994.

IS CLEAN DIESEL AN OXYMORON?

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The subject of this paper is diesel fuel and clean air. The Engine Manufacturers Association (EMA)is an international trade association that represents worldwide manufacturers of internal combustion engines, including Navistar, for all applications except passenger cars and airplanes. Last year the EMA celebrated its 25th anniversary. The North American diesel engine production quantities by manufacturer in 1993 are:

Manufacturer	Engine Production
Navistar	186,000
Cummins	176,000
General Motors	135,000
Caterpillar	79,000
Deere	72,000
Detroit Diesel	71,000

To expand in the diesel business, one must continue to work hand-in-hand with the regulators, and most importantly, the fuel manufacturers.

The inspiration for the title, "Is Clean Diesel an Oxymoron?" comes from an individual, who when asked to comment on clean diesel, responded that "Clean diesel is an oxymoron." When one sees trucks produce a black cloud of smoke, it is easy to understand why someone might say something like that.

The progress made from the unregulated days in oxides of nitrogen (N0x) (Figure 1) and particulate matter (PM) (Figure 2) emissions are quite impressive. The 1992 heavy duty engine certifications as compared to emission standards are shown in Figure 3 where HC is the Hydrocarbon compounds and CO is the Carbon monoxide.

The three major groups of technologies that reduce exhaust emissions are engine modification, after-treatment systems and fuel modifications. The engine hardware technologies known to reduce emissions are listed below:

- Optimized Turbochargers.
- Charged Air Cooling.
- Intake Manifold & Port Design.
- Combustion Chamber Design.
- Oil Control.
- Retarded Injection Timing.
- Higher Injection Pressure.
- Electronic Controls.
- Injection Nozzle Configuration.
- Rate Shaping.
- EGR - Cooled EGR.
- Variable Geometry/Waste-gated Turbochargers.

Exhaust emissions can be further reduced by after-treatment devices shown below:

- Oxidation Catalyst.
- Particulate Traps.
- NO_x Catalyst.

Oxidation Catalyst reduces SOF and global warming Particulate Traps, burn carbonaceous PM (soot), of and NO_x Catalyst reduce $N0_x$ (and must be developed). When new technologies are developed to reduce emissions, other factors should be considered. Some of these new technology issues are:

- Durability.
- Reliability.
- Fuel Efficiency.
- Customer Acceptance.
- Customer Satisfaction.
- Costs
  - Developmental;
  - Initial Purchase; and
  - Life Cycle.

The third method to reduce diesel exhaust emissions is through cleaner diesel fuels. In 1994, diesel fuel has:

- 0.05% by Weight Maximum Sulfur Content.
- Cap on Aromatics at 35% by Volume.
- PM Emissions of 0.065 g/bhp-hr.

California will require a 10% aromatic fuel in 1994 that goes much further in the concept of clean diesel fuel.

From the engine manufacturers perspective, the following changes in diesel fuel properties will improve emissions:

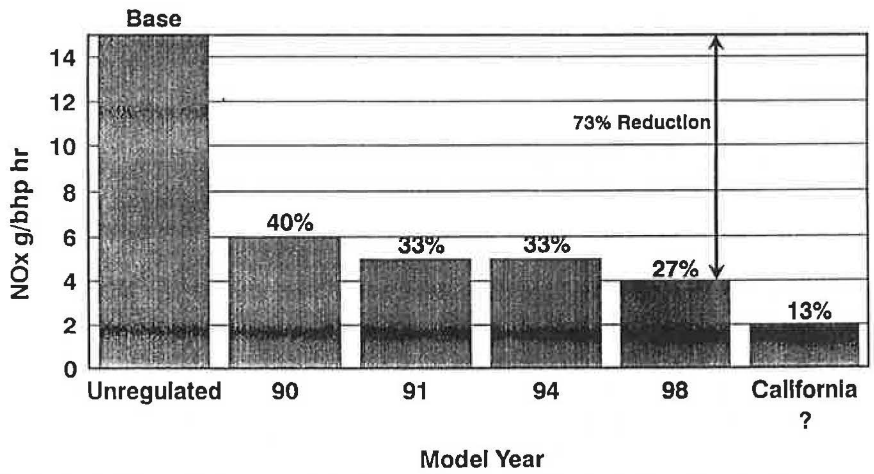

FIGURE 1 EPA Heavy-Duty Truck engine NOx emission standards.

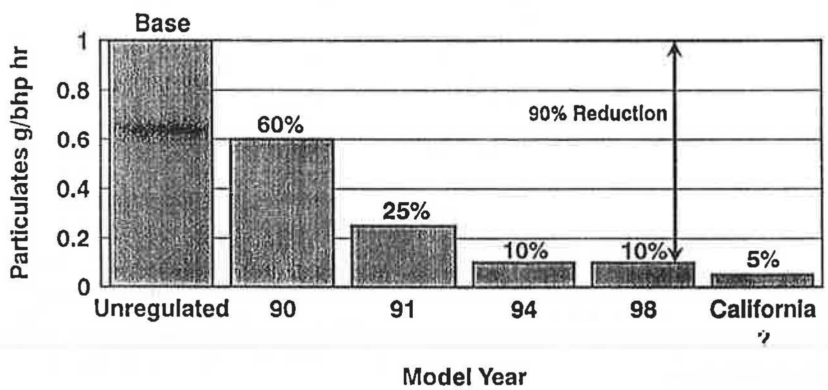

FIGURE 2 EPA Heavy-Duty Truck engine PM emission standards.

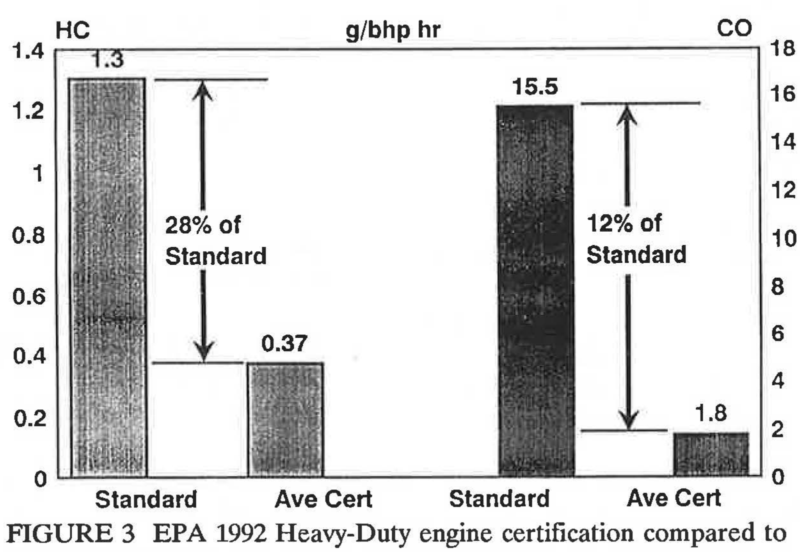

FIGURE 3 EPA 1992 Heavy-Duty engine certification compared to emission standards.

- Sulfur Reduction.
- Aromatic Reductions or C/H Ratio Control.
- Cetane Enhancement.
- Distillation Curve Control.
- API Gravity Control.
- Use of Oxygenates.
- Other Improvements.

Sulfur reduction includes PM reduction, more aggressive oxidation catalyst, and a more feasible NOx catalyst. Aromatics reductions are both PM and NOx reduction with no tradeoff. The EMA believes the Cetane enhancement will be the most cost-effective improvement. They have proposed to API to raise minimum Cetane from 40 to 55. Higher cetane will also help with customer satisfaction in the areas of noise, cold starting and white smoke. The use of Oxygenates will provide large reductions in PM with a small NOx penalty according to a Coordinating Research Council (CRC) study.

Improvements in diesel fuel quality will result in: reduced emissions from all diesel engines, not just future engines; emissions reductions beyond those obtainable with engine hardware changes; emission improvements that will not deteriorate with time; and allowing engine manufacturers the opportunity to make additional engine changes to provide emissions reductions which would not otherwise be practical. Such improvements only serve to add to the environmental advantages of diesel fueled diesel engines. To help overcome the negative connotations of diesel, a former Navistar VP suggested clean diesel fuel should be called "Envirolene."

Clean diesel is not an oxymoron. Diesel engines have played a significant role in helping the United States to become a great industrial nation. Some diesel advantages are:

- Fuel Economy;
- Safety;
- Customer Acceptance;
- Global Warming;
- Low HC & CO Emissions;
- Improved PM & N0x Control;
- Potential of Clean Diesel Fuel; and
- Fuel Infrastructure in Place.

The net result of these efforts is that in the near future one will not be able to tell if a diesel truck is standing still or accelerating by looking at the exhaust stack.

SECTION II WASTE MANAGEMENT

SCRAP TIRE RECYCLING

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ABSTRACT

The South Carolina Department of Transportation (SCDOT) generates more than 20,000 used tires each year from on- and off-road vehicles. In the spring of 1991, there were approximately 40,000 tires at the three-acre Supply Depot site owned by SCDOT. Rain water trapped in these tires provided a breeding ground for mosquitoes causing occupational health hazards considered environmentally unacceptable by the Department of Health and Environmental Control (DHEC). This situation became the focus of attention as the result of an Occupational Safety and Health Administration (OSHA) inspection that found mosquitoes at the site that could cause sleeping sickness, yellow fever and other diseases. In addition, "The South Carolina Solid Waste Policy and Management Act of 1991" prohibited the dumping of tires at landfills.

SCDOT reviewed its tire disposal methods and investigated alternative methods of disposal. A win/win situation for SCDOT, DHEC, OSHA and vendors was identified that involved shredding tires and recycling the products in environmentally acceptable ways.

INTRODUCTION

SCDOT recognized in the spring of 1991 that it was facing problems with used tires that had accumulated at its Supply Depot. There were approximately 40,000 tires stored in a three-acre open area (See Figure 1). These tires accumulated primarily because of problems with low bid contracts to remove used tires, landfill disposal of whole tires, and potential liability issues with used tires.

SCDOT used low bid contracts in the past to remove used tires from the Supply Depot storage area. The bidder would be given a specific timeperiod to do the work. The problem was that vendors would come on-site and take only the tires that could be regrooved or recapped. Unusable tires were left. This method was eventually stopped.

The Department also awarded contracts to landfill operators to dispose of used tires. SCDOT hauled the tires to the landfills where they were buried by the landfill operators. The problem was that over time some tires would work their way to the surface. This concerned SCDOT from an environmental and legal perspective.

Tires were also included in public auctions for SCDOT equipment every month. Buyers got a mixed lot of tires, both good and bad. SCDOT was concerned from a legal perspective that as the seller it may be held liable if a tire was found to have contributed to a traffic accident.

The tire problem came into focus when the "South Carolina Solid Waste Policy Management Act of 1991" was passed. This law prohibited the accumulation of tires on any property unless the owner was licensed to landfill or recycle the tires. DHEC also became involved when they discovered mosquitos breeding in the water trapped in the tires. These mosquitos have been linked to sleeping sickness and yellow fever. This discovery led to a frequent monitoring by DHEC to ensure that the storage area was sprayed once a week to reduce health risks.

ALTERNATIVE METHODS OF DISPOSAL

With 40,000 plus tires on hand and the fact that an additional 20,000 tires would be added annually, corrective action was needed. Several alternative methods of tire disposal were investigated including deep burial, cutting tires in half and tire shredding.

Were there any landfill operators willing to take whole tires? A landfill operator was found who claimed tires would be buried under 8 to 10 feet of dirt. The landfill operator had adequate space. However, it was decided there could be legal problems with an anticipated law that would ban the land filling of whole tires.

Landfills would be allowed to accept tires that were cut up or cut in half. Investigation revealed that there were many types of tire shredders available. Costs for the equipment ranged from $15,000 for a small splitter unit that had a low through put of approximately 12 tires per hour, to a high volume unit that would shred hundreds of tires per hour. The cost for the high volume unit was approximately $250,000. From an economic standpoint the smaller unit would serve the Department's purpose. Installed, the cost would have

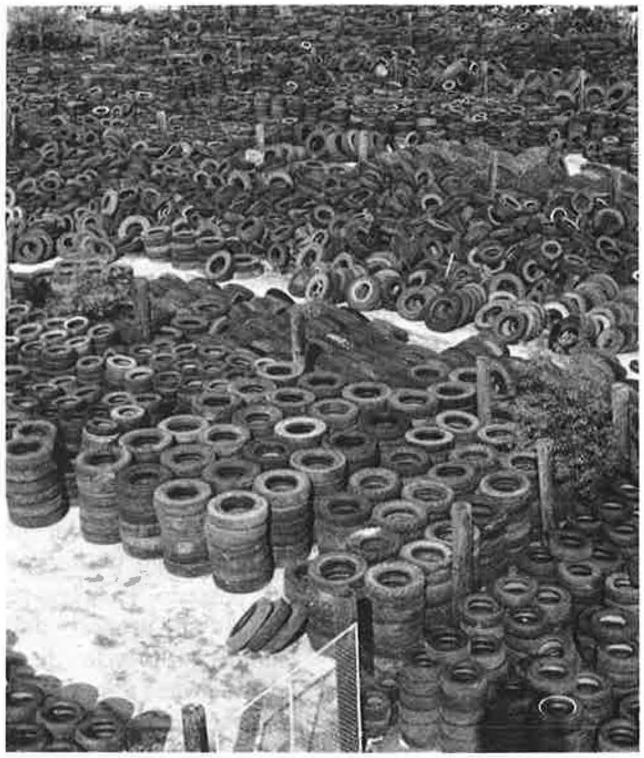

FIGURE 1 Used tires stored in three-acre open area in 1991.

FIGURE 2 Used tire storage under tire recycling program.

been approximately $20,000 - $25,000. There was still the job of hauling the remains to a landfill, paying a tipping fee and record keeping costs. The total annual cost of labor, transportation, landfill tipping fees and record keeping was estimated to be $44,180. In addition, there were still some concerns that there may be legal actions taken against the Department in the future.

At this point attention was shifted to other recycler companies that used shredding machines. Discussions were held with vendors in surrounding states, but there was a great deal of interest in working with a company that had a shredding facility about 30 miles from the SCDOT Supply Depot. A property visit was made to check the facilities and look at recycled products made from the shredded rubber. The visit also revealed that this company was working with other companies to produce floor mats and mud flaps for trucks.

CONTRACT SPECIFICATIONS

A specification was written that included:

- How many tires would be provided to a vendor per year.
- Size of tires, both vehicle and off the road.
- Pick up schedules.
- How the tires were to be processed.
- Final disposition of the tires.
- Documentation for the DHEC.

The unique part of the specification was a section that dictated that the vendor's final disposition of tires would be as a marketable, recycled material subject to the Department's approval. To our knowledge there is not another Department of Transportation that makes that determination. This specification was advertised for bid. There was a pre-bid meeting held and all interested vendors attended as a prerequisite to submitting a bid. The purpose of the meeting was to go through the specification and answer any vendor questions. This meeting also served to identify acceptable vendors.

After bids were received, the proposals were evaluated to determine the low bid and arrangements were made to visit the vendor's site, evaluate facilities and determine final disposition of the shredded tires. One important factor was the cost to transport tires. It was possible that the transportation costs could make the entire job uneconomical for the State or the vendor. We also found that there were nine vendors that could not do the shredding operation as specified. There were two vendors who could do the work as specified. The result of all this work was a five-year contract awarded to a tire recycling processor, approximately 30 miles from the SCDOT property. Table 1 provides an economic summary used in the decision to contract out the shredding job.

In addition, two intangibles entered into the decision to shred the tires:

- Could SCDOT be held responsible in the future for the environmentally unsound practices of disposing tires at a landfill?
- If a tire contributed to an accident, could SCDOT be held liable?

These intangibles helped in the determination to recycle tires. In addition to recycling the shredded tires as described above, SCDOT uses 5% rubber in its asphalt road material according to the Intermodal Surface Transportation Act of 1991. This total increases to 10% in 1994.

RECYCLING PROGRAM AWARDS AND CONCLUSION

SCDOT's recycling program for shredding tires has won two awards:

- The South Carolina Division of Natural Resources' "Keep America Beautiful Award"; and
- Second place in the Federal Highway Administration's "Keep America Beautiful Award."

SCDOT's tire recycling program has been a win/win situation for everyone involved: SCDOT (See Figure 2) vendors, OSHA and DHEC.

TABLE 1 ECONOMIC SUMMARY FOR TIRE DISPOSAL

	SCDOT	VENDOR
CAPITAL	$25,000 (One Time)	In Place

Summary: This cost includes equipment required to split tires (not shredded) plus electric services and weather protection.

LABOR AND MATERIAL		
1- Labor/Yr.	38,000	27,600 (FY 92-93 Contract Cost)

Summary: 12 Tires/hr. x 6.5 hr./day x 5 days/wk x 50 wks./yr. = 20,500 tires/yr. Labor will require 2 employees/yr.: 1 employee to run tire splitter at $19,000 and 1 employee to handle tires with fork lift truck at $19,000.

2- Transportation	680	Incl. in contract

Summary: Fuel 20,000 tires/yr. = 40 trucks/yr.: 500 split tires/truck: Diesel fuel cost = 0.85/gal. ($.022/Liter), 20 miles round trip to landfill (32.2 Kilometer), Trucks average 5.7 MPG (9.18 KPG), 20 miles/5.7 MPG = 3.5 gal./trip (13.30 Liters), 40 trips/yr. x 3.5 gal./trip = 140 gal./yr. (532 Liters/yr.), 140 gal./yr. x 0.85/gal. = $120/yr. ($118 U.S. Dollars). Labor: 2 hrs./trip x 40 trips/yr. = 80 hrs./yr., 80 hrs./yr. x $7.00/hr. = $560/yr.
TOTAL $120/yr. (Fuel) + $560/yr. (Labor) = $680/yr.

3- Tipping Fees	5,000	0

Summary: $20.00/ton 500 tires/truck x 25 #/tire = 12,500 # = 6.25 ton (6.34 Long ton), 20,000 tires = 40 trucks/yr. x 6.25 tons/truck x $20.00/ton, 500 tires truck = $5,000 ($5,072 U.S. Dollars)

4- Record Keeping	500	0
TOTAL (1-4)/Yr.	$44,180	$27,600

WASTE CONTROL PRACTICES AT BUS MAINTENANCE FACILITIES

Douglas Lowell
Acurex Environmental Corporation

SUMMARY

Waste management practices at transit facilities are of great concern for transit agencies. Transit agencies are faced with an increasing number of regulatory requirements for handling the various kinds of wastes generated from their facilities. This Transit Cooperative Research Program (TCRP) synthesis project examined the waste management practices employed at 115 transit facilities for nine different transit facility operations. The synthesis survey showed that the current waste management practices at many transit facilities are excellent ways to handle or minimize waste generated from these operations. The survey also showed that transit agencies actively seek alternative, often innovative means of altering materials or processes to reduce waste generated and cut costs.

The complete report on this effort is published in TCRP Synthesis 9, "Waste Control Practices at Bus Maintenance Facilities" (1994). The TCRP sponsors the preparation of synthesis reports on various transit practices. TCRP is managed by the Transportation Research Board in cooperation with the American Public Transit Association and the Federal Transit Administration.

EFFECT OF REGULATIONS ON BUS MAINTENANCE FACILITY DESIGN

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Dorr Anderson (presenter)
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SUMMARY

This reports on a survey of transit properties to identify the effects of recently enacted legislation and implemented regulations on the design of vehicle maintenance facilities. Also identified are some recent practices that have been incorporated into design of maintenance facilities including modifications to adapt to new technology vehicles.

Recent regulations that affect facility design are those relating to (1) The Americans with Disabilities Act (ADA), (2) The Clean Air Act Amendments of 1990 (CAAA), (3) The Clean Water Act and (4) underground fuel storage tanks. Information was obtained from 16 transit agencies on practices used in the design of recently completed bus maintenance facilities. Ways in which these regulations have affected the design of new bus garages are identified.

ADA regulations to improve handicap accessibility impacts a bus maintenance facility size and functional layout in the following ways: restrooms are larger, handicap parking stalls take more space, elevators may be required, ramps are required for small elevation changes, walkways are wider, and doors may be wider. Special features are required including special signage, drinking fountains, telephones and door hardware. These modifications and special features add to the cost of a new or remodeled maintenance facility.

The Clean Air Act Amendments of 1990 impacts many design features. The biggest impact is on maintenance shop modifications required to accommodate safety requirements for new technology buses using alternative fuels. These include fuel handling, improved ventilation, hazardous vapor venting, explosion proof fixtures, special sensing devices and other automatic controls to provide early warning of trouble. The specific requirements depend on the type of alternative fuel used. It is estimated that the cost to retrofit a shop to accommodate new technology buses using alternative fuels is $25.00 per square foot. Other impacts due to the CAAA include providing more attention to air quality throughout the maintenance facility. Features such as special exhaust systems in the fuel area and repair areas are common. Pits are being designed with exhausts and make up air systems. New equipment items include antifreeze recycling, freon recovery and paint spray booths.

There are many facility design features affected by the Clean Water Act. They include a water recycling feature for the automatic bus wash system. The recycling is limited to about 80 percent of the water and can add $25,000 or more to the cost of a washer. Clean Water Act also affects site drainage requirements. Control facilities are needed to treat site drainage before it drains into the surface water or storm system. The shop floor drainage system also is controlled with most agencies having a drainage system that includes industrial waste treatment such as an oil/water separator which can cost $250,000 for a 10-acre site.

All agencies surveyed store diesel fuel in underground storage tanks. Tank sizes vary from 4,000 to 20,000 gallons. Many tanks are double walled with spill prevention features, leak detectors and inventory monitoring systems.

The complete report is published in Transit Cooperative Research Program (TCRP) Synthesis 7, "Regulatory Impacts on Design and Retrofit of Bus Maintenance Facilities," Transportation Research Board, Washington, D.C., 1994.

SECTION III ALTERNATIVE FUELS

TRI-MET'S EXPERIENCE WITH ALTERNATIVE FUELS

Andrew Aebi
Portland Tri-Met Transit District

INTRODUCTION

Tri-Met is the regional transit district in the Portland area, which includes Multnomah, Washington, and Clackamas counties. Tri-Met operates 26 light rail vehicles, 591 buses, and 122 paratransit vehicles. Of the 591 fixed-route buses, 10 use alternative fuels. Four of the paratransit vehicles use alternative fuels, but this will soon be expanded to 17; it is still early in the test process. The fixed-route buses use liquefied natural gas (LNG), and the paratransit vehicles use compressed natural gas (CNG). Therefore, the approximately 700 vehicles, only 14 are powered by alternative fuel, although this will soon increase to 27 with the additional delivery of paratransit vehicles.

REASONS FOR USING ALTERNATIVE FUEL

Equipment operators are undoubtedly familiar with the Federal Clean Air Act Amendments of 1990 and its increasingly stringent tailpipe emissions, specifically, the particulate emissions standards. Operators are probably also aware of the National Energy Policy Act of 1992. This law aims for a 10 percent reduction in the use of petroleum-based motor fuels by the year 2000, and a 30 percent reduction by 2010. Both pieces of legislation played a role in Tri-Met's purchase of alternative fuel buses. A state of Oregon directive also played a large role. A proposal was made in the 1989 session of the Oregon Legislature for a mandate requiring that all of the vehicles Tri-Met purchased be powered by alternative fuel. Although this proposal did not get very far in the Legislature, another similar broad-based mandate was circulated two years later, in 1991. Federal mandates aside, many other states also have alternative fuel directives either in place or under discussion.

Given the reality of the political constituencies for alternative fuels, the pragmatic approach for Tri-Met was to compromise by trying a small test fleet of alternative fuel buses to minimize the risk. Tri-Met felt this to be prudent than to start with a very large fleet of alternative fuel fixed-route buses with which the agency had no operating experience. It should be noted that Tri-Met also sees the potential reward of alternative fuel buses. The environmental motif on two of the LNG-powered vehicles is part of a marketing appeal; it is designed to curry favor with the popular public perception that bus pollution needs to be reduced by using the latest available technology available.

ALTERNATIVE FUEL FLEETS AND VEHICLES

Tri-Met's 10 LNG buses comprise two fleets. The first alternative fuel fixed-route fleet Tri-Met purchased was manufactured by Gillig Corporation in Hayward, California. These buses are 40 feet long and 102 inches wide with a 279-inch wheel base. Gillig Phantoms are powered by a Cummins L10-G 6 cylinder engine with a Voith transmission. The fuel delivery system was manufactured by Cryogas. As mentioned earlier, these buses are painted with an environmental motif to maximize public visibility; they arrived in September of '92, when operational issues had to be worked out. Substantial preservice work was necessary. Therefore, they did not go into service until March of '93; Tri-Met has just over a year of experience with these buses.

The newer buses were manufactured by Flxible Corporation in Delaware, Ohio. These 10 buses are also 40 feet long, 102 inches wide, but with a 299-inch wheel base. They also have a Cummins L10-G 6 cylinder engine with Voith transmissions. The fuel delivery system was manufactured by CVI. These buses arrived in October of '93 and went into service January 1994.

As mentioned above, Tri-Met is expanding the paratransit fleet of alternative fuel vehicles, which currently consists solely of Ford Champions. These paratransit vehicles are "bifuel," so the cruising range is enhanced because the vehicle automatically switches its fuel source back to gasoline when the CNG runs out. This also allows these buses to be fueled once daily instead of twice daily, as was previously the case. Although CNG is used for paratransit vehicles, LNG was chosen for fixed-route operations.

LNG CHOSEN FOR FIXED-ROUTE SERVICE

LNG is preferred because it provides more energy for the same volume as CNG. The primary factor is weight. A bus powered by CNG weighs about 3,000 pounds more than a similar diesel-powered vehicle because of the heavier fuel tanks. In contrast, a LNG-powered coach only weighs about 300 pounds more than a similar diesel-powered coach. The heavy weight of CNG on a fixed-route bus would result in a larger reduction in passenger capacity, which would also preclude standees. In contrast, the reduction with LNG is not nearly as severe. This reduced capacity is an undesirable limitation for Tri-Met, because the schedules are written with the assumption that some trips carry more than 100 percent of capacity (i.e., standees). This factor will probably become even more important to Tri-Met because a decision has been made to retire 60-foot long articulated buses and to replace them with standard coaches. For these reasons, if Tri-Met were to adopt an all alternative fuel fixed-route fleet, a substantial increase in fleet size would be necessary.

There have been some recent improvements in composite materials that might allow fuel tanks to be made of materials other than steel. This would reduce the weight of the fuel tanks and would, therefore, allow passenger capacity to be increased. Until this becomes a reality, passenger weight capacity limitations will remain a major concern. Another factor in choosing LNG buses is the operating range; the maximum range of the CNG-powered buses is somewhere around 250 miles, whereas an LNG coach can cruise 300 to 350 miles. Several other factors gave LNG the nod over CNG. Unlike CNG, LNG is not stored under pressure at the rate of 3500 psi but is instead chilled to minus 260 degrees Fahrenheit. This allows special handling procedures to be avoided which would otherwise be necessary to minimize the danger from these high pressures. While special handling procedures are required because of the cold temperatures, Tri-Met feels the danger is greater from the pressure than from the temperature. Another major factor is Northwest Natural Gas already has the infrastructure for LNG, so Tri-Met saved the capital cost of building its own fueling facility. Finally, LNG coaches cost less than similar CNG coaches.

Despite these apparent advantages of LNG, CNG is being tried with paratransit vehicles. The main reason is simply to have some operating experience with CNG. The paratransit vehicles are smaller, so the fuel tanks are smaller than on the regular transit bus, so there is not as great of a weight increase. Consequently, it was assumed that CNG would pose a smaller limitation for paratransit vehicles than for fixed-route buses.

FUELING PROCEDURE CHANGES

The LNG and the CNG fuels are supplied by the local natural gas provider, Northwest Natural Gas Company. The vehicles are fueled at NNG's facilities; no CNG or LNG fueling facilities exist at Tri-Met. This off-site fueling does add time to the fueling and servicing process. Once at the fueling site, the actual fueling time is longer because gas is not dispensed as quickly as diesel and because a cooldown process is required. This is necessary to allow the LNG coach fueling system pressure to drop below the pressure of the fueling station. Pressure on the Gillig coach does not need to drop very far as it is at 40 psi and the fueling station is also 40 psi. However, pressure on the Flxible coach must drop from 100 psi to below 40 psi.

Northwest Natural Gas' fueling station is roughly 40 to 50 years old, so it does not have the latest in equipment and technology. Obviously the cold temperature of the fuel does require some safety precautions. The fuel tanks have to be drained when heavy maintenance is performed. They are drained at an off-site facility located 13 miles away. Both factors obviously result in additional inconvenience.

DYNAMICS OF SOLE ALTERNATIVE FUEL SUPPLIER

Because alternative fuels are so new, Northwest Natural Gas and many equipment suppliers are still adjusting to Tri-Met's needs as a customer. It is a new experience for them to get used to the transit market as opposed to their traditional industrial gas customer. Getting the gas from their tanks to our buses quickly and safely is still an issue to be resolved.

The supplier has run out of LNG fuel several times, which is a challenge to transit operations. Tri-Met obviously does not want to miss a pullout because of lack of fuel. This operational issue will be taken into account before a decision is made to go to alternative fuels on a fleetwide basis.

As equipment operators are aware, the alternative fuel market is still in its infancy, so few suppliers exist. In Tri-Met's case, only one exists in town, so the distribution channels are not well established. Obviously, if LNG fueling stations existed on every corner, the dynamics of competition would be much different. The supply would be greater, and the costs would be lower. The critical mass would reduce the likelihood of supply problems. Obviously we are currently nowhere near this scenario yet. For the most part, Tri-Met has not been hit by any major or nasty surprises with the experience so far; it is about as expected.

FUEL COST OF LNG

As far as the LNG buses are concerned, clearly their benefits are environmental, not financial. The fuel cost per mile for diesel buses is less than half the cost for LNG buses; this is explored below. Although quantifying these costs is subjective and difficult, the maintenance cost per mile is clearly higher on the LNG buses as well. The roughest of estimates suggest it is more than double the cost of diesel. The technology of alternative fuel is new, which does result in more frequent breakdowns (road calls). Parts for LNG buses are sometimes difficult to find and take awhile to get.

For fuel cost experience, Tri-Met has been spending about 37 cents per mile for the LNGs versus to 14 cents a mile on the diesel buses. If Tri-Met were to go to an all-LNG fleet tomorrow, Tri-Met would need to spend an additional $5.4 million a year on fuel costs, based on today's price per therm of about 74 cents. This figure could and will likely change; some price reductions are expected as time progresses, particularly if the volume of LNG usage were to increase. Even so, using current technology, the price per therm would have to decline from about 74 cents to about 28 cents for this to be a "break-even" proposition in fuel costs.

MAINTENANCE COSTS AND PERFORMANCE

Meanwhile, maintenance costs, which are not included in the above figures, are much higher. Tri-Met is not certain as to exactly how much higher. First, these costs are difficult to trace; second, the case can be made that over time this disparity could decrease as technology improves and the mechanics progress on the learning curve. However, so far the crudest of estimates suggest the fixed-route LNG buses are over twice as maintenance intensive as a similar diesel-powered fleet.

We know we have had our share of problems, but we feel a strong need to acquaint ourselves with this fuel delivery technology sooner or later. While the worst was expected, the engine problems are less significant than expected. It is too early to render judgment on the LNG vehicles, but the initial operating experience has clearly shown the higher cost of alternative fuels. While the decision to procure alternative fuel buses may not ultimately rest with Tri-Met, the verdict on alternative fuel buses probably rests on whether the environmental benefits of alternative fuels are worth the extra cost.

OPPORTUNITY COST OF ALTERNATIVE FUELS

A neighbor to the north, Seattle, Washington, was once looking at going to an all LNG fleet. They actually signed a contract to do this. A critic of the move said, "Natural gas will not get people out of cars; more convenient transit service will." This speaks to the opportunity costs inherent in any major decision. The $96 million cost of alternative fuels might instead in Tri-Met's case be spent to increase service by perhaps some 845,000 hours a year with diesel buses. Although this is probably on the high side, the opportunity cost of alternative fuels must be considered. One question Tri-Met has is to what extent "clean diesel" might eventually approach the same environmental benefits at a lower cost as LNG.

TECHNICAL CONSIDERATIONS

A brief note on the technical side of what the experience has been. As mentioned earlier, Tri-Met deals with many contractors and small companies. As such, it can be a little difficult coordinating all of them. Many of these suppliers are oriented to traditional customers; transit agencies are a relatively new application for them. There have been some first stage regulator problems with the buses, some cracked engine cylinder heads, and many fuel pumps have had to be replaced, which are quite expensive. The fuel line blockage problems have largely been solved by placing an in-line fuel filter in the fuel line just before the first stage regulator. In addition, the seals in the fuel pumps have been replaced, which has greatly reduced leakage problems. Tri-Met is satisfied with the improvements in maintaining LNG buses, but is disappointed with the fuel costs of LNG vehicles.

CONCLUSION

Alternative fuels are an issue that is increasingly being raised in the public arena. Tri-Met's experiment in alternative fuels will continue. Overall the performance has been close to initial expectations, but Tri-Met is disappointed in the initial disparities in fuel costs and in maintenance intensiveness. The $5.4 million estimate of increased annual fuel costs may decrease over time, but questions remain as to the additional capital, maintenance and servicing costs. Are these additional costs worth it for cleaner air? Tri-Met and the Portland region will soon have to answer this question.

SAFE OPERATING PROCEDURES FOR ALTERNATIVE FUEL BUSES

Douglas Lowell
Acurex Environmental Corporation

ABSTRACT

Alternative fuels are used by transit agencies across the United States, and will become part of the operations of many more transit agencies in coming years. Driven by considerations such as air quality and energy diversification, various mandates and incentives have been created that will lead to the use of alternative fuels for transit applications. The Clean Air Act Amendments of 1990, for example, provide for aggressive improvements in transit bus emissions beginning in 1994. Many state and local agencies are enacting or considering various measures that will either require or provide incentives for the use of alternative fuels in vehicles, including transit buses.

Unlike conventional diesel and gasoline fuel, some aspects of alternative fuel handling and use are not yet covered by regulations, standards, or even accepted practice. While alternative fuels such as compressed natural gas (CNG), liquefied natural gas (LNG), liquefied petroleum gases (LPG), methanol, and ethanol have been demonstrated at the prototype level at several transit locations nationwide in recent years, most transit operations remain unfamiliar with the specific techniques and practices needed for safe vehicle operation, maintenance, and refueling. Education and training of transit managers and operations staff are vital to ensure that the appropriate practices are identified, understood, adopted, and executed.

The complete report on topic is presented in Transit Cooperative Research Program Synthesis 1, "Safe Operating Procedures for Alternative Fuel Buses," 1993, Transportation Research Board, Washington, D.C.

MINNESOTA DOT'S EXPERIENCE WITH A-55 TECHNOLOGY FUEL

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Minnesota Department of Transportation

"How would you like to save $0.33 per gallon of fuel the next time you fill up?" That is possible with the watered-down fuel that A-55 Limited Partnership hopes to market. During the TRB Committee on Maintenance Equipment meeting in January 1993, an informal presentation was made about Mr. Gunnerman's A-55 Limited Partnership invention and the potential savings with using watered-down fuel. Mr. Gunnerman's Reno, Nevada firm has developed a unique fuel mixture consisting of approximately equal proportions of water and carbon fuels, such as gasoline or diesel with a surfactant added. This new fuel mixture was reported to burn more cleanly, cheaply and safely than conventional gasoline or diesel fuel. The new fuel delivers comparable mileage per gallon as regular gasoline and seems to cause the engines to run cooler.

The inventor has found a way to make carbon fuel and water mix, with the water molecules enveloping the gas or diesel molecules, locking in the fumes and essentially fireproofing the mixture. This is accomplished with a solution of readily available chemicals that acts as a surfactant. The surfactant, essentially a detergent, causes the water molecules to merge with the gas or diesel molecules. One end of the surfactant molecule acts like a water molecule, the other end acts like an oil molecule enabling the surfactant to link an oil molecule to a water molecule.

However, the fuel mixture is only one part of the water-based fuel technology. The other part is the engine modification. One will not work without the other. The engine modification is reported to be relatively minor and inexpensive. It involves removing the engine head and applying a nickel-based catalyst on the cylinder walls of the combustion chambers. The interaction of the nickel catalyst and the watergas causes the watergas to combust more thoroughly and burn for a longer time than ordinary fuels. The combination of heat, pressure and the catalyst breaks down at least some water into its base components, hydrogen and oxygen, both of which apparently add to the combustion process. The exhaust is about 70 percent water vapor, A-55 company data indicates. Tests by the Nevada Environmental Protection Division and the California Air Resources Board reportedly have found reduced levels of emission pollutants. The company claims significant reductions in hydrocarbons, carbon monoxide, carbon dioxide, nitrogen oxides, diesel smoke, and cost. A common car or pickup can be converted at a cost approaching $1,500. The cost would drop as production increases. Conversion of a very large diesel engine such as a stationary power plant may cost around $15,000.

Following the presentation in January 1993, the Nevada firm was invited by the Minnesota Department of Transportation to St. Paul to demonstrate the technology. Representatives from cities, counties, industrial equipment manufacturers doing business with the State, and Metropolitan Transit Commission attended the demonstration in December of 1993. A convoy of a half dozen trucks and cars using the water-fuel technology traveled from Reno, Nevada to St. Paul, Minnesota for the demonstration. A stationary diesel engine was demonstrated using the water-based fuel. Following the demonstration, Mr. Bruce Anderson of the Reno Regional Transportation Commission related their experience with using this unique fuel mixture for the previous three months. At the time, a specially adapted 40 foot city bus operated by the Regional Transportation Commission in Reno had logged 7600 miles in daily trips using diluted diesel fuel. This test bus was getting 2.2 miles per gallon on the 50-50 mixture of water and diesel fuel, compared with an average of 3 miles per gallon straight No. 2 diesel fuel. The Reno bus agency had not conducted emission tests, however, they had conducted opacity tests. The results were zero, no smoke. A small amount of exhaust smoke and steam was experienced on cold mornings, but it clears up in about five minutes as the engine warms. Oil analysis is conducted every 3000 miles. The results show no unusual engine wear, no soot and no change in the viscosity or appearance of the oil since being put in the engine.

During the question and answer period, a question was raised whether the water-based fuel would freeze in Minnesota temperatures. If 10 percent ethanol alcohol is added to the mixture, the material will perform. The Reno bus has operated in temperatures close to zero with no freezing problems.

As a result of the demonstration, Mn/DOT requested that A-55 Limited Partnership cooperate with a diesel engine manufacturer to modify an engine for a 1994 snowplow truck and the manufacturer of the highway patrol car. Since March of 1994, the people from the A-55 company quit returning Mn/DOT's telephone calls. As a result, Mn/DOT could not obtain a modified engine for either the snowplow truck or the highway patrol car. On July 6, 1994, the Caterpillar Engine Division and A-55 Limited Partnership of Reno, Nevada announced the formation of a joint venture to develop and commercially apply an alternative fuel and new technology that enable internal combustion engines to operate on a mixture of water and carbon-based fuel. It appears that the engine division of Caterpillar will have exclusive rights to develop the technology commercially.

SECTION IV EQUIPMENT OF THE FUTURE

SNOW PLOW TRUCKS - SPECIFICATIONS FOR THE TWENTY-FIRST CENTURY

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ABSTRACT

As the world of highway maintenance moves though the 1990's to the year 2000, the way highway and transportation agencies conduct business will continue to change at a rapid pace. Contracting of many functions, increased dependence on part time and hourly workers, and changing methods of performing critical maintenance functions will impact on the specification and purchase of vehicles and equipment handled by fleet managers. Nothing better exhibits this changing environment than the work horse of every snow belt state, the snow plow truck.

"More with Less" is the battle cry of the public sector. Every corner of the public sector hears and feels the growing demand from the public for better and more efficient services. Shrinking budgets demand better management and innovative approaches. Reducing full time staff cuts costs, but also often reduces the overall skill level of the work force. To counteract, managers are turning increasingly to the application of new technologies for greater efficiency, longevity and safety. This paper explores the past, present and future application of new technology to the public service of snow and ice control, and the equipment used to accomplish the task.

INTRODUCTION

Only with the coming of the industrial revolution and the mechanical mobilization of man has snow fall become an unacceptable hindrance to the general population. Even today snow is accepted in many places in the world as a routine occurrence left in most part to come and go as nature decrees. This is far from the case in the populated snow belt areas of the United States. The railroads were the first to find that snow fall handicapped their ability to remain on schedule. As such they were the first to use mechanized devices, plows and then blowers, to displace snow from the tracks.

Streets in large cities soon became the next target for mechanized snow removal. While men with shovels and horses with wagons had been used to clear streets and sidewalks after large accumulations for years, the arrival of the automobile and the motor truck demanded a more efficient clearing of snow. The snow plow truck was born in the early 1920's out of need and mechanical application of the tools of the day. Soon public officials discovered the cost to commerce and to public safety when snow storms crippled movement on the streets of the cities and the highways connecting the cities for extended periods. By the 1950's snow removal, keeping roads and streets always passable, become a public service with high priority. As the service got better, the expectation, in fact the demand, from the public grew.

While public expectations vary by location, frequency of storms and historical level of removal service, it is not at all uncommon for most of the public living in the snow belt to expect to travel during and after the storm as if the snow were not there. Many of today's drivers view snow on the road as "here today gone tomorrow." Anything less is most often seen as a lack of service by the responsible public agency. Public agency accountability is today linked to public expectations through the various news media. The application of the latest technology in the coverage of media events means public agency managers must respond instantly to each inquiry. Major snow storms frequently become major media events. Removing snow appears to most people to be a simple mechanical task. Just push or melt it away. "If I can clear my driveway, why can't the state transportation people clear the roads?" Unfortunately the simple notion has become more complex today and will become more complex in the future.

COMPLEXITY OF THE TOOLS

Pushing, plowing and hauling by application of mechanical technology in the form of a truck or other self propelled piece of equipment has been and remains today the principle method of displacing snow from streets and highways. Primary improvements have come in the prime mover, the truck. Motor trucks of the medium-duty size have and continue to be the base component of what the public calls a "snow plow." Evolutionary improvements in these trucks, from engines to transmissions, from tires to safety devices, have resulted in a better truck for plowing operations. Yet these are largely inherited gains. Few if any technological improvements in the medium-duty truck are a result of snow plowing needs. The market share for snow plow trucks is too small. Snow plow users generally take what the bigger customer markets demand and make the best of it.

The plowing equipment attached to the truck is only just beginning to change from the early first designs. Plow shapes and sizes have remained essentially the same since the 1930's. Improved fabrication practices have helped improve the reliability and life of the product and the application of hydraulics in the 1950's, to raise and reverse the angle of plows, has made them easier to use. Only recently has consideration been given to plow design research and the application of materials other than traditional fabricated steel.

Early treatment of packed snow or ice consisted of application of abrasive materials, such as sand, slag or ash, to improve tire traction. Use of chemicals in snow and ice control was limited to the treatment of abrasives. Increasing efficiency of snow removal by adding chemicals, principally salt, to supplement and lessen the time required for removal compared with the purely mechanical approach began in the late 1930's. The application of rock salt, first manually, then through modified spreaders adopted from agricultural markets, soon became a basic part of many agencies' snow fighting arsenal.

Like the snowplow, the salt or aggregate spreader evolved quickly in early use only to become stagnate in terms of technological improvement. The two common designs, hopper and under-the-tailgate for dump trucks, became the industry standards. Improvements, for the most part came in drive systems where hydraulics replaced direct mechanical and independent engine systems. In recent years the use of stainless steel in fabrication has become more common to prevent corrosive failure.

Today new materials, such as CMA and liquid deicers, combination systems and new anti-icing technology are creating new demands for chemical application technology in the snow and ice control industry.

An often over looked enhancement in the snow and ice efforts of public agencies in the 1960's was the application of two-way radio communication. With military roots, two-way radio first appeared in the public sector in the law enforcement arena. Later public works and highway maintenance agencies recognized increased labor efficiency and safety by providing remote communications between driver and supervisor. Basic two-way communications systems are common place in most snow and ice programs today. Used to direct operations, gather information and provide a safety link to the driver operating alone in hazardous conditions, the radio is an important if sometimes overlooked tool of the trade. It is in this area, radio frequency (RF) communications, where the future technologies hold considerable promise for the public agency goals for increased efficiency and "more with less."

The 1970's saw the first application of electronic devices other than two-way radio in the snow and ice arena. The growing demand for clear streets and highways prompted increasing use of salt as a deicer. Simultaneously the environmental impacts of chemical usage were creating a heightened level of public concern. For many agencies dealing effectively with the environmental issues of deicing salt meant improving mechanical control systems to lower cost by applying only what was needed when it was needed. Again drawing from the agricultural market, the automated spreader control was born. The device that monitored the truck speed and adjusted material flow rates proportionally removed a routine task and decision from the driver. A secondary benefit occurred when reducing salt usage helped to reduce the overall cost of services. New computer-based versions improve the reliability and accuracy of the controller and offer the added feature of collecting "management" information as the task is performed.

TRUCK CHASSIS TECHNOLOGICAL ADVANCEMENTS

Future Vehicle Design Considerations in "Medium Duty" Trucks

The sale of medium duty trucks (class 5, 6 and 7) is a highly cost competitive market. From the public sector perspective of efficiently purchasing trucks for snow plow applications, this is good because prices are competitive and reasonable. From an advancement perspective, this high cost sensitivity is bad because new technology lags behind heavy duty "class 8" equipment. From the manufacturers view, the technology must be salable to a highly cost conscious customer who wants a truck for basic functionality without the "bells and whistles." Though slower in the medium duty market, technology is coming. Electronic controls & monitoring systems will soon be standard on medium duty engines as they are on today's over the road rigs. Electronic "computer controlled" systems will permit variable horsepower engines designed to protect components and better match the engine to the task being done. Transmissions such as the Allison MD Series are already using electronic control systems to adjust shift patterns to load and driving style. Computerized shifting of "manual" transmissions appears a near term reality. ABS braking systems, typical on today's automobiles and quickly gaining acceptance in heavy duty highway trucks, will appear in medium duty trucks in the next year or two. This technology along with traction control systems to automatically direct the right amount of power to the correct drive wheel should greatly increase safety and efficiency in the less than ideal condition of plowing snow.

Medium duty truck manufacturers and truck industry engineers see future emphasis on increasing driver visibility. The ability of the driver to see in all directions under all conditions is recognized as a major contributor to increased safety. For years snow plow operators have struggled with visibility problems caused by under designed heating systems, wiper systems and lighting systems. Today manufacturers are starting to hear these concerns and are researching heated windshields and cowls, modified special wipers for plow trucks, improved cab air intake systems, and improved instrument visibility. Another area of improvement long recognized for increased attention by plow drivers and agency safety managers is the need for improving driver entry and egress. Manufacturers are hearing the need and working to make future trucks safer to enter and exit in all weather conditions.

Of interest to those plowing snow in urban environments, all manufacturers are actively working on increasing maneuverability and creating tighter turning angles. Front axles with 45 degree turn angles should appear on the market soon. Alternative fuels and reducing vehicle waste by the increased use of synthetic lubricants can also be expected in future medium duty truck designs. Increasing truck service life is of interest to the customer in any market. To this end, manufacturers promise future trucks with better component parts, heavier non-reinforced frames and increased corrosion protection. All of which are welcome improvements to the fleet managers working to keep their snow plows running with a shrinking replacement budget.

In all but the rarest of cases today's plow truck looks just like any other truck rolling off the truck assembly line. The bare cab and chassis, sometimes with a few special features, heads for final assembly by an allied equipment supplier and/or the end user agency. It is here where a marriage of many unique and diverse component parts join with the bare truck to create a multi-functional tool for the war against snow and ice.

Snow Plow Advancements

As stated previously, snow plow designs have remained largely unchanged until recent years. A simple mechanical device with a limited market potential, the snow plow has generally been built by regional enterprises with the facilities to cut, bend and fabricate steel. Designs were based on the practical knowledge of the fabricator and the user with little more than trial and error testing of prototypes in the field. Users in various geographic areas determined the designs that worked best for them and developed relationships with suppliers who met their needs. Thus, the plows of New England differ from those in the Midwest that differ from those of the West.

It was not until the recently completed Strategic Highway Research Program (SHRP) efforts were undertaken that any significant engineering study of snow plow design occurred in the United States. This program produced two important projects related to plowing and plow design which combine practical knowledge with scientific techniques to address improved casting, scraping and weight issues to reduce fuel requirements. Yet, these projects just begin to scratch the surface of plow design. Future research needs include refinements in all these areas and matching the plow to the variety of snow conditions found in the different regions of the country.

The construction equipment industry has recognized and adopted modern state-of-the-art load sensing hydraulics for improved efficiency and fuel economy. Today this technology is slowly working its way into the snow plow truck. Though more complex than the old "open center" systems used on plow trucks for years, these systems offer many options for improved driver or automated control thus allowing plows, spreaders, scrapers and dump boxes to operate independently in their most effective pressure and flow ranges. The adoption of pulse width modulated control valves and integral speed sensors in hydraulic motors permit easy integration of electronic computerized control systems for operating systems automatically or at the touch of a driver's finger. Not only are these systems growing in ability and sophistication, they also offer increased reliability in the field.

GENERAL SAFETY ADVANCEMENTS

Always recognized as a critical area of concern, snow plow truck lighting and visibility to vehicles approaching and overtaking the truck continues to evolve. Strobe lighting and other warning light systems continue to be evaluated by industry and users alike. The lack of some motorists concern for conditions and speed during snow storms continues to make the snow plow truck and its driver a slow-moving target for inattentive high speed drivers. While many states have undertaken in-house studies to develop lighting systems, no comprehensive independent scientific study has been made. Most product changes come from the manufactures whose principal business encompasses all types of public safety vehicles. Users have made changes to date based on trial evaluations and driver comment. Just as "being seen" is important to the snow plow driver, so is the need to see. Improved plowing lights are an important consideration for operations that frequently continue around the clock. SHRP Project H-206 addressed reduction of the "snow cloud" created by the plow as a major visibility benefit of a new plow design. The National Cooperative Highway Research Program (NCHRP) has recently released a request for proposals (RFP) for research on snow plow visibility issues. Vehicle lighting technology has improved in the general automotive area. Constructive research and testing are likely to bring improvements in snow plow lighting in the not to distant future. Only in the last few years have complete three-point seat belts become a part of the medium duty truck. Yet, in the not to distant future, these same vehicles may catch up to the automobile industry with air bags and other collision mitigation devices. SHRP research and testing have even broken ground for truck mounted attenuators (TMA's) for snow plows as a further aid in protecting motorist and plow driver alike.

Electronics - RF Communications Devices

While truck industry sources predict a some what slower application of technology to the medium duty truck market and highway agencies work with various suppliers to adapt new ideas to the mechanics and hydraulics of snow plows and spreaders, the communications environment for the public sector appears poised for rapid changes into the next century. Already private sector trucking firms are adapting and applying state-of-the-art communications to allow data and voice communication between truck and terminal, to pin point the locations of trucks and their contents, and to monitor the operational performance of the various component and systems. What five years ago seemed to many to be "star wars" is today part of the routine of doing business for many parcel and freight carriers worldwide.

IVHS - Smart Cars Meet Smart Plow Trucks

Work continues in several parts of the country on various approaches to the Intelligent Vehicle Highway System/ Intelligent Transportation Systems (IVHS/ITS). Much of this work involves the combination on smart cars with onboard data collection management and information systems communicating via land based or satellite based systems to highway management centers and occasionally other similarly equipped vehicles. While debate continues about how and when the various aspects of IVHS/ITS will become a reality, it is good bet that this technology will exist in some form early in the next century. Some parts, such as automatic vehicle monitoring (AVM) and location monitoring systems (LMS), are already in field use with the freight tracking systems.

Logical application of IVHS/ITS technology in snow plow trucks includes the use of collision-avoidance systems to help prevent snow plow/motorist collisions in poor visibility conditions, the use of snow plow trucks to gather traffic flow/congestion data during storm periods to update travel times, and routings and AVM technology to monitor truck operating systems and unit operating safety.

Global Positioning Systems (GPS)

Many public safety operations are presently installing computer aided dispatch (CAD) facilities to improve communications throughput with fewer personnel. These CAD systems frequently use GPS to monitor and track the location of various fleet vehicles engaged in routine and emergency operations. GPS and CAD systems allow the dispatcher and supervisory personnel in the communications center to track movement and activity in great detail. While some may debate the need for designing the ultimate "war room" for the battle against winter snow storms, these systems will provide unrivaled monitoring of field operations while reducing use of critical radio communication "air time" by sending high speed data instead of voice-based information.

Instantaneous Information Collection

Linking all these tools into a single on-vehicle device is the mobile data terminal (MDT) which today may be more aptly described as the mobile data computer. Quickly and quietly becoming a common tool of the law enforcement community, MDT's are bringing real time on-line access to computer data bases to personnel in the field. They provide a two-way link to send and receive information at anytime and anywhere, either by user interface with the device or automatically by connecting with various data collection devices onboard the vehicle. A MDT equipped snow plow vehicle could provide up to the minute status reports on work status, i.e., miles plowed, deicer or abrasives spread, hours worked, current pavement status, travel speeds, traffic volumes and even current weather conditions. In addition, drivers could monitor all systems and gather information from onboard pavement temperature sensors and, by remote link, connect to weather and pavement monitoring stations. Highway officials continue to seek better more efficient ways to collect and distribute maintenance management data. *NCHRP Report 361*, "Field Demonstrations of Advanced Data Acquisition Technology for Maintenance Management," reviews many possible applications of GPS, MDT's and hand held computer devices in diverse area as roadway inventory, sign inventory and routine work activity reporting.

Preprogrammed Decision Making

It becomes reasonable to ask: for what practical purpose could this "Desert Storm Technology" be used in the simple task of removing snow and ice from the roadway? The answers are based on the benefit-to-cost comparison of delivering the service the public expects. Efficiency, "leaner and meaner" as some would say, is the ultimate driver of good public service from building roads to clearing the snow. Good snow and ice control programs are based on knowledge, history or experience, and current information. A skilled driver with years of plowing experience supervised by a person with equal or greater skill and experience, and the intuitive ability to predict the weather in any given storm, will have a high likelihood of success given the basic tools and materials of the trade. If all goes well and their decisions are not second guessed by the administration, the public, or the media; the storm will pass; an acceptable pavement condition will be maintained until cleared completely; and the public safety will be maintained.

Yet, as previously discussed, the overall skill levels and experience of public sector employees seem to be on the decline. More emphasis is placed on hiring part-time or hourly drivers. Experience of supervisors is drained as long time employees leave agency service under cost cutting early retirement incentive programs. New management is ever more sensitive to the power of criticism from the media and elected officials. Thus, drivers and first line supervisors of the future are not likely to be left alone to get the job done. Middle and upper managers will want to participate in the process and to be able to respond quickly to any concerns or criticism. To do this effectively will require that both history and current information be available anytime. New technology in snow plow operations will lessen the demand for the driver to decide, permit the delivery of deicing material based on exact conditions, and help coordinate route changes based on status throughout the affected area. In addition, systems can be expected to reduce unproductive operations and improve sequencing of shift changes and material reloading. The data gathered from various systems will promote modeling for future storms, provide documentation for accountability and better decision making, and most importantly increase safety for the plow driver and the motorist.

Driver Skills & Support

Building and maintaining a professional snow removal work team will become even more critical with growing sophistication of trucks and allied equipment. Commercial Drivers Licenses (CDL) have already contributed to minimum standards for professional skill levels. Yet, part-time drivers create potential conflict with the goals of increased driver skill and the demands of economically staffing highway maintenance organizations for the peak and valley demands of snow and ice removal. Given the limitations on training time with part-time staff, keeping the task of operating a snow plow simple and safe for driver and motorist may only be attainable with increased automation. The coming of the electronic age will place increased demands on the service technicians to provide maintenance and repair support, and equal demand on administrators to find and retain the skilled people to support the proliferation of electronic technology.

CONCLUSION

The simple notion of removing snow and ice from the public roadways has grown to be a significant annual public agency effort. The demands continue to grow and the costs continue to keep pace. The Illinois Department of Transportation alone estimates annual snow and ice removal costs at $25 million annually. This represents the single largest highway maintenance cost activity for the Department. Is new technology contributing to the increasing cost? While the simplistic answer could be yes, the increase in the technology used for snow and ice control will be driven not because "it is there," but, because there is a need to meet the demands and expectations of the traveling public. The cost of technology application to snow and ice will be repaid in more effective removal of snow and ice from the pavement and greater public satisfaction with the result.

The application of new technology, be it mechanical or electrical, is an evolutionary process. Not all public agencies will require or demand new technology at the same time. Will every snow plow truck be the sophisticated smart plow truck described above by the year 2000? Most likely they will not. Will some agencies be using some or all this technology by the year 2000? Yes some, if not several, will. Those fleet managers and specification writers responsible for the fleets of public agencies over the next 10 years will, without doubt, see the technology described here and more as they prepare specifications and purchase the snow plow trucks of the 21st Century.

SNOW PLOW TRUCK CAB ERGONOMICS

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SUMMARY

A task force was organized by the Minnesota Department of Transportation in the Fall of 1992 and charged to improve snowplow truck ergonomics in the cab environment. The objective of the effort was to design an ergonomically correct snowplow truck cab that was cost-effective and efficient. The activities of the task force included a literature search, a search for products and ideas, and the formulation of proposals for implementation. The general areas addressed included visibility (mirrors, windshield and lighting), controls (accessories, levers, steering wheel, shift stick and warning systems), and comfort (climate control, noise and seats). The task force made recommendations in each of these areas and in the development of training programs on snowing plowing, winging, and sanding operations. The final report was entitled, "Snowplow Truck Cab Ergonomics Task Force Report" (MN/MO-93/06), and published by the Minnesota Department of Transportation, St. Paul, Minnesota in August 1993.

ERGONOMIC FACTORS IN A ONE-PERSON OPERATION OF SNOW PLOWS WITH ATTACHED WING PLOWS

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ABSTRACT

This paper describes the way in which the Ontario Ministry of Transportation introduced a major policy change in the operation of its snow plows. Traditionally, the Ministry used two persons to operate a snow plow with an attached wing plow; one person drove the truck and the other operated the plow. Several years of operational research and trial experiments revealed that using only one person to operate both the truck and plows could result in significant cost saving without diminishing the service or sacrificing employee and public safety. Following the policy decision to change from a two-person to a one-person operation, the Ministry undertook a detailed investigation of the operation. This resulted in several recommendations concerning equipment modifications, operator training and operational planning. The recommendations were implemented and it is now a commonly accepted practice in the Ministry for one person to operate the truck, front plow and wing plow.

INTRODUCTION

The Ontario Ministry of Transportation (MTO) owns and operates approximately 650 trucks to clear snow from its highways each storm. In addition, MTO hires approximately 425 private trucks for the same purpose. Most of the snow plow trucks in the MTO fleet are 39,000 lbs. GVW dump trucks mounted with a one-way plow on the front and a wing plow on the right (Figure1). Traditionally MTO used two persons to operate a plow truck with an attached wing plow, with one person driving the vehicle and the other person operating the plows from controls mounted in front of the passenger seat.

In the early 1980s, MTO like other jurisdictions, responded to fiscal constraints, in part, by investigating a policy of converting from two-person operations to one-person operations wherever possible. It was imperative not to sacrifice the safety of either the operators or the motoring public for the sake of reducing costs. Consequently, a great deal of discretion was offered to staff to allow for a phased-in approach and to allow for deviations from the normal operating standards and equipment standards to accommodate local needs in converting to a one-person operation.

The management structure of MTO operations is decentralized such that five Regions consisting of 18 Districts across Ontario are responsible for the implementation of operational policies. Before the implementation of the optional one-person operation of a plow with a wing in 1981, various modifications to the vehicles were carried out in the Districts to improve vehicle/equipment operation. Some examples include:

- Relocation and modification of plow controls,
- Redesigned outside mirrors,
- More appropriate type and placement of vehicle lighting, and
- Installation of two-way radios.

After seven years of voluntary operation of trucks and plows with a wing by one person, MTO decided to make a one-person operation mandatory across Ontario for the 1988/89 winter season. Based on the operational experience gained and two operator surveys, a policy was

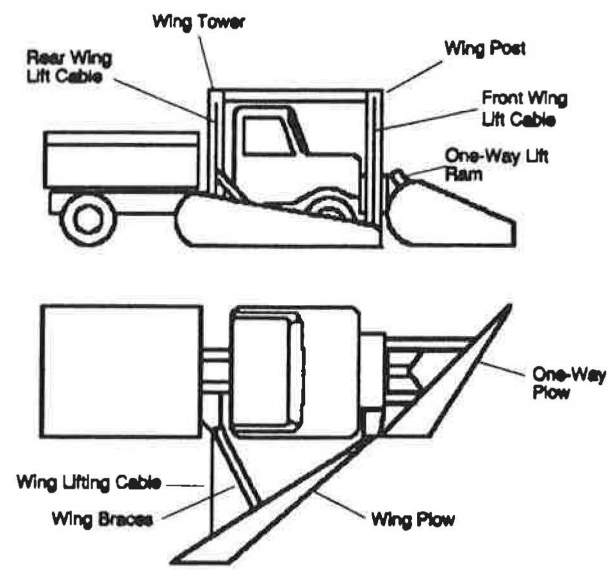

FIGURE 1 Top and side views of a snow plow and wing plow vehicle.

developed that established the procedures to be followed and identified those situations where exemptions to the one-person operation of a plow and wing would be allowed.

However, during implementation of the new policy in the 1988/89 winter season it was determined that refinements to the operating procedures were required. The following objectives were established:

- Develop more explicit criteria for one-person operations involving wing-plowing,
- Review of the plow truck's ergonomics for one-person operation, and
- Address the need for specific training of operators who will operate the truck and wing-plow on their own.

To accomplish these objectives the Ministry commissioned a study by an independent consulting firm during the winter of 1989/90(*1*).

ERGONOMIC STUDY

The project study method consisted of six steps:

- A survey to develop descriptions of the basic types of snow plow equipment being used in present operations;
- A survey of operations to produce descriptions of the different types of plowing operations conducted by the Ministry;
- An operator task analysis designed to produce a detailed description of what an operator must do to perform the plow control tasks in different plowing operations safely;
- Development of recommendations for equipment design and operating procedure changes that might be required for one-person operations;
- Trials to evaluate the effectiveness of some equipment modifications; and
- Development of recommendations covering equipment design standards, operator qualifications and training, and operating procedures.

The findings cover the results of the equipment and operations surveys, operators' task analysis, development of equipment modifications, and trials of the equipment modifications.

Equipment Survey

Operation of the plows requires four continuous action controls: one to raise or lower the one-way plow, one to raise or lower the front end of the wing, one to raise or lower the rear end of the wing, and one to control the angle of the wing. There are three different types of control systems being used to control the plows. One, called the hydraulic lever system, consists of levers on the floor of the cab that have mechanical linkages to the hydraulics that power the plow adjustments. The second system, called the toggle switch air-over-hydraulic system, consists of toggle switches that control a compressed air linkage to the hydraulics that power the plow adjustments. The toggle switches are usually mounted on the dash. The third system, called the pedestal mounted system, is also an air-over-hydraulic system. It consists of 10-centimeter levers mounted on a pedestal.

The equipment survey showed that all three-plow control systems, as installed in truck cabs, had a variety of ergonomic shortcomings. The most prevalent and serious ones consisted of plow controls being outside the normal reach of the operator and plow controls having inappropriate response characteristics. The equipment survey also showed that the operator has very limited feedback for performing plow control tasks. The primary feedback limitation comes from the operator's restricted views of the positions of the plows. These restrictions increase when bad weather cause snow and ice buildup on windows and mirrors.

Operations Survey

By treating the frequency of driving and plow control actions per unit distance as a measure of operator work loads, analysis of the operational sequence data showed that operator work loads on different types of operations were highest for shoulder clearing and lowest for clearing traveled lanes. The data also showed that operators controlled their work loads sometimes by adjusting the plow operating speeds to match the demands of the road and snow conditions.

The operational sequence data showed that the frequency of use of plow controls relative to other vehicle controls tended to be the same across operations. This and other operational sequence results were combined with operator task analysis results to determine the ergonomic requirements of the plow control system.

Operator Task Analysis

The task analysis results showed those plow control tasks could be described in terms of a few basic tasks. Basic tasks included such things as lowering the plows to the ground from their retracted positions and raising the wing to clear a curb. Although the number of these basic control tasks was small, each basic task required a complex sequence of precise control actions. The ergonomic features of plow control tasks included:

- Continuous adjustment control actions;
- Limited feedback for monitoring the results of control actions;
- Requirements for performing multiple control actions in specific sequences; and
- Control errors producing significant risks of injury, damage to equipment, or damage to the road surface.

The task analysis results, in combination with the operational sequence data, were used to specify plow control system design requirements. These requirements showed that most existing equipment would not meet these requirements.

Equipment Modifications

The results of the operations findings were used to specify equipment modifications that would provide a plow control system suited for one-person plowing operations. Some modifications were installed on a test vehicle. The installed modifications included:

- Mounting the existing air-over-hydraulic control unit on an adjustable pedestal to put the controls within reach of the operator;
- Installing a hydraulic control unit that would ensure that the speed of plow movement is proportional to the travel of the control lever and adequate response gain and lag characteristics;
- Increasing the convenience of ancillary systems such as the two-way radio and lighting systems; and
- Improvements in mirror systems used to view the plows and traffic.

The recommended equipment modifications also included improvements in systems for keeping windows clear of ice and snow buildup. However, these modifications were not installed on the test truck.

Trial of Modifications

The modifications were tested by having experienced operators perform a set of off-road exercises that simulated snow-plow control tasks. Fifteen operators from several different areas of the province participated in the trials. After doing the test exercises, each operator completed a questionnaire about the test vehicle and its use in operations.

Except for one flaw in the hydraulic control test unit, the off-road exercises showed that the equipment modifications would permit operators to perform standard plow control tasks safely and effectively. The flaw in the test unit consisted of an inertial response lag in the hydraulic unit that canceled many beneficial effects of the unit's other characteristics. In particular, the inertial response lag made it difficult for the operator to make small precision adjustments of the plow heights.

The questionnaire asked the operators to rate the effectiveness of the equipment modifications as compared with the equipment on the trucks they usually drove. In response to questions about using the plow control unit for different plow control tasks, the operators thought the test unit provided some improvement over existing equipment. However, most of the operators commented during the trials that the inertial lag in the test unit's response reduced the benefits of the unit's other characteristics. Operators had more positive opinions about the improvements provided by the other equipment modifications. The main improvements came from having the plow controls within reach of the operator, improvements in the mirror configurations, and improvements in the layout of radio and lighting controls.

As part of the questionnaire, the test operators used a standard work load rating scale to rate the operator work loads imposed by different types of plowing operations. In making the ratings, the operators were to assume that they were using the test vehicle on these operations. The results of the operator ratings of work loads were consistent with the relative work load estimates derived from the operational sequence data. Taken together, the work load estimates suggested that most operations impose substantial but acceptable work loads. The major exception was the case of clearing unfrozen shoulders. All the findings, including operator work load ratings, showed that expecting operators to clear unfrozen shoulders without occasionally plowing off shoulder material along with the snow was unrealistic.

Performance of the test exercises showed that operators performed some plow control tasks incorrectly. In a few cases, the tasks were performed incorrectly almost as often as they were performed correctly. In other cases, control tasks were performed incorrectly only occasionally. These results suggested two things:

- The complexity of the task made it prone to errors, and
- The operator's skill level was deficient.

RECOMMENDATIONS

The recommendations covered three aspects of one-person operations: equipment requirements, training and qualifications of operators, and operating procedures.

Equipment Requirements

The recommended equipment requirements for one-person operations include:

- The use of a pedestal mounted air-over-hydraulic control unit as the standard control unit;
- Locating the plow controls, radio and microphone within the reach of the operator;
- Minimum specifications for the response characteristics of the plow control system, e.g., capability to retract the wing in less than 5.0 seconds; and
- Installing a system of mirrors similar to the mirror configuration of the test vehicle.

Besides the above, the consultants' report recommended continued development of other modifications that were not installed on the test vehicle. These include improving the plow control unit to meet its original specifications, developing shape coded plow controls, and improving the windshield wiper and defrosting systems.

The report also recommended further research and development to see if automating standard control sequences would be feasible. This would allow an operator to perform standard movement sequences with single control actions. The task analysis and operational sequence data showed that the present control system provides far more degrees of control freedom than are needed for actual operations. Tailoring the control system to operational requirements would greatly reduce operator work load and increase operating efficiency.

Training and Qualification of Operators

The report recommended that operators be provided with basic formal training in the following areas:

- Inspection of the equipment for safety and serviceability,
- Mounting and detaching the plows,
- Performing the basic plow control tasks correctly and quickly,
- Safely combining driving and plow control tasks on the road, and
- Knowledge and familiarity of the plow routes.

Operating Procedures

The report suggested that most current plowing operations may be satisfactorily performed by one person. The general exceptions would be operations that include clearing unfrozen shoulders. The report included criteria for defining other specific exceptions such as unusual weather conditions.

IMPLEMENTATION

The Ministry appointed a small group of staff to formulate a policy statement and an implementation plan for a one-person plow with wing plow operation, based on the consultants' report and the collective experience of the group. The implementation plan featured the following:

- Equipment specifications for new plow trucks and minimum requirements for modifications to existing equipment, and
- Operator training plan and checkout procedure.

The actual implementation of one-person operations became the responsibility of the field operations staff.

Ministry staffs modified new vehicle specifications and are continuing to work with suppliers to make improvements. From year to year, enhancements are made as new equipment becomes available and the needs become better defined.

Recommendations were documented and ranked to improve existing equipment. As staff gained experience in modifying equipment and calibrating the speed of hydraulic equipment, the information was shared, and within a matter of months every plow required for a one-person operation was converted.

During the same period all operators were checked out to ensure they possessed the necessary skills to operate a plowing unit alone. Training was provided where required. With respect to the plowing routes and types of operators, a review was carried out and adjustments were made to distinguish between one person and two person situations.

EVALUATION

From 1981 to the winter of 1991/92 major changes have occurred to plowing operations in the Province. Before 1981, close to 100% of the plowing operations in the Ministry were carried out by two persons. The only exceptions occurred when plow trucks without a wing plow were used. The following table shows the status of plowing operations during the 1991/92 season.

1991/92 SUMMARY OF OPERATIONS

OPERATION		ONE-PERSON	TWO-PERSON
Plow and Wing		624	189
Plow Only		126	0
	TOTAL	**750**	**191**

As can be concluded from the above table, 80% of the fleet is equipped for and performing in a one-person operation. The remaining 20% is mostly due to situations that allow for exemptions from the one-person mode of operation as discussed in the earlier section titled `Operating Procedures.' Since conditions will change due to construction, new routes, etc., the percentage of one-person operations will continue to change during the season and from year to year. With improvements in equipment over time it is likely that the percentage will increase although it will most likely never reach 100%.

MTO has, as a result of implementing one-person operations, reduced its staff by approximately 500 persons or one third of the total operator complement. This has been achieved without sacrificing safety or the performance of the operation.

Following implementation the Ministry has monitored accident and incident reports to ensure that safety consequences were not jeopardized. Analysis of these reports to date does not show any increase in the number of accidents attributable to a one-person operation. Through this exercise the Ministry has verified that if development of a major policy is conducted in an open and consultative fashion, the challenges of the future can be successfully met.

REFERENCE

1. Engel and Townsend, *Ergonomics Study Of One-Person Operation Of A Snow-Plow With Wing Plow*, Toronto, Canada, 1990.

IMPROVED UNDERBODY PLOWING

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ABSTRACT

One of the more severe winter hazards is ice or compacted snow on roadways. While three methods are typically used to combat ice (salting, sanding and scraping), little effort has been applied to improve methods of scraping ice from roads. In this study, a new test facility was developed comprising a truck with an underbody blade, which was instrumented such that the forces to scrape ice from a pavement can be measured. A test site was used with ice layers being sprayed onto the pavement and subsequently scraped from it, while the scraping loads were recorded. Three different cutting edges were tested for their ice scraping efficiency. Two of the blades are standard (one with a carbide insert, the other without) while the third blade was designed under the Strategic Highway Research Program (SHRP) H-204A project.

Results from the tests allowed two parameters to be identified. The first is the scraping efficiency which is the ratio of vertical to horizontal force. The lower this ratio the more efficiently ice is being removed. The second parameter is the scraping effectiveness which is related to the horizontal load. The higher the horizontal load the more ice is being scraped. The ideal case is thus to have as high a horizontal load combined with the lowest possible vertical load. Results show that the SHRP blade removed ice more effectively than the other two blades under equivalent conditions, and did so with greater efficiency and control. Furthermore, blade-angles close to 0° provide for the most efficient scraping for all three blades.

The study has shown that field testing of plow blades is possible in controlled situations and that blades can be evaluated using this system. The system has potential to be developed in many ways to provide the means for optimal ice scraping with improved safety for plow operators.

INTRODUCTION

Maintaining safe driving conditions in winter weather is a complex task. Accordingly, a variety of approaches are used to keep road conditions as safe as possible. There are three main methods used to remove snow and ice from the road surface. The first is to use salt, or another chemical, to depress the freezing point and thus melt the snow and ice from the road surface. The second method is to use sand to increase the friction of an ice-covered road and by that make the road more driveable. Often this method is combined with the first by applying a mix of salt and sand to the road. This creates an immediate improvement in traction caused by the presence of the sand and allows the salt to melt the ice over time. The third method is to remove the snow and ice mechanically by means of a plow. This can be extremely effective in heavy snow falls, but tends to be much less effective when ice or compacted snow is present on the pavement surface. These materials can form very strong bonds with the road surface and are hard to remove by scraping.

Of the three methods given above to remove ice from roadways, salting is probably the most widely used method, but it also poses several problems. Salt can cause serious degradation of bridges and pavements, and corrosive damage to automobiles. Environmental concerns, such as contamination of ground water and damage to vegetation, are also associated with the use of salt. Furthermore, the use of sand may lead to hazardous levels of airborne particulate. Given these concerns over the use of salt and sand, investigating methods of improving ice removal by scraping seems prudent.

Recent studies have shown that the shape of the cutting edge used on a plow blade is very important in determining the loads acting on the plow. These studies, which were part of the Strategic Highway Research Program (SHRP), examined the effect of several parameters on the forces required to remove ice from a sample of pavements in the laboratory (*1,2*). Some parameters studied included clearance angle, attack angle, rake angle, and blade flat width. These parameters are shown in Figure 1. It was found that if a blade had a non zero clearance angle (specifically, in this series of experiments, if the clearance angle was 2° or greater) then the forces on the blade were reduced by a factor of twenty when compared with a blade with a zero degree clearance angle. It was also found that the scraping forces increased when the blade flat width was more than 9.5 mm (3/8").

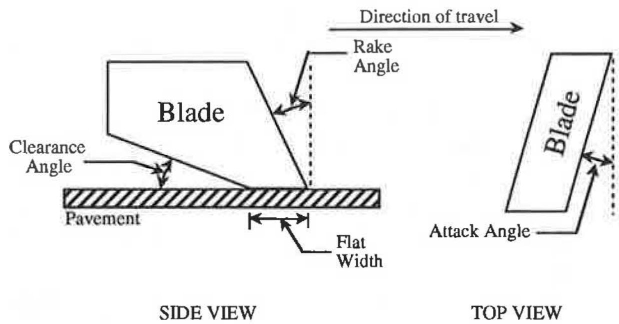

FIGURE 1 Definition of terms used in SHRP study.

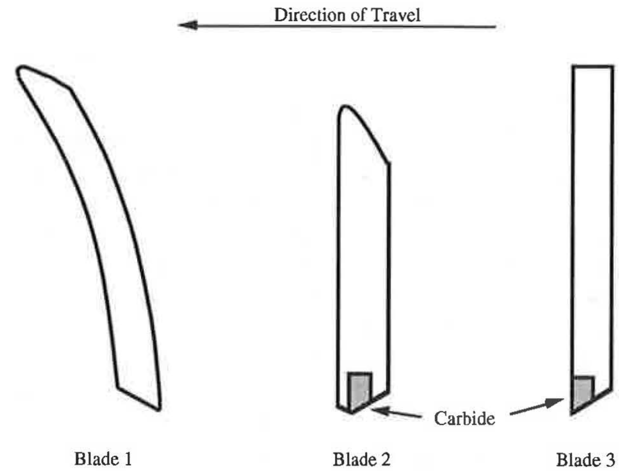

FIGURE 2 Cutting edges used in experimental study.

The tests performed in the laboratory were under much more ideal conditions than those found on true road surfaces and were also on a much smaller scale. Because there is a lack of data on the loads experienced by a snow plow during ice removal, the need for full scale tests with current snow removal equipment became apparent. Accordingly, a project was conducted in which a truck with an underbody plow was instrumented. The instrumented plow was then used to scrape ice off a road surface. A full description of these results is given elsewhere (*3*).

The purpose of this paper is to discuss some results from the instrumented plow study from the aspect of how they might lead to improvements in underbody plowing techniques and designs. A brief description of the experimental method and results is presented, followed by a discussion of ways in which these results could be implemented to optimize ice and compacted snow removal by mechanical methods.

EXPERIMENTAL METHOD

The tests were performed using a 1975 International Fleetstar 2050 25 ton gross vehicle weight (GVW) dump truck on loan from the Iowa Department of Transportation (IDOT). The truck was fitted with a Wausau truck grader (Model HH8-7983-5) from now on called an underbody plow. The underbody plow was bolted to the truck's frame midway between the front and rear axles. Five hydraulic control levers in the truck's cab allowed the operator full use of the underbody plow. The driver controlled the left and right vertical position (and thus download), the blade-angle, cast-angle, and cast-angle-lock. The most significant benefit of an underbody plow is the ability to place a variable download on the cutting edge or blade of the plow. This cannot be accomplished with standard front mount blades or "skippers" as they are called. Blades of this type have only their own weight for a download force. Underbody plows on the other hand can have download forces that approach the truck weight.

The cutting edge or blade was bolted to the blade support to allow for easy replacement. For this series of tests three different blades were tested. The first was a standard steel blade that came with the truck. This blade was 18 x 125 x 2440 mm (3/4 x 5 x 96 inches). The other two blades both had carbide inserts. The first was a commercially available blade, built by Kennametal. The second was a custom designed and built blade. This blade was designed under the Strategic Highway Research Program (SHRP) project H-204A, and built for use with this truck. The geometries of the blades are shown in Figure 2. The second and third blades were nearly the same dimensions as the original blade, except that each was made of two sections that were 1220 mm (48 inches) long.

Forces on the blade were measured using pressure gages in the hydraulic lines to the cylinders responsible for the download force or vertical displacement and the rotation of the blade. For this three International Pressure Products ST-420 0 - 20 MPa (0 - 3000 psi) gages were used; one gage for each side of the vertical motion and one for the pair of cylinders that rotate the blade-angle. Each gage had a self-contained signal conditioner that converted the pressure measurements into a voltage signal, which was recorded by a computer. After the calibration of the system, the vertical and horizontal forces on the blade were determined from the pressure gage data. The angle that the blade had with the pavement was measured with an inclinometer. A Schaevitz Angle Star Protractor System was used for this task. The inclinometer was located on the left side of the blade in a protective box.

Data signals from the sensors were collected on a portable PC. For these tests a Kontron IP Lite was used. This PC was chosen because it was shock rated for operation up to five g. This shock rating was needed to guarantee normal data acquisition because the truck bounced greatly during testing. An analog to digital circuit board in the PC allowed the software to collect and store the data. A Metrabyte DAS-8 analog to digital board was used along with the CODAS data acquisition software by Dataq Instruments. Data was written to the PC's hard drive during testing and then analyzed after testing at the Iowa Institute of Hydraulic Research (IIHR) ice laboratory. Power for the computer and sensors was obtained from the truck batteries through a power inverter and filter system built at IIHR.

All tests were performed at the spillway apron of the Coralville Reservoir located approximately five miles north of Iowa City. This site was chosen because it was flat and inaccessible to the public during the winter months. Water was sprayed onto the pavement surface using a truck mounted tank and spraying system. Water used to make the test ice was obtained from the University of Iowa Water Treatment Plant and taken to the testing site where the temperature of the water and the air were recorded. The water was then sprayed on the concrete using the previously mentioned spray system. The water was applied by driving back and forth over the testing area. The area covered was approximately 7.7 x 55 m (25 x 180 ft). The truck traveled at approximately 0.62 m/s (2 ft/s) during the spraying process. Provided the temperature was low enough, the water was frozen within two minutes, and the entire 2800 liters (750 gallons) were sprayed in 40 minutes. The ice was then left to harden overnight and the testing took place the following morning. The ice sheet formed was six to 12 mm (1/4 to ½ in.) thick. Further details of the ice sheet preparation process are given in Reference (*3*).

To provide better tire traction during testing, the area around the tank in the box of the truck was filled with gravel, and the tank was filled with water. This gave the truck a total weight of 20 Mg (44,000 lb.) with a full tank of water. Air temperature at the concrete surface, ice thickness and ice conditions were recorded before testing. The truck was positioned in line with the ice sheet approximately 46 m (150 ft) from the ice. This allowed enough distance for the truck to accelerate to the desired testing velocity of 24 kph (15 mph). The angle of the blade was set using the display of the inclinometer in the cab. When the truck began to drive on the ice, the download on the blade was applied until the desired pressure was shown on the computer screen in the cab of the truck.

The pressure gages were calibrated by means of a set of calibrated hydraulic jacks. The blade was first set in position, the jacks were then used to push against the blade at known increments and the voltage from each pressure gage was recorded by the computer at each increment. The known pressures of the jacks was then used to relate the voltage directly to a force and the calibration coefficient was calculated. This was performed for both horizontal and vertical components of the blade force.

Vertical force on the blade was calculated from the readings on two pressure gages located on the hydraulic cylinders for the vertical motion. Horizontal forces were determined from the pressure in the cylinders that rotate the blade-angle. This pressure however, includes a vertical component that varies with the blade-angle. As the blade-angle increased, the pressure in the cylinders due to the vertical component also increased. From recording the pressure due to a known vertical load over a range of angles, the relation between angle and vertical loads was determined. Calibrating in this way allowed for the change in the lever arm length of the blade mechanism, or how the mechanical advantage changed with the angle. Once the vertical component was known for a given download, as a function of the blade-angle, the horizontal force on the blade was determined. The calibration of the inclinometer required measuring the blade-angle with a protractor level for various angles and determining the calibration coefficient.

The testing parameters studied were the blade, down pressure, and angle of the blade. For each of the three blades previously described the down pressure was tested at a low (3.45 MPa - 500 psi) and high (8.27 MPa - 1200 psi) value. These were the value of the pressure in the hydraulic cylinders responsible for the download. The angle of the blade was set to nominal values of 0°, 15°, or 30°. In reality, these values were not achieved with great accuracy, but a sufficient range of angles was tested to provide some measure of the effect of the angle on the forces. Due to the physical limitations of the system, achieving the 0° blade-angle for blade two and three was not possible. A total of 65 tests was conducted.

RESULTS

Examples of raw data obtained from the sensors on the truck are shown in Figures 3 and 4. For this test

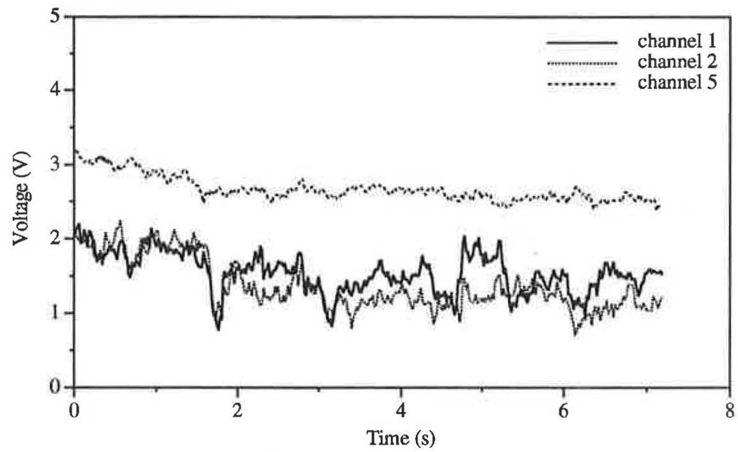

FIGURE 3 Raw data from sensors for test number 28.

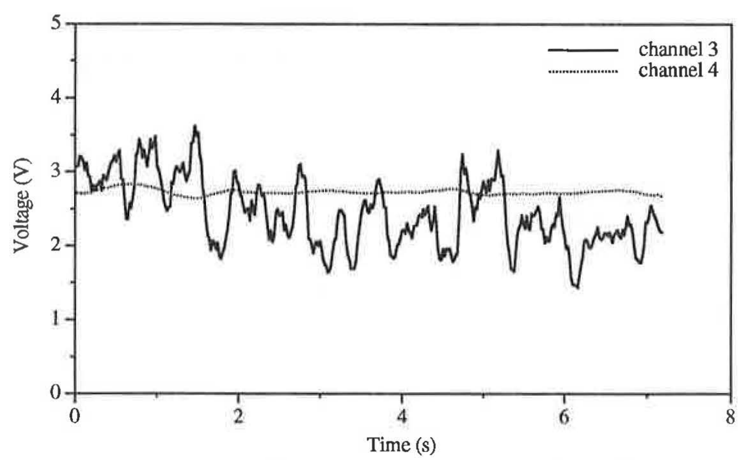

FIGURE 4 Raw data from sensors for test number 28.

(number 28) blade three was used with a low download pressure and a blade-angle of 30°. Figure 3 displays the voltage from the left and right download sensors and from the speed wheel showed as channel one, two and five, respectively. Figure 4 displays the horizontal loading cylinders and the blade-angle sensor, shown as channel three and channel four, respectively.

The raw data can then be transformed to show the loads, blade-angle and speed of the truck as shown in Figures 5 and 6. The vertical force is the sum of channels one and two. The horizontal force is the difference of channel 3's recorded force and the force due to the vertical loading as determined from the calibration of the system. It should be noted that all values are plotted against the distance traveled from the beginning of the test. The starting point was taken as the point where the raw data of channel one and channel two leveled off indicating that the download pressure was no longer being increased. A complete presentation of the test results is given in Reference (*3*).

One aim of this project was to maximize the quantity of ice removed by scraping. The more ice removed by the blade, the greater is the effectiveness of the blade. From the test results it appears that the quantity of ice removed is directly proportional to the horizontal load. Accordingly, in this study, it was assumed that the horizontal force is a measure of the effectiveness of the blade, with a higher horizontal force suggesting a higher effectiveness. It should be noted, however, that it is not clear how well effectiveness is consistent from blade to blade. Thus a horizontal force of 50 kN on blade one may not be as effective (i.e., may not remove as much ice) as a 50 kN horizontal force developed by blade three. Further work is required to

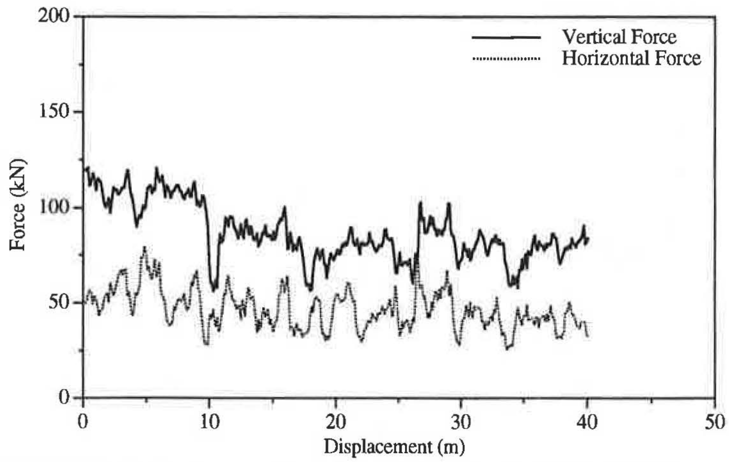

FIGURE 5 Vertical and horizontal forces on blade for test number 28.

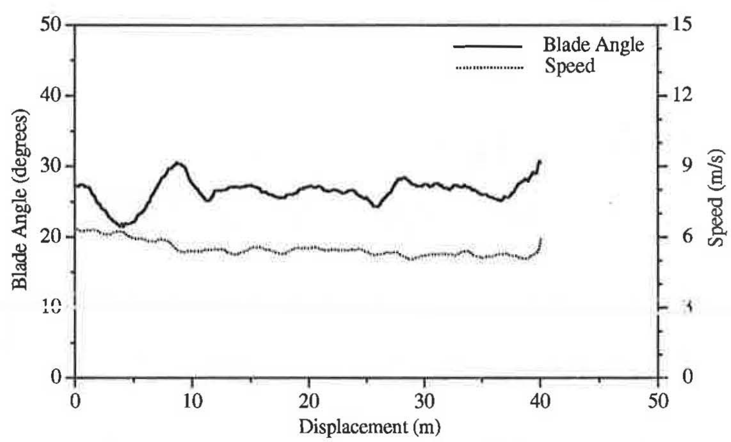

FIGURE 6 Blade-angle and speed of truck for test number 28.

develop this correlation. Nonetheless, a high horizontal load is desirable.

Working against the benefit of a high horizontal load is the tendency of the blade to ride up onto the top of the ice surface, thus cutting no ice. To counteract this tendency to ride up, a vertical download is applied to the blade essentially forcing it into the ice. This vertical load is not directly beneficial to the scraping process, other than forcing the blade into the ice. Further, a high vertical download is cause for concern because it reduces traction from the truck's axles, and makes the truck rest predominantly on the cutting edge. Accordingly, the most desirable condition for ice scraping is a high horizontal load (implying much ice removal) and a low vertical load (implying the truck is supported on its axles, rather than on the blade). Thus the ratio of vertical to horizontal force provides a good measure of what might be termed scraping efficiency. However, some care must be taken in the use of this force ratio, because when both vertical and horizontal loads are very low, no ice is being cut. Very low values of the force ratio may be observed, apparently implying excellent scraping efficiency, when in fact no ice is being scraped at all. As the value of the force ratio rises it suggests the condition of the blade riding across the surface of the ice as opposed to scraping of the ice. The ideal situation for ice removal is thus a low efficiency ratio and a high effectiveness (horizontal force).

Using the efficiency ratio allows a comparison to be made among the three blades. The mean efficiency ratio is plotted against the mean blade-angle for each test and shown in Figure 7. Not all tests are shown,

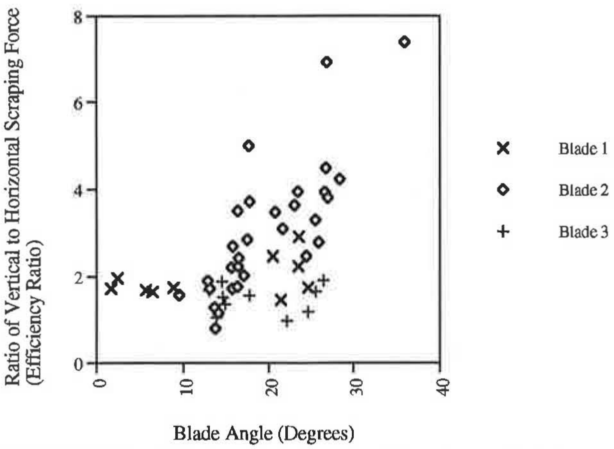

FIGURE 7 Efficiency ratio as a function of blade angle.

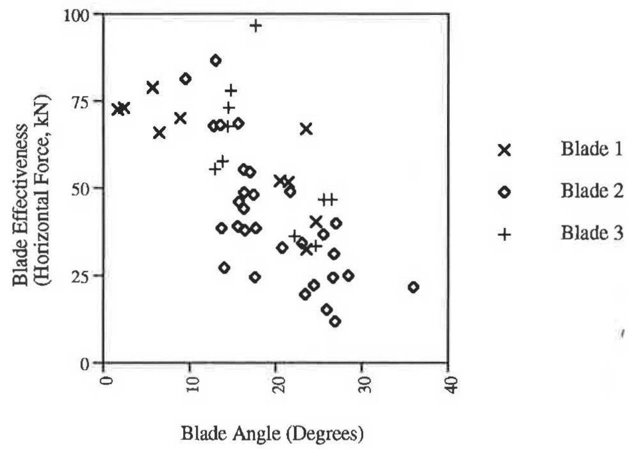

FIGURE 8 Effectiveness as a function of blade angle.

since some results were greatly affected by excessive wear of one blade during a severe storm. The horizontal force experienced by the blade during testing allows a comparison to be made of the scrapingeffectiveness of the three blades. The mean horizontal force for each test is plotted against a mean blade-angle in Figure 8.

As can be seen in Figures 7 and 8, there is a considerable scatter in the results. Such scatter is to be expected given the nature of field tests. After some statistical analyses (*3*) three trends became apparent. First, the blade effectiveness clearly decreases with increasing blade-angles for all three blades. Second, for blade two only, the efficiency ratio increases with increasing blade-angles. Third, of the three blades, the best overall performance was given by blade three. The implications of these results are considered below.

FUTURE DIRECTIONS

There are three major implications of the study undertaken on the Iowa DOT truck and reported in (*3*). The first is that there now exists a test bed upon which a variety of underbody blades and cutting edges can be tested. The effectiveness of these blades at removing ice and compacted snow from pavements can be measured in a rational and quantitative way, and thus blade designs and operating conditions for ice and snow removal can be optimized. Some work still needs to be undertaken before the full potential of this system can be realized. In particular, it must be shown that the results obtained in the "closed track" field trials reported in Reference (*3*) represent real field conditions. It is hoped that a study will be undertaken to verify these results, which will provide confidence that the "test bed truck" can provide useful guidance for operating trucks. One result in this area that shows the promise that this "test bed truck"notion may hold is the excellent performance of the SHRP blade which outperformed the other two "traditional" blades at ice removal. In short, the "test bed truck" has the potential of delivering significantly improved ice and compacted snow removal cutting edges.

Another major area of technological promise is that of providing more information to the truck operator. From discussions with truck operators the standard way of setting underbody plow blade down pressures is apparently, quite literally, by the seat of the pants. This means that training new operators is difficult and costly, since such a calibration method of necessity implies a high degree of experience. By using data from the pressure sensors, the download and horizontal force experienced by the underbody blade can be displayed directly in the cab, enabling the operator to adjust the pressure much more accurately and effectively, and thus allowing "good" plowing even by inexperienced operators.

The third area of potential development lies in the possible use of computers to control the plowing process. This would have significant safety benefits, since operating both the truck and the plow on an icy road is hazardous. It would also provide the optimal ice removal conditions, if an expert system was created which ensured that those conditions were created by adjusting pressures and blade-angle. The start of such an expert system lies in the work already done and described herein, in which the ideal blade-angle and combination of horizontal and vertical force were found. The system would have to incorporate the experience of current operators also. While such a system might be futuristic, many pieces for such a system are already in place on the test bed truck. The benefits of such a system would include improved safety, plow performance and a reduced need for highly experienced plow operators. Of course, developing such a system will be costly, but the final product need not be too expensive and should provide a healthy cost-benefit ratio.

CONCLUSIONS

From the work performed in this study, the following conclusions can be drawn.

- A test technique was developed which can measure and record forces on a cutting edge while scraping ice in near field conditions. The testing apparatus is available to use with other blades and can be a useful tool in the development of new cutting edges.
- Two parameters (efficiency and effectiveness) were defined which provide a measure of how well a cutting edge removes ice from the pavement. The efficiency is the ratio of vertical to horizontal force. The lower this is the more ice is being removed for a given download. Effectiveness is related to the horizontal load. The higher the horizontal loads is the greater the depth of ice being removed.
- Three blades were tested and compared in this study. All three blades performed best (removed the most amounts of ice) at angles close to 0° with high downloads. Blade three displayed the best effectiveness and efficiency of the three blades by removing the largest amount of ice with the smallest vertical to horizontal force ratio.
- Advances in computers and feedback control systems make it possible to develop an automatic control system to adjust the blade (angle and download) for the best scraping performance. Concomitant with development of such a system is the need to survey practitioners who operate plows with underbody blades, to help in the development of the expert system required to exercise computer control over the cutting edge during testing. Besides optimizing ice removal, an automated computer controlled system of this sort would have significant safety benefits.
- Many further tests could be made using the system developed in this study. The system is now operational. Its use is limited only by the scope of testing required. Possible tests that could be conducted include the following:
  - Tests of other, more exotic cutting edges, such as scalloped blades;
  - Tests of automated systems as described in the previous point, along with in-cab display systems to provide more operator information;
  - Tests of the relationship between horizontal forces and the depth of ice removed; and
  - Tests of the effectiveness of chemical pre-treatment on ice scraping forces.
- The final series of tests which are an obvious development of such a system are a full scale field trials. While this limited field study has suggested that the new cutting edge appears more effective than a regular cutting edge, only field use will determine if this is really the case. Accordingly, a study could be envisaged in which two trucks in a given District are equipped with appropriate measuring devices, one with the new blade and one with a more standard blade. They would be deployed in appropriate weather (with suitably trained personnel) and real comparisons between the two cutting edges could be made. Now that forces have been measured successfully on one truck, the application of similar measuring devices to other trucks is much simpler, and more easily accomplished.

ACKNOWLEDGMENTS

This study was made possible by funding from the Iowa Department of Transportation, Project Number HR 334. This support is gratefully acknowledged. The support of the Acting Director of the Iowa Institute of Hydraulic Research, Dr. Robert Ettema, enabled this study to proceed. The shop staff at IIHR led by Mr. Jim Goss made these experiments possible with their insight and assistance. Experiments were assisted by Dr. Larry Weber and Mr. Mike Pokorny. Thanks are extended to all these people.

The truck used in the field testing was provided by the Iowa Department of Transportation. The assistance and advice of Mr. Lee Smithson throughout the project have added significantly to the benefits obtained from this study. Permission to use the test site at the Coralville Reservoir was given by the US Army Corps of Engineers. The support and assistance of Mr. Smithson, and both organizations, are gratefully acknowledged.

REFERENCES

1. Nixon, W. A., "Improved Cutting Edges for Ice Removal," *Strategic Highway Research Program Report*

No. SHRP-H-346, Strategic Highway Research Program, National Research Council, Washington, D.C., 1993.

2. Nixon, W. A., T. R. Frisbie, and C.H. Chung, "Field Testing of New Cutting Edges for Ice Removal from Pavements," *Transportation Research Record 1387*, Transportation Research Board, National Research Council, Washington, D.C., pp. 138-143.

3. Nixon, W. A., and T. R. Frisbie (1993). "Field Measurements of Plow Loads during Ice Removal Operations," *IIHR Report No. 365*, Iowa Institute of Hydraulic Research, University of Iowa, Iowa City, IA 52242-1585.

SECTION V HUMAN RESOURCE MANAGEMENT

EQUIPMENT OPERATOR AND MECHANIC TRAINING PROGRAMS

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ABSTRACT

The Pennsylvania Department of Transportation (PennDOT) has training programs for equipment operators and for mechanics. The following is a brief description of the basic characteristics of these programs.

EQUIPMENT OPERATOR

The goal of the Operator Training Program is to assure:

- Efficient operation of the equipment for the purpose intended;
- Extend vehicle service life and value;
- Reduce the frequency and severity of accidents;
- Lower operating cost of the equipment; and
- Instill pride and professionalism in equipment operators.

The program is guided by a committee of rank-and-file and management employees. The committee is tasked with developing policies and procedures for executive approval and to function as a sounding board for new training initiatives.

The focal points of the Department's operator training program are its three regional training sites. Three to four hundred students can be trained per year at these sites. Training and certification on dump trucks, loaders, graders, backhoes, and excavators have been identified as "CORE" equipment. These are (1) essential to many maintenance operations, (2) are costly and complex in nature, and (3) require extensive training for proficiency and safety awareness. As such, the training on these equipment is highly structured, demanding and must be completed at a regional training facility.

The total staff for these three sites are three site administrators and 12 operator instructors. Equipment inventory includes 13 dump trucks, nine front-end loaders, two hydraulic truck mounted excavators, five backhoes and four graders.

All training and certification on non"CORE" units, i.e., rollers, oil distributors, stone chippers, etc., also require a structured program and are taught at a field operation within each District. To help consistency, a Department publication of standard course curriculum and lesson plans are used to guide field operators.

MECHANIC TRAINING PROGRAM

PennDOT employs 500 mechanics per year. The turnover rate is approximately 5% or 25 new mechanics per year. To train mechanics, the Department uses Original Equipment Manufacturer training courses required in new equipment specifications, conducts local courses using selected Department mechanics as instructors and operates a centralized three week training program for all new mechanics.

The formalized new mechanic training is conducted by Department mechanics trained as instructors. This course is offered quarterly and is three weeks in length. New mechanics are required to attend the course and pass a hands-on and written test within their 6-month probationary period. The program was started in January of 1992 and has to date trained 106 mechanics.

RESULTS IN GOVERNMENT WITH PERFORMANCE MEASUREMENT

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Oregon Department of Transportation

ABSTRACT

A pilot project was developed in July 1989 to implement Performance Measurement (PM) at the Oregon Department of Transportation (ODOT). This program quantifies measures of efficiency and effectiveness for management teams and work teams, and the Department as a whole, and equates this data on a common scale. PM represents a change in philosophy. Rather than monitoring individual activities, the program focuses on results. Key factors in the accomplishment of results are tracked and the outcomes are communicated on a regular basis. Efficiency measures gauge the volume of production and the cost while effectiveness measures track quality and customer satisfaction. This new focus has seen increasing success as the 27 ODOT Highway Division work crews (7 percent of the total work force) participating in the pilot steadily improved productivity, culminating in savings of more than $3.5 million. The success of the pilot has lead to not only full implementation of the program at ODOT, but caught the eye of Oregon's Department of Administrative Services who mandated the program for all state agencies. PM has become a requirement for federal agencies with President Clinton signing legislation in 1993.

HISTORY

State government in Oregon has evolved over the past century by adding commissions, boards, agencies and, in turn, program upon program for what seemed important reasons at the time. Those reasons can become lost over time, needs disappear, and yet activities and costs of programs often remain. Without a mechanism for ongoing evaluation, this can build inefficiencies along with a lack of effectiveness and accountability due to the absence of a clear mission, purpose and focus.

The Oregon Department of Transportation (ODOT) had no readily visible signs of this malaise, yet in reality, did suffer from some of these symptoms. In 1988, the new State Highway Engineer, Don Forbes, asked questions that did not always have answers at the time. He asked such things as: how much does it cost to maintain the average lane mile; how accurate are construction contract estimates; does the transportation planning process lead to accomplishment of Department goals; and what is the public's perception of the Department? The search began for a method to provide answers to these questions, and more, and to quantify the efficiency and effectiveness of the ODOT.

The method for answers was found in a program developed at the Oregon State University Productivity Center by James L. Riggs and Glenn Felix. The program, called Performance Measurement (PM), establishes measures of efficiency (cost or volume of output) versus effectiveness (quality of output and customer satisfaction). The purpose is to improve performance by providing a tool to quantify and express results. It also provides data on which to base decisions to optimize efficiency and effectiveness.

With the strong support of Don Forbes, now the ODOT Director, PM is currently in full use throughout ODOT. To date, measures exist throughout the organization, for all branches and for all major operations. In the program areas of transportation project development, construction and maintenance, measures exist at all team levels (top-level, mid-level and front-line). For support functions, measures exist at all top-levels, most mid-levels and some front-line. An internally developed performance measurement information system is in place to generate reports for upper level teams. Work is currently underway to expand system availability to all teams in ODOT.

WHY MEASURE PERFORMANCE?

A well-managed organization, be it public or private, needs to have clear purpose, goals and objectives, base decisions upon data, provide regular feedback and have some form of recognition for above-the-norm performance. The general state of our nation's economy suggests that many U.S. companies do not enjoy this type of management even under the powerful motivation of profits. Government agencies, too, suffer a similar lack. Initiatives for a tax overhaul suggest the public have lost confidence in government to operate efficiently and effectively. Over the decades, as layers of programs build up, a governmental organization can lose its focus without a regular, data-driven evaluative process in place. PM provides that evaluative process for the ODOT.

PM clarifies the overall mission of ODOT and the purpose of its branches, sections and units. It provides direction by presenting data against a backdrop of historical averages and historical bests or goals. Presented in a matrix, seemingly disparate information can be converted to a common scale allowing evaluation of the interaction between efficiency and effectiveness. This enables managers and staff alike to base decisions upon data and to evaluate strategies for improvements to achieve the optimum balance between improved efficiency and effectiveness. This feedback is provided on a regular basis to help managers manage better at the program level and to show to those involved what is going well and what needs more attention. Because the focus is on programs and work teams, not individuals, teamwork is improved at all staff levels. The simple act of performance measurement alone usually prompts improvements since what is measured is what will surely get done.

KEY ELEMENTS OF PERFORMANCE MEASUREMENT

Results Versus Activities

Results are the points at which products or services are delivered; activities are the actions that lead to delivery of products or services. In the past, most forms of measurement at ODOT placed greater emphasis on forecasting and tracking activities - work load measurement. ODOT now places emphasis on results. Activity-based measurement reinforces the accomplishment of only activities; results-based measurement reinforces the accomplishment of results.

Group-Based Versus Individual Measures

A key part of the process to develop performance measures is the involvement of the work team. Work teams are taught the notion of PM and then facilitated in development of measures for their unit. Often, the individual members of the teams have had minimal awareness of all functions of the team so the discussion fosters a better awareness of the work team's priorities. Managers have reported improved work team cohesiveness following such discussion. Measuring the performance of individuals can be divisive whereas measuring group-based results causes the members of the group to work better together to produce better results.

Performance Versus Work Load Measures

Where work load measures capture just the number of activities, performance measures gauge results. When only activities are counted, desired results may not be produced because the focus is limited to the activities. This limited focus does not provide an environment to culture improvement strategies where measurement of results does provide such an environment. As improvement strategies surface, they can be evaluated via the performance matrix.

Work Group Versus Individual Developed Measures

The process of implementing PM begins with a management team that develops an appropriate set of measures for that level in the organization. Then work teams within that part of the organization develop performance measures based upon their intimate knowledge of what they do and what they believe to be important. This ensures more accurate measures because no one knows more about what is being done than the people who are doing the work. A review process enables work team members at various organizational levels to understand what is being measured and why it is important. This becomes two-way communication allowing important ideas to roll "up" and "down" through the organization.

Efficiency and Effectiveness Versus Amount Done Measures

PM looks at both efficiency and effectiveness. Efficiency means doing the right things with the best use of resources. Effectiveness means doing the right things well and customer satisfaction with the product and/or service.

This program tailors measurement of quality to the product, service and customer because quality holds different meanings for different people. For example, timeliness, accuracy and availability of services equal quality for the driver and vehicle licensing functions of ODOT. Pavement condition and bridge sufficiency ratings are measures of effectiveness for not only highway maintenance, construction and design, but also the department as a whole. Bridge design teams measure efficiency in their design cost by square foot balanced by their effectiveness in terms of construction cost per square foot along with other success criteria. This ensures efficiency in one program area does not come at a negative cost for another program area.

Credibility in State Government Versus Distrust of the Unknown

ODOT's goals, and those of other government agencies, and information about how well they are being achieved can be conveyed to the public via PM. State government budgets will now be based upon program performance and more effectively presented to the legislature because program cost (efficiency) and effectiveness must be demonstrated. This can also create a new role for government that has not habitually played a proactive role in communicating exactly what it is trying to accomplish, the real cost of the accomplishment and the quality of the accomplishment.

The Visual Element

The performance matrix, a complex-appearing document, is actually how PM keeps things simple. Once understood, the performance matrix will show at a glance if an entire organization's performance in key areas is improving or declining.

THE PERFORMANCE MATRIX

The matrix is not as complex as it initially appears. In fact, it can be understood in less than 30 minutes.

In the sample matrix in Figure 1:

- Row A identifies *Emphasis Areas* of efficiency and effectiveness. Efficiency measures monitor production volume and cost. Effectiveness measures record the quality of products and/or services such as timeliness, accuracy and conformance to standards. A mandatory effectiveness measure is customer satisfaction which is the customers' perception of products and services provided. Safety and work life quality are two more areas that could and should be included.
- Row B identifies more specific *Key Measures* of performance important to the organization in each emphasis area. In the first column of Figure 1, the key measure is Transactions Per FTE (Full-Time Equivalency).
- Row C contains the *Actual Results* achieved over the reporting period for each measure. In this sample matrix, the actual average Transactions Per FTE was 130.
- Row D shows the *Potential* results targeted to be achieved; in other words, a goal for each measure. Potential is based upon either a historical best or an absolute goal such as 100% customer satisfaction or zero errors. The "10" is the level achieved when the goal is reached. In the example, the potential for Transactions Per FTE is 200.
- Row E lists *Baseline* results or average, standard or regularly expected performance based upon historical averages. The "0" is the level achieved when average results are achieved. In this illustration, baseline for Transactions Per FTE is 100. Because neither exactly average nor potential results are always achieved, a range of performance is also identified. Since performance, when measured, is more likely to be above average than below, ODOT's format contains ten levels above the baseline and only five below. The range between each level is determined by dividing the difference between baseline data and potential by ten. For Transactions Per FTE, 200 (potential) minus 100 (baseline) divided by 10 equals a range of 10 per level. This range is taken in the opposite direction for the negative levels.
- Row F is where the *Level Achieved* based upon the actual results is shown. These levels are the common scale that can compare the interrelationships between measures that would otherwise be incomparable. The level achieved is reflected here because it is multiplied by the relative weight shown in Row G.
- *Relative Weight* in Row G is a method of weighting or ranking the key performance measures. By convention, all the relative weights in a matrix total 100. The assignment of relative weights is determined by the work groups once their measures have been developed. This process is somewhat arbitrary, but the measure of greatest importance is the measure with the greatest relative weight. Conversely, the measure with the lowest relative weight is the measure of lowest importance. In Figure 1, the labor efficiency measure, Transactions per FTE, has the greatest weight so it is of highest importance. The measure with the least weight and of lowest importance is a work force measure, Safety.
- Row H shows the *Earned Value* of each measure which is the result of multiplying the level achieved in each measure by its relative weight. For example, level three was achieved in the Transactions Per FTE measure in Figure 1 which has a relative weight of 25 thus providing an earned value of 75.
- The *Performance Index* at the bottom of the matrix is the sum of the earned values for all measures contained in the matrix. This one number shows overall

A	Emphasis Areas		EFFICIENCY		EFFECTIVENESS				
			LABOR	COST	QUALITY		PERCEPTION	WORK FORCE	
B	Key Measures of Performance		Transactions Per FTE	Cost Per Transaction	Percent Delivered On Time	Percent Of Work Corrected	Percent Satisfied Customers	Work Life Quality Index	Safety
C	Actual Results		130	$2.30	90%	12%	80%	−10	0.11
D	Potential	10	200	$1.70	100%	0%	100%	100	0
		9	190	$1.75	98%	1%	98%	90	0.01
		8	180	$1.80	96%	2%	96%	80	0.02
		7	170	$1.85	94%	3%	94%	70	0.03
		6	160	$1.90	92%	4%	92%	60	0.04
		5	150	$1.95	90%	5%	90%	50	0.05
		4	140	$2.00	88%	6%	88%	40	0.06
		3	130	$2.05	86%	7%	86%	30	0.07
		2	120	$2.10	84%	8%	84%	20	0.08
		1	110	$2.15	82%	9%	82%	10	0.09
E	Baseline	0	100	$2.20	80%	10%	80%	0	0.1
		−1	90	$2.25	78%	11%	78%	−10	0.11
		−2	80	$2.30	76%	12%	76%	−20	0.12
		−3	70	$2.35	74%	13%	74%	−30	0.13
		−4	60	$2.40	72%	14%	72%	−40	0.14
		−5	50	$2.45	70%	15%	70%	−50	0.15
F	Level Achieved		3	−2	5	−2	0	−1	−1
G	Relative Weight		25	15	15	10	20	10	5
H	Earned Value		75	−30	75	−20	0	−10	−5

Performance Index: 85

FIGURE 1 Performance matrix.

how well an organization or work group satisfied their priorities. A total of zero means that the performance overall was average. A positive number means some degree of overall above average performance. A negative number means some degree of overall below average work. Because the relative weights must total 100, achieving the maximum or goal potential in all measures would equal a performance index of 1000; achieving level -5 in all measures would equal a performance index of -500, thus giving some relativity to the positive or negative degree of overall performance. A performance index of 85 in the sample matrix indicates slightly above average effort.

Various levels of achievement attained in each of the key measures contribute to an overall indicator. These measures can be evaluated individually to determine if performance was below average in any specific area. When performance is below average in more than one area, the relative weights and the earned values can be examined to focus improvement strategies. In Figure 1, equal negative levels were achieved in two measures, Cost per Transaction and Percent of Work Corrected. Cost per Transaction would be the area of highest priority to improve due to its higher relative weight and greater negative earned value.

Analysis of the matrix in Figure 1 reveals a work force working at a high production rate to deliver increased products/services with a greater percentage on-time. The negative side is a tired staff making more errors and working less safe. Increased timeliness counterbalanced by decreased accuracy could account for average customer satisfaction. One improvement strategy could be to reduce production and timeliness just enough to increase accuracy. Another strategy might be to add staff that could reduce production per FTE, but could increase accuracy, timeliness and customer satisfaction. A third strategy could be to evaluate processes to increase production, timeliness, accuracy, etc. The matrix would show which strategy produced optimum results.

THE PROCESS OF IMPLEMENTATION

Implementation begins with a steering committee consisting of *all* senior managers ideally or, at a minimum, the agency head, the budget officer, information services manager, personnel manager and a performance coordinator. This group is taught the concept of PM before going on to develop guidelines and performance measures that are very broad in scope.

The mid-level management team participates in the same workshops as PM progresses to the next level in the agency. This group develops measures that are still broad in scope, yet specific to that level in the agency while conforming to the guidelines and measures developed by the steering committee.

The measures continue to get more specific as work teams learn about PM. Through workshops, they go on to develop their measures within the steering committee's guidelines.

At each level, the team decides what is important to measure within agency guidelines. This hierarchal approach allows data from all over the agency to feed into agency-level performance measures. For example, one Motor Vehicles Division quality measure tracks timeliness. This is a measure of the percentage of transactions meeting service levels in twelve different service areas. The work teams then develop a measure to track the timeliness of the specific service offered by the team.

RESULTS OF PERFORMANCE MEASUREMENT

The initial pilot of PM aligned measures with financial incentives. This pilot involved 27 work teams which amounted to 7 percent of the total department work force. At the end of the two-year pilot period, savings/cost avoidance through improved efficiency by the teams totaled more than $3.5 million.

These teams accomplished this by working smarter and using their performance measures to evaluate new processes. One construction crew doubled the distance between labor intensive "hubs" or grade markers. They reduced the labor to install hubs by 50 percent and found through their performance measures that quality remained the same.

A transportation permit crew was anticipating twice the work load due to new requirements so they doubled their staff. They were surprised to find through their performance measures that this actually reduced their output. This crew reevaluated and redesigned their processes, reduced their staff back to the original number and found they doubled their output. Using the evaluative tool the measures provide, the permit crew found a way to handle double the work load without increasing staff.

The results orientation, the savings generated and the above examples of success are among the primary reasons ODOT proceeded with full implementation of PM. However, the pilot also revealed some potential pitfalls to avoid.

LESSONS LEARNED

During the pilot phase of PM, it was determined that the program could beneficially affect results. Beyond seeing improved performance, four key lessons were learned to carry out the program department-wide better.

- An automated reporting process must be in place before agency-wide implementation begins. Without automation, data gathering can become extremely labor intensive making it difficult to produce timely reports. Once the measures have been developed and data gathering has begun, work groups are anxious to receive regular feedback. Confidence in the program and its benefits can be lost if this part of the program is not done.
- Union representatives must be involved at every step of both a pilot and full implementation to learn the concept, the process, the reasoning behind steering committee guidelines and, above all, to realize performance measures are based upon results produced by a group and are not individually focused.
- A communication and decision making process must precede agency-wide implementation. The steering committee must decide such things as the level of the

agency responsible for review of the measures, baselines and potentials; the frequency of review; the criteria to be used to determine baselines, etc.

- All levels of management must be actively involved in the PM process and kept informed. In addition, senior management must understand, support, champion and promote the program.

ODOT has been quick to incorporate these improvements into the program to streamline implementation as it continues through the agency.

CONCLUSION

As of July 1992, 27 pilot work groups, amounting to 7 percent of the work force or 350 FTE, saved ODOT more than $3.5 million through improved efficiency and effectiveness. In addition, if success can be measured by what others imitate, PM at ODOT can be considered a resounding success. What began as a pilot program within ODOT, has become a full scale initiative throughout state government in Oregon. The Department of Administrative Services, overseer of state government in Oregon, recognized the value of the PM program and mandated it for all state agencies. ODOT aided in the success of this initiative by teaching representatives from more than 115 state agencies the program concept and implementation. ODOT expertise helped countless agency management teams with development of performance measures.

Oregon state government introduced performance measures to budget documents and the legislature in 1992 & 1993. This was done to build a foundation for a new and consistent platform for state program budget discussions. Agencies will be required to show program efficiency and effectiveness in the coming budget and legislative cycle in 1994 & 1995. This will enable funding decisions, in a time of significant budget shortfall, to be based on data.

In August of 1993, President Clinton signed legislation requiring implementation of performance measures in the federal arena over a ten year period. Oregon and ODOT have been contacted for information and assistance by many state and federal agencies.

Oregon was awarded the "E for Effort Award" by *Financial World* magazine as a result of the magazine's annual evaluation of state government. The award is given to honor a state that has taken a leadership role in dealing with present issues facing state government. In the annual rankings by *Financial World*, Oregon has moved from 34th in 1990 to 17th in 1991 to 6th in 1992. The state's "trailblazing work in performance measurements" was the primary reason cited by the magazine for Oregon's movement into the top 10. At last report, Oregon remains in the top ten. Because government is so new to PM, a *Financial World* speaker at a conference on this topic in 1993 used an early childhood development analogy to compare states. He said that none were walking with confidence or running, but many were learning to crawl. Only one was beyond the crawling stage to the toddler stage (walking with some unsteadiness) - that state is Oregon.

ODOT will soon begin to see all efforts in PM come to department-wide fruition. January 1995 is the anticipated completion date for all teams at all levels in the organization to have performance measures in place. Don Forbes, ODOT Director, expects branch managers to begin using performance measures to manage their branches beginning in July 1994 and will make this part of manager performance plans. Some managers have already taken this a step further. One branch manager uses performance measures as one of the short list of criteria upon which his mid-level managers are evaluated. Another mid-level manager meets monthly with his unit supervisors as a group to evaluate the latest results of their unit measures.

Here in Oregon and especially here at ODOT, we want to change the culture of government. We want to focus on results. We want to test our ability to influence things that are seemingly beyond our control. For example, something like safety on our transportation system is subject to many external influences. Yet ODOT can manage for optimum results if we look for system designs and safety programs that produce cost-effective results. We look forward to improved management of transportation programs via Performance Measurement.

REFERENCE

G. Felix, *Performance Measurement in Oregon State Government, Using the Productivity Matrix,* Special Edition for Oregon State-Government Operations, The Howard Publishing Company, Tualatin, OR, 1991.

MAINTENANCE TECHNICIAN TRAINING: AN INVESTMENT IN THE FUTURE

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ABSTRACT

Over the years technology has changed to the point that employees can no longer learn their job through observation. Technological change is occurring so fast that the technician cannot advance in proficiency by using the outmoded methods of "watch me and learn." People, and the skills they posses, are the greatest and most expensive assets an organization has. Managing these assets involves not only managing a very costly asset for today, but also managing the future of the organization.

This paper provides information on the importance of needs-driven training of maintenance technicians; the opportunities for cost-free training from manufacturers; the importance of continuous review of all training; the growing importance of contract management; and the vital role of Preventive Maintenance.

NEEDS-DRIVEN TRAINING

Under the Continuous Improvement, Decentralization, Empowerment concepts of management being utilized today, it seems apparent that the individual supervisor should make all arrangements for training of personnel. That sounds good in theory, but training is one of those things that must be consolidated for cost effectiveness. How does one overcome this dilemma? The answer is through a cooperative effort between the training specialist and the supervisor. The concept is for the training specialist to ask of the supervisor what training is needed, then consolidate these needs and provide the training.

This is sometimes easy to say, but very difficult to implement. It seems that the domain of the supervisor has always included "training" for the subordinates, and this is not something the supervisor cares to turn over to an outsider. This can be overcome if a comprehensive training needs survey technique is developed with full cooperation and input from all supervisors involved. Another technique to secure the support of the supervisors is to solicit their involvement during course development. The supervisor can then see that the course will meet the needs of the personnel, and not be just another waste of time and resources. The training specialist should also encourage the supervisor to include the training needs on the subordinate's performance evaluation plan so that both know and understand the need for training.

TxDOT has addressed this problem by developing a training catalog that gives the supervisor (and the prospective trainee) a comprehensive description of each available course. The catalog and a training needs survey are sent out to all supervisors once each year. The training suggested by the supervisor on this survey is then consolidated, purchased or arranged through an in-house program. The allocations for training are then returned to the supervisor. Theoretically everyone needing training would receive a reservation for the needed course. The reality of budget constraints prevents a 100% training rate, but the Department does manage to secure enough funds to meet approximately 90% of the stated training needs. This is also a way to see that training is funded. One problem is that if no clear need for training is proven, then the money to conduct training is hard to justify in the budget.

Several attributes of this program contribute to its success. One is that the supervisor knows that the training is driven by stated needs, not by the ambitions of the training specialist. The training becomes an internalized objective of both the supervisor and trainee, and much more reasonable to all concerned. As stated above, allowing the supervisor to have an active role in the development of the training also helps to internalize the training objectives. TxDOT surveys each supervisor who will be using the course for a list of topics that should be covered in the prospective course. Another reason for the program's success is that whenever training is needs-driven, the training dollar is wisely spent to provide just the training needed, and the supervisor gets more training accomplished with fewer work hours lost. The only thing worse than having a person in a class who should not be there is to be tasked with encouraging an unwilling student's learning.

Another positive aspect of needs-driven training is that it can be projected into the future for several years. The ability to foresee the need for training should be an item on all supervisors' evaluations. If it is, then the need survey will be much more reliable. With a more reliable need survey the budgeting process becomes much easier. Objectives are clear and concise, and the need for training dollars can be justified. Training can be budgeted instead of managed by "crises." Upper management can be challenged with the decision to budget the dollars needed for the training or be responsible for a correlated reduction in training.

Needs-driven training will also allow the maintenance or equipment supervisor to request training when new equipment is purchased. This can be done in one of two ways. The supervisor would normally request new equipment long before it is received. The supervisor can add the new piece of equipment to the annual need survey and begin the wheels turning to get the classes established before the new equipment is received. In this way, training can be provided at the optimum time rather than waiting until the equipment is received to request training.

The second procedure is to include training by the manufacturer in the cost of the equipment. This is not an easy solution, because this procedure requires exact wording on the purchase bid/order to insure that the training purchased meets training needs and not the desires of the manufacturer. This procedure will also require close monitoring of the contract for a longer period to insure that the training is delivered and that it meets the needs. This will increase the initial cost of the equipment purchase but will pay large dividends in the future. Better maintenance on the equipment from the start means a longer life with less down time and thus meeting roadway maintenance obligations with fewer pieces of equipment. Another point to ponder is that the TxDOT has a reputation for selling old equipment at auctions at a price higher than industry average because of our outstanding maintenance of the equipment over its lifetime. This reputation begins with getting effective training from the manufacturer at the time of delivery.

TRAINING FROM MANUFACTURERS

Technology waits for no person, particularly vehicle service technicians! With some $465 million worth of equipment in TxDOT, there is a challenge to "keep 'em rollin'." The key to good equipment use is for the equipment to be always ready for use and in top operating condition. It matters not if it is a four-door sedan or a tracked loader, when it is needed it must be ready.

TxDOT spends approximately $1.5 million each year on training for maintenance technicians, but this is not enough. The problem is that as the technicians are returning from training, they notice that a new piece of equipment is being delivered that they know nothing about. Development time is needed for the trainers to produce a course on the latest innovations on a piece of equipment. That delay can be costly. Therefore, TxDOT keeps up with the technology by involving the manufacturer! After initial contact with the manufacturer of equipment, do not be too discouraged if they do not rush out and train all of the mechanics the next day. Remember that the makers of this equipment are in business to make a profit and will normally want to weigh the "profit" results of training the technicians. Perseverance overcomes discouragement. Continue to seek their help.

TxDOT is classified as a "Fleet" customer. This status takes second place to the dealer simply because the dealer sells vehicles for a profit. However, there are many seats still available after the dealers have trained their technicians. An explanation to mechanics might be in order here, informing them that their training might not be confirmed until near the date of training. Preparing them for this well in advance has aided in keeping a very positive attitude among the technicians attending this training. Explain that although on a "standby" list, they will be receiving the best possible training which will cover the latest up-to-the-moment technologies.

Here are some tips that might help when dealing with manufacturers. First, find the sales representative in the region for each major manufacturer, for example, Ford, General Motors, Cat, Gradall, John Deer. Talk to these individuals about getting mechanics into their training programs and explain how it will help the performance of their equipment over time. Always play up the fact that the agency has millions of dollars worth of their equipment, and play down the fact that you want the training free. Mention things like, "you do not mind being kept on a waiting list if you get your technicians trained." Ask about their traveling technicians and could they to teach in your facilities?

An example of this training is the training TxDOT got from Gradall. When the company sales representative was told of the electrical and hydraulic problems with the new G3WD Gradalls, he suggested that the problem might be with the mechanics and not their equipment. TxDOT then offered to help by scheduling training based on the availability of their instructor, and that the Department would provide all facilities and equipment needed. He suggested that the operators and mechanics be paired so that the operator could tell the mechanic what to look for, and the mechanic would know how to solve the problem. A poll found that approximately 150 mechanics and operators wanted training on the maintenance of the Gradall. Using the location of the mechanics and the suggested class size, the class dates and locations were arranged. In three months, Gradall trained approximately 150 mechanics and operators on troubleshooting and maintenance of the G3WD at no direct cost to TxDOT. Results of this effort are that the downtime for Gradalls in nearly every region of the state were reduced substantially.

TxDOT currently receives free training from Ford and General Motors. Ford provides a class schedule for their mechanics, technical and truck training. General Motors provides schedules for all of their training conducted in Texas. General Motors modified their teaching schedule to allow for two classes for Department personnel in June 1994. This was an opportunity for 24 mechanics to receive a week long course at no cost to the Department. Hopefully, Ford and Chrysler can be persuaded to follow the lead of General Motors.

The Department is currently undergoing a conversion to alternative fuels vehicles. The State Railroad Commission has completed training (free) for all of TxDOT's shop mechanics and supervisors. The Department is currently working with suppliers of Propane and Compressed Natural Gas (CNG) to help train all of the mechanics on the maintenance of the converted vehicles once the warranty on the conversion expires. This is a mutual effort between the TxDOT and suppliers, and is at no cost to the Department. The conversion of vehicles was mandated by the Texas Legislature several years ago, directing that all state vehicles be converted to fuels other than gasoline by the year 2000.

CONTINUOUS REVIEW OF ALL TRAINING

Just as a person's technical skills become obsolete at an ever increasing speed, the training needed to prepare the technician for the job at hand has a sharp obsolescence curve itself. One thing worse than no training is training that fails to meet the objective for which it was established. For obsolete or outdated training, an organization spends money and time with no positive results. For these reasons, it is imperative that all training is reviewed on a continuous basis to insure that not only is it up to date, but also to guarantee that the training is meeting the goals and objectives established initially.

Who should review the training to insure its appropriateness? Good question. One approach is to leave it to the training technician in personnel with the expertise. This will never work because the training technician cannot stay current on the technical aspects of all jobs any better that the technician can stay current without assistance. Building a review procedure into all training at the time of its creation is best. This review should consist of at least three individuals: the technician, the technician's immediate supervisor, and the training technician.

The ideas from the trainees should come in the form of an end-of-course critiques. Each student should complete a critique stating whether the class met their needs. Even more critical than the critique is a review of the critiques. So many organizations have end-of-course critiques to make the program "look good," but no one ever reads the critiques. A close review of a well-written critique can tell a lot about the appropriateness of the training in the course. However, one word of warning may be in order here. If the organization has an authoritarian atmosphere, the responses may have to be kept anonymous to get a true indication of training effectiveness.

The second person who should be involved with the review of the training is the supervisor. A well-liked instructor, a pleasant class, and a good time by all does not necessarily mean that the technician's performance on the job changed after attending the class. All training should be evaluated by the change in behavior of the student, and the supervisor can observe this. Also, the supervisor knows of new equipment or technological advancements that may be coming in the future. As mentioned above, input from the technician is valuable but at times the worker does not know of pending job assignments and upcoming equipment changes. Another important benefit to involving the immediate supervisor in the development and evaluation of training is the feel that a part of the training is the supervisor's brainchild.

The training technician's job as part of this review committee is to see that the basic principles of adult education are followed always. Sometimes the supervisor knows that the course could be improved, but is not confident in all the "educational stuff" and therefore may vote for leaving the course alone. The supervisor shouldn't be blamed for these feelings, for this is the job of the training specialist. Determining correctly stated objectives and proper methods of evaluation should be left up to the instructor and training technician. The invaluable technical input from the supervisor should never be endangered by insisting that the supervisor go beyond his expected skills in developing or evaluation training.

The frequency of review for a course should be determined by the technological advancements in a field, not by the calendar. If all training is reviewed one every two years, this may have been a good approach in the past, but it should be changed. Some technicians' skills may remain current for two years, while others may need annual training to stay current. Look at every person's qualifications and determine the frequency necessary for review. An entry on the student course critique asking if anything should be added to the course will be of assistance. Often the technician will know of new technologies, new equipment, or new procedures before anyone else.

As mentioned under needs-driven training, a technician who feels that performance on the job is hindered by the lack of new skills or technologies will be a source of valuable information. This will apply to the review of training and the initial development. Subtle clues may appear during performance evaluations when the technician makes statements like "Boss, I can't seem to keep up with the changes in the equipment. There is always something new that I haven't heard." Or maybe a statement like "Back in the old days, we did not have this problem because the procedures were so much simpler. I just can't keep up with the new procedures outlined in the operator's manual." Listen for these types of comment. They are good pointers for telling that it may be time to review the available training courses.

CONTRACT MANAGEMENT

It is often easier to do something yourself than to see that someone else does the task, and does it correctly. This feeling has been around since the beginning of time. Yes, sometimes it is true. It takes more effort to insure that someone else does a job and does it correctly than if done by you. However, it is not always possible to "do it yourself." The legislature in Texas has been encouraging State agencies to do more routine work by contract rather than doing the job with State forces. Politically, this is a good move. The feasibility of this shift is not a topic for evaluation here, but it does change the role of the maintenance technician drastically.

Once the routine work once done by the technician is contracted to a private enterprise, the maintenance technician must monitor compliance with the contract in place of doing the task. There is a whale of a difference between monitoring the performance of a contract and doing the work. Please do not fall prey to the concept that since "ol' Joe has been mowing right-of-way for 20 years that ol' Joe can easily monitor the new contract let with XYZ Company to mow the right-of-way." This is about as logical as saying someone who enjoys a good movie would make a wonderful movie producer or director! There might be a connection between the two, but it is so slight that it is accidental.

Before tasking a technician with monitoring a contract, be sure they are prepared for this new role. This has nothing to do with the technical competence of the technician, but instead relates with the ability to get the work done through someone else, someone not even directly under the technician's control. It normally becomes more of a human relations task and less of a technical task. A mini course in contract law may be in order. What is a contract? What is nonperformance? How does one read a contract? Even more important, how does one write a contract?

The Department has found that many problems with the enforcement of a contract begin with the specifications developed for the letting of the contract. This is a place where the technical expertise of the maintenance technician can be very beneficial. However, do NOT hand the job of contract development over to the maintenance technician without assistance. This is mixing apples and oranges. Let the technician with years of experience work with someone thoroughly familiar with the development of contracts and assist in the development by lending technical input about the task to be done.

TxDOT has also developed several options for training of the technicians assigned responsibility for monitoring contract compliance. Construction inspectors will normally be more familiar with contracts and can help in the indoctrination of the maintenance technician toward contract monitoring.

The Department has an in-house training program for construction personnel where several hours are dedicated to establishing and maintaining good relations with the contractor. The maintenance technicians are encouraged to attend this class and learn more about how to enforce a contract and get along with the contractor. This has been very beneficial, surprisingly not only for the maintenance technician but also educational for the construction inspectors. It has also been an opportunity to bring the two groups closer together as a team.

TxDOT recently experienced a retirement incentive that reduced the work force by some 1000 employees, and the maintenance area was hit just as hard as anyone else. In some Districts, 60% of the supervisors in the maintenance area left. In response, the Department is in the process of cranking up a "maintenance supervisor's" training course. The development and monitoring of contracts will be a major module of instruction in this course and should be of assistance to those supervisors who have never been tasked with contract monitoring. Much of the course will be taught by senior maintenance supervisors, but this portion will probably be taught by someone with more experience in monitoring contracts.

In summary, please remember to prepare technicians for this new role as contract monitor. It is a challenge that each of them will face much more readily if they are prepared for the task. It does require a new list of human relations skills, but nothing that cannot be mastered.

PREVENTIVE MAINTENANCE

Preventive maintenance programs have come and gone. Over the years, several preventive maintenance programs have been implemented only to fade into oblivion in a short time. The Department has uncovered a revolutionary concept. Preventive maintenance must be a frame of mind, and not a "program." The concept of preventive maintenance is to prevent problems before they happen, and the first preventive maintenance is to create an atmosphere conducive to preventive maintenance before creating a preventive maintenance program.

A contract instructor called one day to complain. He seemed so frustrated that he was ready to give up and void the training contract he was fulfilling. It seems that he went into a section to teach preventive maintenance on the various pieces of equipment available in the section. He said that he had commented to the section supervisor about the students complaining to him that once they left the class they would never be allowed to use the knowledge gained in the class. The supervisor commented to the instructor that maybe he should address the class and clarify this matter with the students. The supervisor then proceeded to tell the class "You guys listen to everything this instructor has to say. It's important information about preventive maintenance. Then, I want all those trucks out of the yard in five minutes or less! Is that understood?"

TxDOT has a very effective preventive maintenance program with only a few supervisors not fully supporting. In recent years the Department experienced a budget deficiency that required a cut back on the amount of equipment purchased for about two years. The Fleet Management Section tracked the cost of maintaining the equipment during this period and yes, the cost did rise. However, it was proven that through a good preventive maintenance program the equipment can be kept operating efficiently for a longer period. It is not suggested to arbitrarily extend the expected life of equipment, but good preventive maintenance can do this.

One thing TxDOT did that helped the overall preventive maintenance program was to update the training available for our technicians. About a year ago the Department reviewed the existing preventive maintenance training courses. There were two individuals from the Human Resources Division, three maintenance supervisors from various locations across the state, three young maintenance technicians who would be attending the training, and part of the contracted instructor staff who had been teaching the courses in preventive maintenance for several years. The results of the review showed that over the years courses were developed one at a time to meet a particular need, and there were areas of overlap and duplication and some areas that weren't addressed at all. A thorough review allowed consolidation of several courses, several were eliminated, and one was created to meet the needs of the technicians better. Approximately 250 technicians will be trained before the end of this fiscal year. The results of the training conducted this year will be reviewed and the materials modified as needed for next year. As mentioned earlier, the involvement of the technicians and supervisors helps to improve the content of the course and it also helps to convince them that the training is designed to meet their specific needs. Much better support for any training program can be achieved this way.

CONCLUSION

The five topics covered will enhance a technician training program if implemented. TxDOT is not going to be able to hire the technicians needed off the streets in the not to distant future. The Department's technicians must be prepared to fill the roles of future technicians and maintain systems that haven't yet been brought to market. The best way to prepare for the future is to begin now by preparing the technicians to meet the future as it arrives. Everyone must keep in mind that we no longer live in a work-world that allows a person to become qualified and then be set for life. Technologies are changing so fast that everyone will need to learn two or three careers. This training for the future must be a never ending process. You owe it to your organization, and to the technicians that are now part of your organization to prepare for the future by preparing your technicians for their future tasks.

SELF-DIRECTED MAINTENANCE TEAMS

Sam Wilkins, Jr.
Oregon Department of Transportation

SUMMARY

There is substantial evidence that self-directed workers in "bottom-up organizations" have high productivity and morale. Most examples of organizations making a successful switch to empowering front line workers have come about due to economic necessity. Companies facing financial crises have found they can survive and prosper when layers of management are removed and workers are turned loose to do their jobs. For this to occur, the employees *must* share the organization's values, avoid scapegoating (blaming one's failure on someone else), and above all, not become silent saboteurs. Oregon state government is currently facing an economic crisis due to the passage of the tax limiting Ballot Measure 5. Oregon Department of Transportation (ODOT) with its stable funding source is the only Oregon state agency that is experimenting with self-directed crews on a large scale.

The organizational structure developed during the area maintenance manager (AMM) pilot program is a marked departure from the structure that stood in place during our preceding seventy-five years (see Figure 1). The change is basic to the new philosophy that transfers certain responsibilities and authority to where the work is getting done. In this case, it is the crew as a team. The net impact on the new structure is a reduction in first line supervisors, from 21 supervisors to seven managers. Each of the seven AMMs oversees the operation of three crews. The crew/manager relationship is significantly different. Each crew is expected to prepare a work plan covering 30 days, 60 days, or even up to a year negotiated and agreed upon with the AMM. Each AMM has one area coordinator. This position is significant and allows for "state-of-the-art" automation equipment (PCS, FAX machines, copy machines, etc.) to be provided at the crew level in manageable numbers. Also, this position handles most of the routine paperwork, and performance tracking and reporting, thus removing much of the paperwork from the crew team level.

A team training model was developed by a consultant and based on developing creative thinking and consensus decision making. Team training was top-down, beginning with the ODOT management team, followed by region management team, districts, areas and crews. Shortly after the region management team was trained, the self-direction concept was conceived. After a false start, it became apparent that an implementation plan would be required to clarify the many steps and milestones that would be necessary to convert to self-directed teams. In July 1990, the Director, Don Forbes, approved the two-year pilot program after reviewing the implementation plan. This was followed by a half-day meeting with all supervisors and managers to explain the concept and proposed change. The first formal training was a two-day awareness workshop for all employees.

A course titled, "Working Program" was started. This was a formal course consisting of four to five half-day sessions over four months to improve group communication skills. Formal team assessments were conducted for all crews to determine if they were ready to do the actual team-building. As crews were ready, team-building was scheduled. This class normally took two days. Throughout the two-year period, team-building was repeated for crews experiencing difficulties with the concept. Most of all the above training was accomplished in a six-month period.

Highway maintenance employees in ODOT are represented by the Oregon Public Employees Union (OPEU). OPEU is a statewide labor union that represents employees in approximately 50 different state agencies, and also counties, municipalities, and other local government agencies throughout the state. Labor relations between the state of Oregon and OPEU have been under some strain in recent years. The first ever statewide strike of state workers occurred in 1987. The strike was not focused exclusively on ODOT issues. In the fall of 1990, OPEU and ODOT's Region 4 signed a "Letter of Agreement" (LOA) which allowed for highway maintenance crews in central Oregon to work without "on site" supervision for a two-year period. This pilot program left the existing labor contract in place with very minor modifications. The LOA was ratified by a vote of the union members in Region 4. Although Region 4's relationship with OPEU on a local level has not been particularly troubled during the pilot program

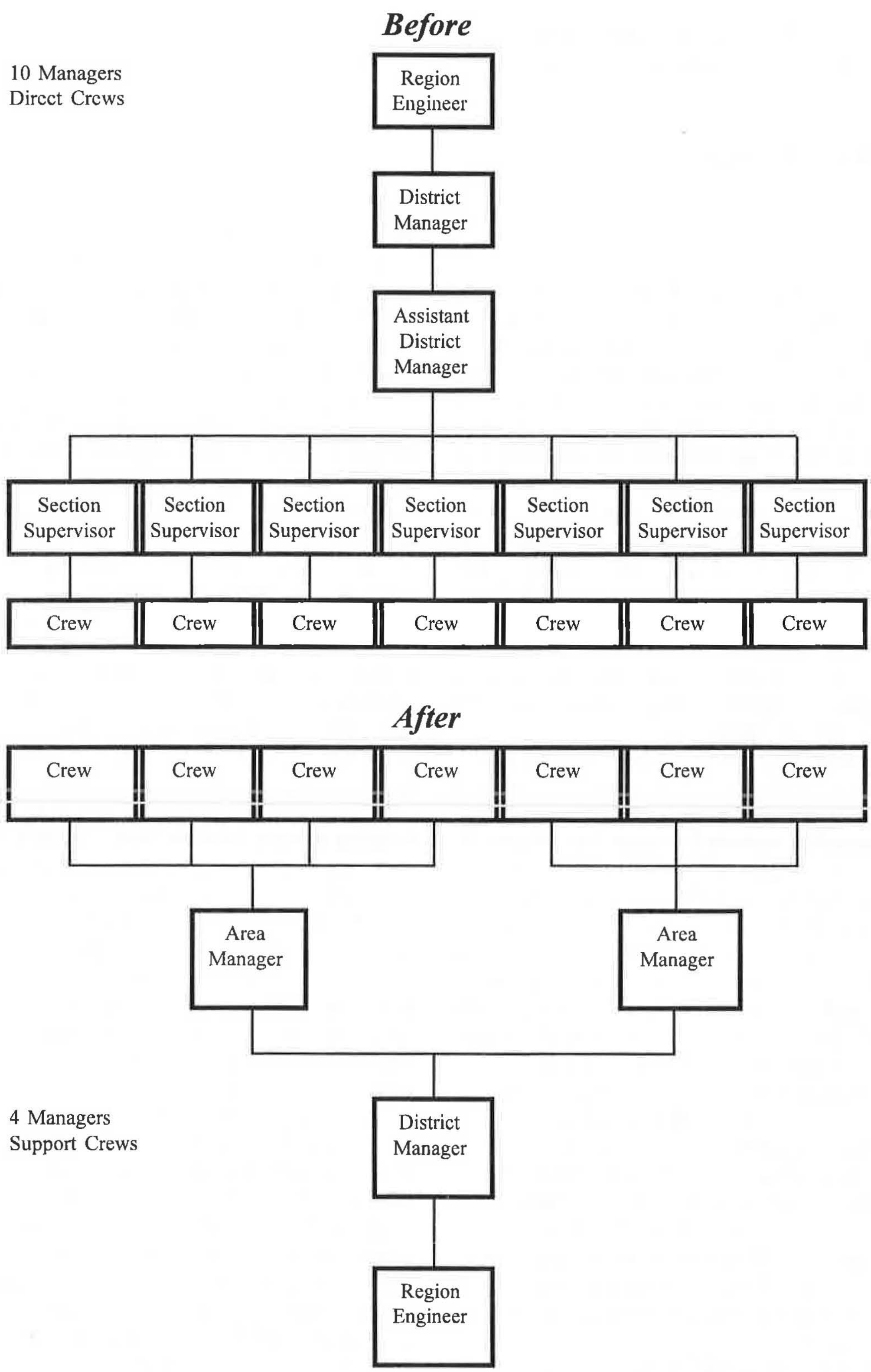

FIGURE 1 Change in organizational structure with self-directed maintenance teams.

it has not been the best possible environment in which to try to build a working relationship that is dependent on trust and cooperation.

In January 1992, sixteen months into the pilot program, the Region 4 labor/management committee asked all employees participating in the self-management pilot program to complete a survey asking for opinions on the experimental program and for suggestions on how to improve the program. Of the 200 employees working on self-managed crews, 150 individuals completed and returned the survey form. The narrative responses made coding difficult, but approximately 88% of the workers believed self-directed crews were a better way to run a highway maintenance organization than the traditional supervisor directed crews. In February 1992, ODOT and OPEU representatives agreed to extend the terms of the LOA for eight months to coincide with the normal expiration of the labor contract. It was agreed if ODOT wanted to continue the program beyond June 1993, the terms of a future agreement would have to be negotiated during the normal bargaining period that would begin in January 1993.

As an organization, OPEU has encouraged the governor, the legislature, and the management of state agencies to reduce the number of supervisors in the work force in response to the budget cuts brought on by the passage of the tax limiting Ballot Measure 5. While OPEU may not object to the basic structure of an organization that empowers its workers, the union has to be aware of the internal political implications. While workers like the autonomy the system gives them, a major problem with the program is it reduces the number of promotional opportunities for maintenance workers. To this point OPEU has been reacting to ODOT's initiatives on the pilot and has not been brought in as a decision-making partner. Labor/management committees in ODOT operate under the guidelines of Article 106 of the labor agreement and have no authority to make meaningful changes. The "meet and confer" format has not allowed ODOT and OPEU to adjust along the way.

This program is novel and innovative, and brings more value and public service to the users. It is a semi-finalist in the 1994 Innovations Awards Program sponsored by the Ford Foundation in collaboration with the Kennedy School of Government at Harvard University.

SECTION VI EQUIPMENT MANAGEMENT

CRADLE TO GRAVE TRUCK RADIO MAINTENANCE SYSTEM AS PART OF A MAINTENANCE MANAGEMENT SYSTEM

Dennis H. File and Richard W. Hunter
Illinois Department of Transportation

INTRODUCTION

Most states equip their snowplow trucks and other vehicles with two-way radios to communicate management and emergency messages. The Illinois Department of Transportation is no exception. Since the 1960's the state has equipped trucks with two-way radios. Originally, installation of the radio enabled the state to decrease the number of snowplow personnel in each truck from two to one. Since then, the mobile radio has become a required and expected management tool. It is very important for the radios to function properly and without failure especially during times of operations such as those involved with snow removal and ice control.

To ensure the radios maintain a high level of readiness, the Department subscribes to a regular maintenance program for all critical radio equipment. In Illinois, the work is performed by a contractor. The experience for the past 20 years has been very positive. However, with the advent of new management systems and decreasing work force, the need to improve the radio maintenance program became very apparent in the last few years.

BACKGROUND

The Illinois Department of Transportation has more than 1,600 single-axle and tandem-axle dump trucks in its fleet. These are radio equipped. In addition, other vehicles such as those provided for the field engineers, front-end loaders at salt stockpiles, special equipment such as vactors and lane stripers, emergency patrol vehicles, construction and other vehicles are radio equipped. These additional vehicles increase the number of radios in vehicles to approximately 4,000 under the control of the Department.

The Department has its own radio communications network consisting of low-band (47 Megahertz) throughout most of the state and a combination high band system (150 Megahertz) and UHF (450 Megahertz) for the District in the Chicago area. For the last several years, the successful bidder for the radio maintenance contract has been Motorola Communications and Electronics. Motorola contracts with or maintains several local radio maintenance shops across the state. Included in the maintenance contract are not only requirements to maintain the radios on a scheduled basis and respond to unscheduled failures; but also, to install, modify and sometimes replace units. The radio contract is administered by the Central Bureau of Operations in Springfield with a coordinator in each of the Department's nine District offices. The radios are located in a variety of vehicles throughout 108 highway maintenance team sections, several traffic operations headquarters and other bureaus. Therefore, it has been a monumental task to ensure all radios receive proper maintenance on schedule, all repairs are properly accomplished and appropriate billing made. In addition, budgeting of the maintenance contract that includes "cost plus" items and regularly scheduled items, is a very difficult task since unexpected events may trigger increased costs at any point during the fiscal year.

The Department installed a statewide Maintenance Management Information (MMI) System on July 1, 1987. The system includes a central processing cluster consisting of a VAX 6510 and two 8700's. The dedicated lines from 252 terminals in the field directly access data on the database for all users and provide data storage of entries for users at all field locations of the Department.

TRUCK MAINTENANCE

Truck repairs, fuel and oil, and preventative maintenance, have been included in the MMI System. The problems associated with maintaining an equipment fleet are very similar to those for maintaining the radio equipment. After, the Department considered the similarities, a system similar to that for trucks and off-road equipment was designed to manage the radio system. The design of the radio management system requires:

- A complete inventory of all radio equipment;
- Knowledge of the vehicle and "owner" of each radio;

MMIS445 MMIG4321 MMIR445 ILLINOIS DEPARTMENT OF TRANSPORTATION PAGE: 1
05/24/94 140234 BUREAU OF OPERATIONS
RADIO INVENTORY SUMMARY

--------SELECTION CRITERIA--------

CATEGORY LIST	MODEL YEAR LIST	MAKE LIST	MODEL LIST	ASSIGNED ORGAN.	DELIVERY YEAR	SERVICE CENTER	ON WARRANTY	CONTRACT (B/C/NONE)	DISPOSAL PENDING	SORT ORDER
801-899	ALL -	ALL	ALL	088076	ALL	ALL	ALL	Y Y Y	N	INVENTORY NUMBER

INVEN. NUMBER	ASSIGNED LOCATION	ASSIGN ORG.	CTG CODE	CATEGORY DESCRIPTION	MODEL YEAR	MAKE	MODEL	SERIAL NUMBER	MONTHLY ATTACH TO	MAINT. COST	SERV CTR.	CONT TYPE	ON WAR.
B32148	UNIT G D22061	088076	862	RADIO - MOBILE - LOW BAND	1992	MOTR	MXTRC	428ASS0003	D22061	9.80	0501	C	N
B32150	UNIT A JOHNSON	088076	862	RADIO - MOBILE - LOW BAND	1992	MOTR	MXTRC	428ASS0005	T22613	9.80	0501	C	N
BB6568	DAY LABOR	088076	853	RADIO - PORTABLE - UHF	1993	GE	GP450	9207513		.00			Y
BB6578	DAY LABOR	088076	853	RADIO - PORTABLE - UHF	1993	GE	GP450	9207560		.00			Y
BB6589	DAY LABOR	088076	853	RADIO - PORTABLE - UHF	1993	GE	GP450	9207610		.00			Y
BB6590	DAY LABOR	088076	853	RADIO - PORTABLE - UHF	1993	GE	GP450	9207609		.00			Y
BB6591	DAY LABOR	088076	853	RADIO - PORTABLE - UHF	1993	GE	GP450	9207646		.00			Y
BB6592	DAY L ABOR	088076	853	RADIO - PORTABLE - UHF	1993	GE	GP450	9207649		.00			Y
BB6600	UNIT F JONES	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL5417	T22612	.00	0501	C	Y
BB6626	UNIT F HARBIN	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3508	T22158	.00	0501	C	Y
BB6627	UNIT GOOLSEN	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3509	C08331	.00	0501	C	Y
BB6628	UNIT G FOSTER	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3510	C08314	.00	0501	C	Y
BB6629	UNIT GOBRUNETT	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3511	C08661	.00	0501	C	Y
BB6630	UNIT B SCARLET	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3512	C09178	.00	0501	C	Y
BB6631	UNIT D KRIEG	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3513	T21421	.00	0501	C	Y
BB6632	UNIT A RUDER	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3514	T22912	.00	0501	C	Y
BB6633	UNIT GOFAVRI	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3515	C09118	.00	0501	C	Y
BB6634	UNIT F MELTON	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3516	T20931	.00	0501	C	Y
BB6635	UNIT F DYER	088076	862	RADIO - MOBILE - LOW BAND	1993	MO TR	MXTR	428ATL3517	T17991	.00	0501	C	Y
BB6636	UNIT F ACHAS	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3518	T20932	.00	0501	C	Y
BB6637	UNIT F LEAMON	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3519	T20074	.00	0501	C	Y
BB6638	UNIT F JARRETT	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3520	T21603	.00	0501	C	Y
BB6639	UNIT F T21751	088076	862	RADIO - MOBILE - LOW BaND	1993	MOTR	MXTRC	428ATL3521	T21751	.00	0501	C	Y
BB6640	UNIT F T22156	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3522	T22156	.00	0501	C	Y
BB6641	UNIT F T21750	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3523	T21750	.00	0501	C	Y
BB6642	UNIT F T22157	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3524	T22157	.00	0501	C	Y
BB6643	UNIT F T20935	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3525	T20935	.00	0501	C	Y
BB6644	UNIT F ELDRIDG	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3526	T21105	.00	0501	C	Y
BB6660	UNIT F T22155	088076	862	RADIO - MOBILE - LOW BAND	1993	MOTR	MXTRC	428ATL3542	T22155	.00	0501	C	Y
D91761	UNIT A JOHNSON	088076	853	RADIO - PORTABLE - UHF	1989	MOTR	HT600	649APC3841		.00			N
D9 1762	UNT A JOHNSON	088076	853	RADIO - PORTABLE - UHF	1989	MOTR	HT600	649APC3842		.00			N
D91763	UNIT G FOSTER	088076	853	RADIO - PORTABLE - UHF	1989	MOTR	HT600	649APC3843		.00			N
D91764	UNIT G FOSTER	088076	853	RADIO - PORTABLE - UHF	1989	MOTR	HT600	649APC3844		.00			N
D91774	UNIT PL JONES	088076	862	RADIO - MOBILE - LOW BAND	1989	MOTR	SYNTR	483HNS0167	T20932	.00	0501	C	N
D91777	UNIT D MCSPARN	088076	862	RADIO - MOBILE - LOW BAND	1990	MOTR	MXTRC	428HQJ2899	T21578	9.80	0501	C	N
D91778	UNIT B HOWLETT	088076	862	RADIO - MOBILE - LOW BAND	1990	MOTR	MXTRC	428HOJ2900	T21579	9.80	0501	C	N
D91779	UNIT A WATKINS	088076	862	RADIO - MOBILE - LOW BAND	1990	MOTR	MXTRC	428HQJ2901	T21580	9.80	0501	C	N
D91780	UNIT B BRITZ	088076	862	RADIO - MOBILE - LOW BAND	1990	MOTR	MXTRC	428HQ J2902	T21581	9.80	0501	C	N
D91781	UNIT D COX	088076	862	RADIO - MOBILE - LOW BAND	1990	MOTR	MXTRC	428HQJ2903	T21582	9.80	0501	C	N
D91782	UNIT A PL	088076	862	RADIO - MOBILE - LOW BAND	1990	MOTR	MXTRC	428HQJ2904	T21583	9.80	0501	C	N
D91783	UNIT D FLETCHR	088076	862	RADIO - MOBILE - LOW BAND	1990	MOTR	MXTRC	428HQJ2905	T21584	9.80	0501	C	N
D91784	UNIT B BASLER	088076	862	RADIO - MOBILE - LOW BAND	1990	MOTR	MXTRC	428HQJ2906	T22614	9.80	0501	C	N
D91785	UNIT G SIDDENS	088076	862	RADIO - MOBILE - LOW BAND	1990	MOTR	MXTRC	428HQJ2907	T21752	9.80	0501	C	N
D91786	UNIT A ROBINSN	088076	862	RADIO - MOBILE - LOW BAND	1990	MOTR	MXTRC	428HQJ2908	T21753	9.80	0501	C	N
D91787	UNIT A VANATTA	088076	862	RADIO - MOBILE - LOW BAND	1990	MOTR	MXTRC	428HQJ2909	T21072	9.80	0501	C	N

RADIO INVENTORY COUNT: 45 SELECTED RADIOS TOTAL CONTRACT COST: 127.40

*** END OF REPORT ***

FIGURE 1 Example of inventory summary report.

- Information concerning the radio shop responsible for maintenance of each radio on inventory;
- The schedule of maintenance for each component of the radio system (base stations, mobile units, towers, etc.);
- Access for inquiry for all users;
- A preventive maintenance "warning" forecast of equipment needing attention within the next 30 to 60 days; and
- Various reports containing lists of charges, warnings and budget projections.

With these goals in mind, the Department spent approximately one year to develop, test and implement a radio management system to provide this information to all users. The system was initialized January 1, 1994 and is operational at this time.

DISCUSSION

The first step in the process was to develop a complete inventory of all radios within the Department. The

ORGANIZATION 088076 DAY LABOR

INV NO	YEAR	MAKE	MODEL	ATTACH TO				OVERDUE
CATEGORY : 862 RADIO - MOBILE - LOW BAND								
B32148	1992	MOTR	MXTRC	D22061	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 09/01/93	
B32150	1992	MOTR	MXTRC	T22613	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 09/01/93	
D91774	1989	MOTR	SYNTR	T20932	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/21/90	****
D91777	1990	MOTR	MXTRC	T21578	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/12/91	****
D91778	1990	MOTR	MXTRC	T21579	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/12/91	****
D91779	1990	MOTR	MXTRC	T21580	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/12/91	****
D91780	1990	MOTR	MXTRC	T21581	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/12/91	****
D91781	1990	MOTR	MXTRC	T21582	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/12/91	****
D91782	1990	MOTR	MXTRC	T21583	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/12/91	****
D91783	1990	MOTR	MXTRC	T21584	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/12/91	****
D91784	1990	MOTR	MXTRC	T22614	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/12/91	****
D91785	1990	MOTR	MXTRC	T21752	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/12/91	****
D91786	1990	MOTR	MXTRC	T21753	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/12/91	****
D91787	1990	MOTR	MXTRC	T21072	LAST INSPECTION	/ /	12 MONTH INSPECTION OVERDUE 06/12/91	****

*** END OF REPORT ***

FIGURE 2 Example of PM reminder report.

MMIS412 MMIG4333 MMIR448 ILLINOIS DEPARTMENT OF TRANSPORTATION PAGE: 1
05/24/94 145432 BUREAU OF OPERATIONS
EQUIPMENT WARRANTY EXPIRATION LISTING

SELECT CRITERIA: CATEGORY CODE = 862-862 ASSIGNED ORGANIZATION = 800000 DISTRICT 8 SORTED BY EXPIRATION DATE

EXPIRATION DATE	INVEN. NUMBER	MODEL YEAR	MAKE	MODEL	SERIAL NUMBER	ATTACHED TO	EXP.
862 RADIO - MOBILE - LOW BAND							
07/23/94	BB3413	1993	MOTR	MRTRC	776ATL0583	T23040	
07/26/94	BB3817	1993	MOTR	MRTRC	776ATL0578	T22901	
07/26/94	BB3816	1993	MOTR	MRTRC	776ATL0585	T22900	
07/26/94	BB3897	1993	MOTR	MXTRC	428ATL5728	T22902	
07/26/94	BB3412	1993	MOTR	MRTRC	776ATL0586	C09452	
07/26/94	BB3898	1993	MOTR	MXTRC	428ATL5722	T23030	
07/26/94	BB3903	1993	MOTR	MXTRC	428ATL5651	T23026	
07/26/94	BB3889	1993	MOTR	MXTRC	428ATL5672	T23032	
07/26/94	BB3818	1993	MOTR	MRTRC	776ATL0595	T23107	
07/29/94	BB3905	1993	MOTR	MXTRC	428ATL5655	T23031	
07/29/94	BB3821	1993	MOTR	MRTRC	776ATL0572	T23034	
07/29/94	BB3892	1993	MOTR	MXTRC	428ATL5663	T23036	
07/29/94	BB3820	1993	MOTR	MRTRC	776ATL0576	T23033	
07/29/94	BB3895	1993	MOTR	MXTRC	428ATL5682	T23035	
07/29/94	BB3891	1993	MOTR	MXTRC	428ATL5687	T23028	
07/30/94	BB3819	1993	MOTR	MRTRC	776ATL0602	T23029	
07/30/94	BB3822	1993	MOTR	MRTRC	776ATL0580	T23037	
07/30/94	BB3904	1993	MOTR	MXTRC	428ATL5659	T23027	

CATEGORY EQUIP INVENTORY COUNT: 18

TOTAL EQUIP INVENTORY COUNT: 18

*** END OF REPORT ***

FIGURE 3 Example of warranty expiration report.

MMI System contained an inventory of the radios controlled by the Bureau of Operations (formerly the Bureau of Maintenance) for the Department. Radios were under the control of the Bureaus of Administrative Services, Traffic, Project Implementation, Local Roads and others. Therefore, the first step was to include all radios in the inventory. The inventory information includes many data items necessary for normal inventory control and some required by the radio management system. The items displayed in Figure 1 are some items included in the inventory. Several are those items specifically included to support the Radio Management System.

A very important observation in the development process for the Radio Management System was the need to include the vehicle or other equipment to which it is

MMIS414 MMIG4329 MMIR447 ILLINOIS DEPARTMENT OF TRANSPORTATION PAGE: 1
05/24/94 153017 BUREAU OF OPERATIONS
RADIO IDENTIFIER AND CALL NUMBER LISTING

SELECT CRITERIA:CATEGORY CODE = 862-862 ASSIGNED ORGANIZATION = 088076 DAY LABOR SORTED BY IDENTIFIER

CTG.	INV. NO.	I.D. NO.	CALL NO.	VEHICLE #	LICENSE #
862	B32148			D22061	
862	D91774			T22032	
862	BB6660			T22155	
862	BB6600	0200	M 36	T22612	U01569
862	BB6626	0201	M-38	T22158	U04441
862	BB6627	0202	M-21	C08331	U03924
862	BB6628	0203	M-23	C08314	U02296
862	BB6629	0204	M-26	C08661	U02299
862	BB6630	0205	M-28	C09178	U00684
862	BB6631	0206	M-27	T21492	U13835
862	BB6632	0207	M-24	T22912	U07969
862	BB6633	0208	M-20	C09118	U02297
862	BB6634	0209	M-29	T20931	U11227
862	BB6635	0210	M-40	T17991	U10040
862	BB6636	0211		T20932	
862	BB6637	0212	M-37	T20074	U02303
862	BB6638	0213	M-42	T21603	U00944
862	BB6639	0214		T21751	
862	BB6640	0215		T22156	
862	BB6641	0216		T21750	
862	BB6642	0217		T22157	
862	BB6643	0218		T20935	U02307
862	BB6644	0219	M-35	T21105	U04520
862	B32150	0221	M-39	T22613	U00914
862	D91777	0222	M-66	T21578	U00428
862	D91778	0223	M-65	T21579	U00416
862	D91779	0224	M-61	T21580	U00430
862	D91780	0225	M-64	T21581	U17775
862	D91781	0226	M-68	T21582	U13833
862	D91782	0227	M-60	T21583	U00432
862	D91783	0228	M-67	T21584	U00420
862	D91784	0229	M-69	T22614	U02309
862	D91785	0230	M-70	T21752	U07249
862	D91786	0231	M-62	T21753	U18824
862	D91787	0232	M 60	T21072	U13838

*** END OF REPORT ***

FIGURE 4 Example of I.D. cross reference report.

attached with the radio record. This ensures no item can be shown attached to more than one other item. Secondly, it is important to include all the radio maintenance repair shops and to assign all radios to one of these shops. This had already been done informally and is usually governed by the repair shop's proximity. By assigning the radio inventory to a particular repair shop, Motorola guides the workload to the locations most likely to be used. Motorola maintains parallel information for their managers in the field. Third, the maintenance contract includes a price list of the various services to be offered and the cost of each. Most remote field users of the radios are not aware of the costs of repairs or maintenance for their radios. The master contract contains these unit prices, but they are not widely distributed. The cost of repair when made, is automatically calculated and included. Therefore, the radio contact people in the districts and those requesting repairs can comprehend the cost to maintain their radios and the cost of particular requests.

PREVENTIVE MAINTENANCE

The Department requires all radio equipment be included on a schedule of maintenance. Mobile units, for example, are inspected once a year, base stations twice a year and other equipment on similar schedules. It is important for the Bureau to ensure the contractor has, in fact, performed this maintenance and that all 4,000 radios in the system have been given the appropriate maintenance service (See Figure 2).

MMIS409 MMIG4334 MMIR433 ILLINOIS DEPARTMENT OF TRANSPORTATION PAGE: 1
05/24/94 141654 BUREAU OF MAINTENANCE
RADIO COST REPORT

SELECT CRITERIA: CATEGORY CODE = 862-862 ASSIGNED ORGANIZATION = 700000 DISTRICT 7 SELECT DATE = 04/94 BY CATEGORY

INV. NBR.	TS	YEAR	MAKE	MODEL	SERIAL NUMBER	CONTRACT TYPE	04/94 FIXED $'S	04/94 EXTRA $'S	04/94 TOTAL $'S	FYTD FIXED $'S	FYTD EXTRA $'S	FYTD TOTAL $'S
CATEGORY: 862 RADIO - MOBILE - LOW BAND												
J18001	732	1992	MOTR	MRTRC	776ASN0290	C	$ 11.15	$ .00	$ 11.15	$ 89.20	$ 21.75	$ 110.95
J18002	732	1992	MOTR	MRTRC	776ASN0278	C	$ 11.15	$ .00	$ 11.15	$ 89.20	$ 21.75	$ 110.95
J18003	732	1992	MOTR	MXTRC	428ASN1626	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18004	732	1992	MOTR	MXTRC	428ASN1631	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18005	732	1992	MOTR	MXTRC	428ASN1637	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 133.95	$ 212.35
J18006	732	1992	MOTR	MXTRC	428ASN1639	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18007	732	1992	MOTR	MXTRC	428ASN1643	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 134.20	$ 212.60
J18008	732	1992	MOTR	MXTRC	428ASN1651	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 134.20	$ 212.60
J18009	732	1992	MOTR	MXTRC	428ASN1648	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 134.20	$ 212.60
J18010	732	1992	MOTR	MXTRC	428ASN1632	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18011	732	1992	MOTR	MXTRC	428ASN1633	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 170.55	$ 248.95
J18012	732	1992	MOTR	MXTRC	428ASN1646	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18013	732	1992	MOTR	MXTRC	428ASN1644	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18014	732	1992	MOTR	MXTRC	428ASN1656	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18015	732	1992	MOTR	MXTRC	428ASN1653	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 67.60	$ 146.00
J18016	732	1992	MOTR	MXTRC	428ASN1650	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18017	732	1992	MOTR	MXTRC	428ASN1640	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18018	732	1992	MOTR	MXTRC	428ASN1652	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18019	742	1992	MOTR	MRTRC	776ASN0286	C	$ 11.15	$ .00	$ 11.15	$ 89.20	$ 21.75	$ 110.95
J18020	742	1992	MOTR	MRTRC	776ASN0284	C	$ 11.15	$ .00	$ 11.15	$ 89.20	$ 21.75	$ 110.95
J18021	742	1992	MOTR	MXTRC	428ASN1642	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18022	742	1992	MOTR	MXTRC	428ASN1647	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18023	742	1992	MOTR	MXTRC	428ASN1645	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 97.60	$ 176.00
J18024	742	1992	MOTR	MXTRC	428ASN1655	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 69.30	$ 147.70
J18025	742	1992	MOTR	MXTRC	428ASN1627	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18026	742	1992	MOTR	MXTRC	428ASN1649	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 97.60	$ 176.00
J18027	742	1992	MOTR	MXTRC	428ASN1654	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18028	742	1992	MOTR	MXTRC	428ASN1630	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 51.75	$ 130.15
J18029	742	1992	MOTR	MXTRC	428ASN1641	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18030	742	1992	MOTR	MXTRC	428ASN1635	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 82.46	$ 160.86
J18031	742	1992	MOTR	MXTRC	428ASN1628	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18032	742	1992	MOTR	MXTRC	28ASN1638	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18033	742	1992	MOTR	MXTRC	428ASN1657	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18034	731	1992	MOTR	MXTRC	428ASN1629	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18035	731	1992	MOTR	MXTRC	428ASN1634	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 170.30	$ 248.70
J18036	731	1992	MOTR	MXTRC	428ASN1636	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18037	731	1992	MOTR	MXTRC	428ASN4710	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18038	731	1992	MOTR	MXTRC	428ASN4700	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18039	731	1992	MOTR	MXTRC	428ASN4694	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18040	731	1992	MOTR	MXTRC	428ASN4689	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18041	731	1992	MOTR	MXTRC	428ASN4692	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18042	731	1992	MOTR	MXTRC	428ASN4734	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18043	731	1992	MOTR	MXTRC	428ASN4727	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18044	731	1992	MOTR	MXTRC	428ASN4737	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18045	731	1992	MOTR	MXTRC	428ASN4702	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 133.95	$ 212.35
J18046	731	1992	MOTR	MXTRC	428ASN4729	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18047	731	1992	MOTR	MXTRC	428ASN4736	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18048	731	1992	MOTR	MXTRC	428ASN4691	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18049	731	1992	MOTR	MXTRC	428ASN4718	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18050	741	1992	MOTR	MXTRC	428ASN4715	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18051	741	1992	MOTR	MXTRC	428ASN4699	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18052	741	1992	MOTR	MXTRC	428ASN4731	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 21.75	$ 100.15
J18053	741	1992	MOTR	MXTRC	428ASN4693	C	$ 9.80	$ .00	$ 9.80	$ 78.40	$ 170.30	$ 248.70
J18255	780	1992	MOTR	MXTRC	428ASN4939		$ .00	$ .00	$ .00	$ .00	$ 21.75	$ 21.75
J18256	780	1992	MOTR	MXTRC	428ASN4923		$ .00	$ .00	$ .00	$ .00	$ 21.75	$ 21.75
J18257	780	1992	MOTR	MXTRC	428ASN5051		$ .00	$ .00	$ .00	$ .00	$ 21.75	$ 21.75
TOTAL CATEGORY 862 RADIO - MOBILE - LOW BAND							$ 2394.20	$ .00	$ 2394.20	$ 19153.60	$ 9668.75	$ 28822.35
TOTAL DISTRICT 7							$ 2394.20	$ .00	$ 2394.20	$ 19153.60	$ 9668.75	$ 28822.35
REPORT TOTAL							$ 2394.20	$ .00	$ 239.20	$ 19153.60	$ 9668.75	$ 28822.35

*** END OF REPORT ***

FIGURE 5 Example of radio cost report.

MMIS430 MMIG4335 MMIR434 ILLINOIS DEPARTMENT OF TRANSPORTATION PAGE: 2
05/24/94 143257 BUREAU OF MAINTENANCE
SUMMARY OF RADIO LIFE TO DATE
REPAIR FREQUENCIES AND COSTS
DISTRICT 7
EFFECTIVE 05/24/94

--EQUIPMENT DESCRIPTION--- YEAR MAKE MODEL	NUMBER UNITS	REMOVALS	INSTALLS	PM/INSP.	RECEIVER	SCANNER	TRANSMITTER	POWER SUPPLY	OTHER	ALL REPAIRS
		----------------REPAIR ACTIITY								
CATEGORY : 862 RADIO - MOBILE - LOW AND										
1992 MOTR MRTRC	25									
NUMBER OF REPAIRS		3	3	0	0	0	0	0	27	33
TOTAL COST ($)		109	336	0	0	0	0	0	640	1085
AVG COST OF REPAIR $)		36	112	0	0	0	0	0	23	32
1992 MOTR MXTRC	231									
NUMBER OF REPAIRS		9	20	1	0	0	0	0	247	277
TOTAL COST ($)		327	2247	32	0	0	0	0	5976	8582
AVG COSTOF REPAIR ($)		36	112	32	0	0	0	0	24	30
CATEGORY : 862 RADIO - MOBILE - LOW BAND										
NUMBER OF REPAIRS		12	23	1	0	0	0	0	274	310
TOTAL COST ($)		436	2584	32	0	0	0	0	6616	9668
AVG COST OF REPAIR ($)		36	112	32	0	0	0	0	24	31

*** END OF REPORT ***

FIGURE 6 Example of radio cost summary report.

WARRANTY TRACKING

During development of the radio management system, the Department was in the midst of upgrading much of its mobile radio fleet. All new equipment was purchased with a 12-month warranty for parts and labor from the manufacturer. Since new equipment was installed of a period of several months, it became important to track and notify radio coordinators and the maintenance contractor when new equipment was nearing the end of the warranty period to add it to the maintenance contract. A specific report was created to project warranty exportations 60 days before the end of warranty. This report not only aids the radio coordinators, it also helps to track warranty expirations on all types of vehicles and equipment monitored by the MMI System (See Figure 3).

CROSS REFERENCING TO MEET USERS NEEDS

Traditionally the Department has assigned simple coded radio call signs to either the vehicle or the individual assigned a two-way mobile radio. These "on-air" call numbers are well established and are frequently memorized by operators and dispatchers. Each mobile radio also carries a unique Department inventory control number used to track the item within the inventory systems. New radios have programmable digital identifiers that allow selective signaling and interrogation of the radio from the control console. All these codes have some meaning to various people associated with the use, management and control of the radio system. Therefore, each is made a part of the master inventory record for each radio. The need to cross reference these unique codes became an obvious report to include in the radio management program. The report can be produced in three sorts: inventory number, call number and I.D. number (See Figure 4).

COST OF OPERATION

As with other equipment, tracking and knowing the ongoing operating cost of operating and maintaining the radio system was the number one objective in formulating the radio management module of the MMI System. Since all payments originate with the central offices, district radio coordinators had no solid understanding of the cost of the system under their control. Costs beyond contract costs for removals, installs and modifications could easily get out of control. The local coordinators could not track the cost and was not responsible for controlling the budget. The cost tracking report shown in Figure 5 provides local and state coordinators and managers with cost tracking for the most recent month and year to date. This allows the local coordinator to know the impact of the fixed and above contract expenditures, and to control costs that might otherwise go unchecked.

NATURE OF REPAIRS

In purchasing new mobile radio equipment for a large part of its operation the Department expects to reduce the overall cost of operating the radio system and improve the reliability of radio service for routine and emergency operations. In previously developed equipment management report systems, an effort was made to categorize and track the frequency and cost of repairs for products from different manufacturers. This categorized tracking approach has been adapted for the radio management system. Figure 6 shows the general layout for reporting the nature and cost of various radio repairs.

CONCLUSION

Two-way communication is a vital link for the day-to-day operation of the Department and other state DOTs. The future will likely produce even more dependence on radio transmission of voice and data to meet the ongoing needs of transportation agencies. The Department has come to realize two-way radio management is not secondary to the management of the vehicle and equipment fleet. It is an integral part of the management process. To this end the Department has integrated radio system management into the total maintenance management program and is training personnel to optimize the use of the various records and reports. This system is in its infancy. No specific results can yet be attributed to its implementation. However, the application of fundamentals learned in the seven years of using and refining the total system prompt belief that this too will be a successful and well-used tool in day to day operations management.

NEW YORK STATE DOT REPAIR PARTS MANAGEMENT SYSTEM

Edward G. Fahrenkopf
New York State Department of Transportation

INTRODUCTION

The New York State Department of Transportation issues approximately $11 million in parts and supplies each fiscal year. For the most part the purchasing of these parts is done on a local basis. However to assist the regions in parts purchasing contracts, most are awarded centrally to establish preset prices and delivery conditions. These contracts may have a vendor in each region or there may be only one vendor for the State depending on the volume to be purchased and the number of vendors Statewide.

The Repair Parts Management System (RPMS) is an on-line computer system that runs on a Unisys main frame. However, the Department is currently converting central processing applications to an IBM main frame. The Department is also doing a lot of distributive processing on PC's connected to the main frame.

There are 10 major stock locations or warehouses Statewide. These are located at the major repair facilities in each region. Each of these facilities services the mechanics that work in the major region repair facilities. They also service the satellite repair facilities in the Highway Maintenance residencies and sub-residencies of which there are 85. A residency's jurisdiction normally corresponds to a county, however, some do extend into adjoining counties. Most of the preventive maintenance (PM) and minor repairs are done in the residencies. A residency may have from $20,000 to $30,000 worth of stock on-hand depending on the size of the fleet and the distance from a regional facility. The RPMS facilitates the stocking of parts in the region warehouse and in the residencies. It is an on line, real-time system connected to a Unisys main frame via leased lines.

FEATURES

The features of the RPMS include:

- Automatic cross referencing of part numbers;
- Automatic matching of parts to multiple applications;
- Three year consumption history;
- Automatic setting of minimum/maximum levels;
- Ability to override the calculated minimum/maximum;
- Restock of satellite locations; and
- Overstock obsolete reports.

Cross Referencing

To explain the automatic cross referencing feature, back ground on what is used for part numbers is in order. During the design of the system there was considerable discussion on whether manufacturers' part numbers should be used or if "State part numbers" should be created. The main issues surrounding the use of State created parts numbers were that the generation of these numbers from a central location would provide control over what could be entered into the database, and it would require a central staff that was not available. In addition, the system was being set up to save money, not increase overhead costs.

The final decision was to use manufacturers' part numbers combined with the manufacturer's code (abbreviation) which was already being used in the fleet inventory system. This code consisted of a five-letter abbreviation (if needed) of the manufacturer's name. To keep track of records within the computer, a record keeping number is generated by the computer and assigned to a new part when it is entered into the database. This approach allows the system to be run at the region level without any central office involvement. Simply stated, any location can create a new record and once created any other location can use that record.

Once a record is created, another part number can be added as a cross reference at the regional level. Entry by any equivalent part number will provide the same record. The RPMS combines the efforts of cross referencing done at any location. As an example, if both Regions 1 and 2 stock Ford part number XYZ and Region 1 determines that Ford XYZ is the same as GM UVW, entry by any Region on either part will get stock information on both parts. There is also a cross reference inquiry to aid in the purchasing process.

Applications Record

An applications record is used to prevent the disposal of parts that may be thought to be obsolete. This also assists in identifying problem equipment by listing all the applications for a part. Each time a part is used, the issue record contains the unit ID number on which the part was installed. This then creates or updates for the using region a record containing the consumption history for the part by make, model and model year.

Consumption History

The database contains consumption history for all parts for up to three years. The current year's data are kept by quarters which is summarized in an annual consumption history. This is done after the minimum and maximum stock levels are calculated at the end of the fiscal year.

Minimum/Maximum Settings

Minimum and maximum stock levels for each region are reset each year. They are based on consumption history for the last year. For a part to be considered for stock, it must have been used at least three times during the previous year. The maximum is the single highest quarter usage. The minimum is based on quarterly usage and lead time with a 20% safety stock.

Override of Calculated Minimum/Maximum

Historical consumption may not be the best basis for predicting future consumption of parts. Therefore, the system allows personnel in the regions to manually override the calculated minimum/maximum for use in reordering. The reorder programs use the override if it is present. Reorder reports by product line, vendor, contract application, etc., are available.

Restock Reports

There are 85 stock locations other than the major repair facilities and warehouses. All parts stocked at these locations have a three-year consumption history and are controlled by a stock-level. This stock-level can be set either automatically using a set consumption formula or manually. Most stock locations are restocked from the main warehouse weekly, while some are biweekly depending on consumption. These decisions are made at the local level. When a residency stock location is to be restocked, a restock report is run. This lists all the parts with a balance less than the stock-level for the stock location. This list is produced in bin number order to simplify filling of the order at the main warehouse. The stock clerk simply goes up and down the aisles once to fill an order. The restock report becomes the packing list and a copy is used to post the transfer from the main warehouse to the residency.

Overstock Obsolete Reports

Parts become stale or obsolete when the equipment fleet requirements decrease or are eliminated. To minimize this, stock room personnel use an overstock obsolete report. This report can list parts based on several selection criteria. These are by equipment make, model and model year, no use for a certain number of days or parts that are in excess of the calculated maximum, or by any combination of these criteria.

In addition to these reports, the Department has a policy that before parts are ordered, the other region parts- levels must be checked to see if they are overstock. If another region is overstock, the parts are shipped to the region that needs them. Each year parts worth several hundred thousand dollars are transferred from one region to another. This reduces the potential for parts becoming obsolete.

ENHANCEMENTS

Bar Coding of Data Entry

Currently all data entry is done manually from a terminal in the 10 major warehouses. However, bar code readers are being installed at the main warehouses and residencies. These will be used for scanning all high volume transactions, such as issues, receipts of orders, transfers, and inventory adjustments and counts. This concept is one step being taken to move toward a paperless operation.

Local Purchase Quote System Via Fax

Besides the State's official accounting system, a PC based accounting system has been developed that feeds the State's system via modems. Because this is PC based, it can be tailored to fit the operation. Like most all state-of-the-art accounting systems it prints requisitions, purchase orders, vouchers, etc. For purchase of parts that are not on contract, a quote is faxed to vendors known to carry the parts. The vendors in turn fax back the information on price and availability. A Purchase Order is then cut based on the best price.

SECTION VII TOWARD EQUIPMENT STANDARDIZATION

SHOULD THERE BE A UNIFORM NATIONAL COLOR FOR DOT VEHICLES?

Edward L. Kocan
North Carolina Department of Transportation

ABSTRACT

All state departments of transportation (DOTs) share a concern for employee safety, and for decades have chosen highly visible colors for their on-highway equipment to reduce accidents. This area is being reviewed by many DOTs due to the pressures of higher costs, tighter budgets, environmental regulations and quality problems involving color consistency. Color quality control and environmental concerns shared by most states are briefly reviewed. Considerations for implementing a definitive paint/marking standard are discussed. Reducing costs, meeting tighter environmental regulations, and implementing a standard color/marking may be practical objectives. The benefits of uniformity in color/markings among states such as reduced paint costs and increased safety for interstate travelers may be worthy of the combined efforts of state DOTs. A national research study is proposed on relative conspicuity of highly visible colors, markings, driver reaction times, and evaluation of functional considerations.

INTRODUCTION

The high visibility of on-highway equipment has long been considered an important concern for highway workers who are vulnerable to high speed traffic. This safety area is being reviewed by many DOTs due to the pressure of higher costs, tighter budgets, environmental regulations, and quality problems involving color consistency. Also, more recent studies of color conspicuity and evaluation of other markings, such as retroreflective and fluorescent materials, suggest more effective means to promote safety. The purpose of this paper is to propose a study of up-to-date safety marking techniques. A method which is highly effective, minimizes costs and accommodates growing environmental regulation is a worthwhile objective. The methods could include a range of options. Considering the psychological aspect of conspicuity and the economics of uniformity, a single uniform identification may be most desirable.

BACKGROUND

All state DOTs have shown concerns for safety by painting on-highway equipment in colors considered highly visible. An exhibit prepared by the Arkansas State Highway and Transportation Department for the Southeastern State Equipment Managers in 1992 demonstrated the colors used by 12 DOTs and a unanimous concern for safety and awareness of the positive effects of good visibility. Most colors were in the yellow or orange family although several states were using white. Typical colors were Omaha Orange, Federal Yellow No. 13538, and GM Orange No. WA-9408. These colors are difficult to distinguish from most state colors.

Hagler (*1*) presented Texas DOT experiences to the 9th Equipment Management Workshop (1992) and concluded that nonstandard paints cause longer delivery times and additional costs for equipment. Noted were the high light reflection of white and shorter delivery periods when manufacturers' standard colors were ordered. Texas DOT has changed to manufacturers' standard white for all on-highway equipment, Federal Yellow (13538) for all off-road equipment, and standard light colors for sedans.

The original Arkansas display generated considerable interest and in fact so many other DOTs have borrowed the display the North Carolina DOT reassembled the chips last year to prepare a display for its own use. In the period since the original display and following the presentation by the Texas DOT, several additional states have changed their colors to standard white. Several states outside the southeast such as Texas, Ohio, Connecticut, and Pennsylvania have met with the southeast group and their colors were included with the display.

A summary of state colors is provided in Table 1. States are placed in three groups: orange, yellow and white. Their official colors are listed along with a representative color. All of the oranges are extremely close to Omaha Orange. The group with the biggest differences is the yellow and among these, the N. C. Highway Yellow is probably the most different. With all the different paint colors specified by these 16 states, there are basically three colors: Omaha Orange, Federal

TABLE 1 ON-HIGHWAY EQUIPMENT COLORS (SOUTHEASTERN STATES EQUIPMENT MANAGERS MEETING)

STATE	OFFICIAL COLOR	COLOR MATCH
Connecticut	Omaha Orange	Omaha Orange
Louisiana	PPG-Delstar #60156	Omaha Orange
Mississippi	Omaha Orange	Omaha Orange
Tennessee	Omaha Orange	Omaha Orange
Virginia	GM Orange #WA-9408	Omaha Orange
Florida	Fed. Yellow #13538	Fed. Yellow #13538
Georgia	DuPont #174AH	Fed. Yellow #13538
No. Carolina	DuPont Centauri #54701AK	Fed. Yellow #13538
Pennsylvania	PPG # DU82546	Fed. Yellow #13538
So. Carolina	DuPont Centauri #LFG8112	Fed. Yellow #13538
Alabama	Standard White	Standard White
Arkansas	Standard White	Standard White
Kentucky	Standard White	Standard White
Ohio	Standard White	Standard White
Texas	Standard White	Standard White
West Virginia	Standard White	Standard White

Yellow and standard white. There is some move toward standardization as evidenced by states changing to standard white.

RECENT NORTH CAROLINA EXPERIENCE

North Carolina DOT changed its paint specification several years ago to exclude lead and chrome content. Subsequently, suppliers failing to match North Carolina DOT Highway Yellow became a problem. The new paint specification was more acceptable from an environmentalist view but it caused supply problems. First, obtaining paints to match the color was difficult for equipment suppliers since vendor cross reference information was not readily available. Second, the supplier who originally formulated the paint supplied it with volatile organic compound (VOC) levels that present problems using the paint in North Carolina DOT shops.

Problems associated with accepting various shades of color received with new equipment purchases were resolved by providing specification paint chips. Using these chips to specify color, identifying acceptable alternative paints and providing reference for equipment inspection made it easier to apply paint color discipline early in the delivery process. North Carolina DOT has looked at the use of color measuring instruments, in the color acceptance process but has settled on a simpler approach. Visual inspection is the most widely used matching procedure, so North Carolina DOT matches chips from suppliers with the standard chips of North Carolina DOT Highway Yellow. This provides an early opportunity to resolve differences in color before a production run is initiated.

The problems experienced upon change in paint specification by North Carolina DOT may be repeated as environmental regulations change. More restrictive regulations on VOC have prompted increased interest in water base paints, for example. A new potential problem for paint suppliers is the ability to match the high gloss of present paints with water-based paints.

There are likely additional equipment costs due to specifying nonstandard colors. There will be problems in changing paint formulations to adjust to new environmental regulations. From a national perspective these problems are compounded dramatically by the fact that many states have their own special colors.

FACTORS AFFECTING CONSPICUITY

Conspicuity is a term similar to the layman's concept of visibility but it also includes the act of recognition and psychological effect on the viewer. The psychological effect will be explained below. Olson (*2*) defined a conspicuous object as "one that will, for any background, be seen with certainty $p>90\%$ within a short observation time ($t=250$ MS) regardless of the location of the object in relation to the line of sight." Review of past studies shows important factors affecting conspicuity defined below.

Color

Color has been defined by researchers in precise mathematical terms. One of the more widely used systems for specifying colors in three dimensional space was developed in 1905 by the artist, Albert H. Munsell. This system was developed 23 years before instrumentation was available to measure color.

The Munsell system uses three attributes to specify a particular color numerically:

- L = Lightness - distinguishes "light" colors from "dark" colors,
- C = Chroma - is used to show how concentrated a color is or how different it is from gray, and
- H = Hue - is the attribute of color perception by which an object is judged to be red, yellow, green or blue.

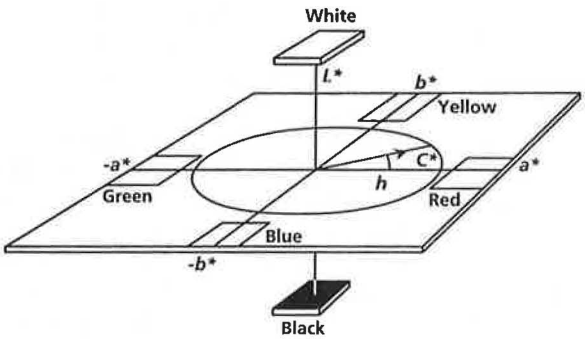

FIGURE 1 CIE 1976 (L*A*B*) color space.

The systems for specifying colors have been refined over the years and instrumentation is available to measure color. The Commission International De L'Eclairage (CIE) systems, presented in Figure 1, are commonly used (*3*). The CIE L*C*H* system uses mathematical expressions for the attributes defined above. The L*A*B* system that is also shown in Figure 1 uses different mathematical expressions to define color.

Light Sources

Color perception is partially a result of the light source. With today's street lighting and automotive light technologies, there are a variety of light sources. A color is seen because the surface reflects light of wavelengths producing that color perception. Different light sources produce light in different compositions of wavelengths. Figure 2 shows Spectral Power Distribution data for a few of these light sources (*4*). This effectively can make a color appear different. An illustration of the result is shown in Figure 3, which is taken from a study of colors and signs in workplaces (*5*). This data shows many instances where less than 50% of the observers recognized orange when viewed under Low Pressure Sodium Light. Typical light sources are Daylight, Incandescent Light, Cool White Fluorescent Light, Clear Mercury, Metal Halide, High Pressure Sodium and Low Pressure Sodium.

Contrast

How well one sees a color depends upon the background. For example, the visibility of white vehicles against a snowy or cloudy background is poor. Contrast is usually defined in terms of a black object on a white background but other logical combinations of colors should be considered.

Retroreflectivity

This term applies to reflection characterized by the flux in an incident beam being returned in directions close to the direction from which it came. There are several types including prismatic and spherical lenses. This aspect has been evaluated in studies by Olson (*2*), Aoki

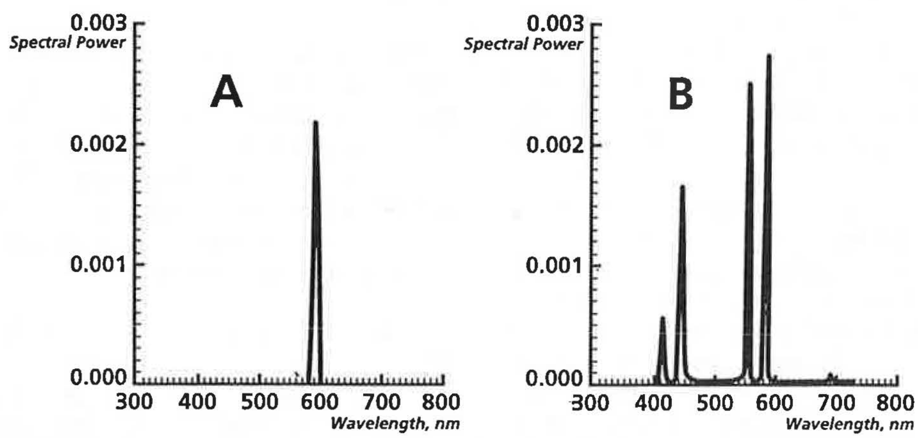

FIGURE 2 Spectral power distribution of various light sources: A) Low pressure sodium, and B) Clear Mercury.

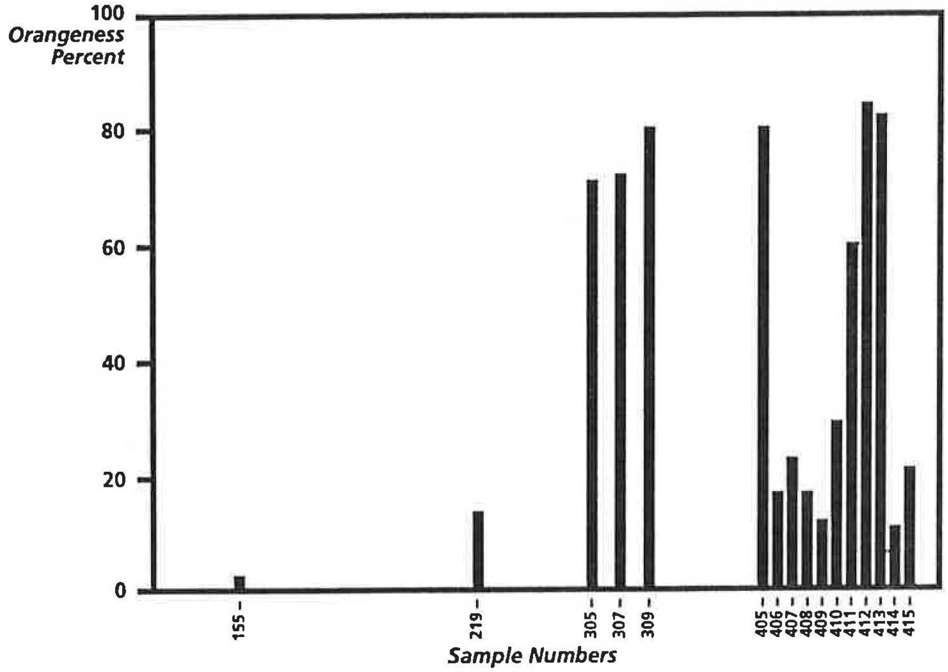

FIGURE 3 Percentage of trials in which designated color samples were identified as orange under high pressure sodium light.

(*6*), and Glass (*5*). Results from the work by Aoki *(6)* are shown in Figure 4, and show those retroreflective colors such as blue, red and green show up as much brighter than yellow.

Color Vision Defects

Collins (*3*) points out that color interpretation is complicated by the fact that 8-10% of the population has either inherited or acquired color vision defects. A frequent defect is the ability to perceive mid-wavelength pigments. Aging or acquired vision defects usually affect the short wavelength portion of the spectrum.

Pattern

Olsen (*2*) investigated use of retroreflective materials to upgrade marking systems on large trailers. Laboratory and field studies were conducted to assess the use of a pattern in the retroreflective material, the form of the pattern, the placement of the pattern, configuration, interference with other signals, the effect of environmental dirt on the performances of the marking systems and the durability of retroreflective material in this use. Figure 5 shows patterns recommended for marking large trailers.

Psychological Behavior

Reviewing articles in the literature, one becomes aware of four stages in responding to a situation: one detects, recognizes, decides to react, and then acts. For example, an English Study (*7*) noted that white is a passive color and communicates no sense of urgency. This report also concluded that a slight mixture of green with yellow was found to have psychological value and tends to be associated with unpleasant things. The behavioral assessment by Collins (*8*) raises questions about the role of color in determining sign visibility. Consistency, wide acceptance and identification of hazard situations requiring reaction are the desired psychological behavior.

FUNCTIONAL CONSIDERATIONS

Considering the problems described earlier, some practical aspects have to be considered when using paint

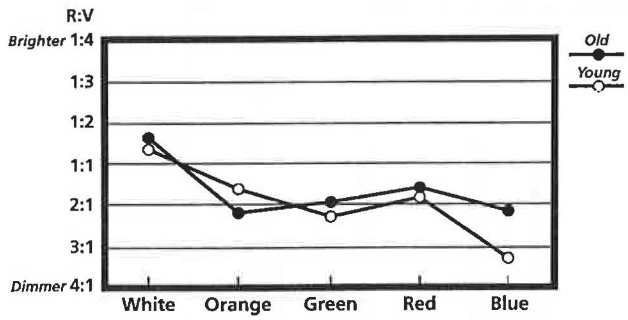

FIGURE 4 Luminance ratio of other colors to yellow, when subjects judged them equal in brightness. *(6)* "Old" subjects were 60-75, "Young" subjects were 18-30.

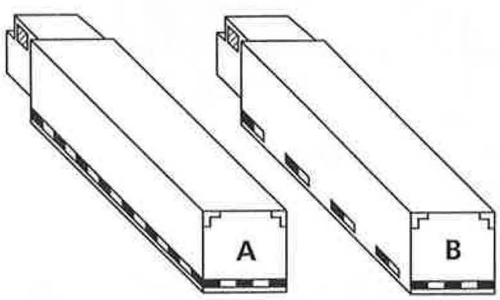

FIGURE 5 A) Recommended configuration of retroreflective materials, and B) optional treatment with gaps on sides. *(2)*

or other marking systems. Some considerations are noted below and should be part of the evaluation process for selecting effective marking systems.

Durability

How long does the material retain the desirable conspicuity attributes, and what are the frequency and cost of replacement?

Environmental Compliance

Is the material environmentally safe and will it meet existing Federal and State Environmental Regulations? Are there potential threats to future use because of developing environmental issues?

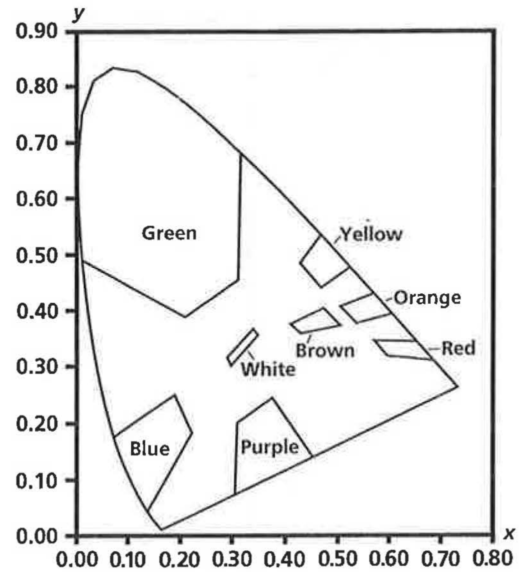

FIGURE 6 Chromaticity regions specified by the CIE for ordinary colors under D65, daylight *(3)*. The CIE Tristimulus Values are x and y. Following the perimeter changes hue and saturation changes from center to outer edges.

Adaptability to Change

How easily will adjustments to markings be implemented in cases of future regulatory changes and what are the costs involved?

Matching

How readily can materials be matched after repairs of a vehicle or when the material must be replaced due to loss of function? What are costs of replacing and matching materials and are large inventories of materials needed?

Uniformity

Is it effective to describe a range of colors or markings which meet the requirements for conspicuity and functionality, such as the colors shown in Figure 6 (*3*), or do other functional concerns indicate that a uniform marking is most desirable at either the state or national level? Are costs, psychological aspects of conspicuity and ability to change to regulatory requirements sufficiently enhanced by large scale uniformity?

PROPOSED RESEARCH PROJECT

The studies conducted so far provided a great deal of insight into conspicuity of various paint colors and markings. However, none of the studies have specifically addressed the complete spectrum of conspicuity factors for on-highway equipment. A research project to address on-highway equipment is outlined in Table 2.

A review of the referenced studies should provide an excellent start for accumulation of data needed for the proposed study and this would initiate Phase I. The data can be reviewed to determine the important factors and colors/markings to be included. The final product of this phase would be recommendations of colors/markings to be evaluated and laboratory tests recommended to obtain additional data on conspicuity factors.

Laboratory tests can be conducted in Phase II to supplement data needed to evaluate paint and marking alternatives. Functional considerations such as durability, environmental compliance, adaptability to change, ease in matching and benefits of uniformity would also be evaluated in Phase II. There is no intent to place economic values on human lives, but cost-benefit analyses of the functional considerations are necessary to utilize funds in a manner where they will be the most effective in promoting safety.

As part of this evaluation, assessment can be made whether paints and/or markings should be defined as a range of acceptable colors and configurations or whether sufficient benefits exist for establishing requirements for uniformity at either the state or national level. The final product of Phase II would be the recommended colors/markings for field test and the recommended test program.

The Federal Highway Administration (*9*) is conducting an evaluation program for fluorescent strong yellow green crossing signs. The field tests of this program provide some insight into the field testing that would be necessary in Phase III of the proposed project. It is important that the best alternatives be field tested in the best representation of the environment where they will be used. The psychological aspects of conspicuity can best be evaluated in the field tests. Considerations for field test include the number of alternatives to be evaluated. The number of alternatives should be reduced to a minimum through literature assessment and laboratory testing. Additionally, the various situations for field tests must be selected such as daylight, twilight, or evening and conditions such as clear, cloudy and snowy days.

The number of observation points, observers and observations to be recorded must be chosen best to evaluate the alternatives.

TABLE 2 PROPOSED RESEARCH PROGRAM

PHASE I
A. Literature review
B. Determine colors/marking for evaluation
C. Determine conspicuity factors to be considered
D. Recommend colors/marking and laboratory tests for relevant conspicuity factors

PHASE II
A. Conduct laboratory tests
B. Obtain data and evaluate functional considerations
C. Determine relative effectiveness of paint/markings for conspicuity
D. Determine rank of alternatives including functional considerations
E. Recommend alternatives for field tests
F. Recommend field test plans

PHASE III
A. Field test most promising alternative(s)
B. Obtain base case for comparison
C. Recommend most effective alternative including most desirable amount of uniformity

CONCLUSION

The research study proposed above will utilize existing studies and will supplement research data in areas where needed. The project also includes field testing in the actual environments where the markings are used and will obtain factual, objective information. The recommendations will provide credible, objective information which is not currently available. This information will provide an improved basis for DOTs to decide the best means to provide safe identification markings for on-highway equipment.

REFERENCES

1. Glenn R. Hagler, *"Comparison of Equipment Paint Specifications."* Transportation Research Circular No.

418, December 1993, *Presentations from the 9th Equipment Management Workshop,* Transportation Research Board, National Research Council, pp 12-14.

2. Paul L. Olson, *Performance Requirements for Large Truck Conspicuity Enhancements,* The University of Michigan Transportation Research Institute, February 1992.

3. Belinda L. Collins, *Evaluation of Colors for Use on Traffic Control Devices,* NISTIR 88-3894, U. S. Department of Commerce, National Institute of Standards and Technology, November 1988.

4. Belinda L. Collins, Belinda Y. Kuo, Suzin E. Mayerson, James A. Worthey and Gerald L. Howett, *Safety Color Appearance Under Selected Light Sources,* NBSIR 86-3493, U. S. Department of Commerce, National Bureau of Standards, December 1986.

5. Robert A. Glass, Gerald L. Howett, Karen Lister and Belinda L. Collins, *Some Criteria for Colors and Signs in Workplaces,* NBSIR 83-2694, U. S. Department of Commerce, National Bureau of Standard, April 1983.

6. Toshiaki Aoki, Dennis S. Battle and Paul L. Olson, *The Subjective Brightness of Retroflective Sign Colors,* The University of Michigan Transportation Research Institute, July 1989.

7. "Yellow-For Safety," *Traffic Safety,* May 1970.

8. Belinda L. Collis and Peter J. Goodlin, *Visibility of Exit Directional Indicators,* NISTIR 4532, U. S. Department of Commerce, National Institute of Standards, March 1991.

9. M. R. Parker, Jr., *Guidelines for Evaluating Fluorescent Strong Yellow Green Crossing Signs,* Publication No. FHWA-SA-93-035, U. S. Department of Transportation, Federal Highway Administration.

SINGLE AXLE DUMP TRUCK COMPONENT STANDARDIZATION IN PENNDOT

Ronald D. Doemland
Pennsylvania Department of Transportation

SUMMARY

1. Air dryer - Midland AD-9 Air Dryer. One element fits all dump trucks and improved serviceability.

2. Alternator - Delco Remy 30 SI Alternator. Improves inter-changeability and rebuild exchange to support the field maintenance units.

3. Engines - IHC = DT466, MACK = E7250, CAT = 3116ATAAC, CUMMINS - 8.3L C Series, FORD = FD1460, DETROIT DIESEL = 50 Series, WHITE = GMC-VE-7-250B.

4. Hoist Assembly and Hydraulic System - Commercial SD63CB-78, Custom DAT63-78.

5. Mirrors - Delbar heated mirror. One mirror head fits all applications and wiring compatibility. Also centrally stocked to support the field maintenance units.

6. Revolving Lights - Federal. Allows for interchangeability of complete lights, lens and bulbs. Also centrally stocked to support maintenance units.

7. Seats - Bostrom 915, National 195, DuraForm Air Command.

8. Starter - Delco Remy 42MT. Improves interchangeability and rebuild exchange to support the field maintenance units.

9. Tires - Goodyear and Michelin radials. Specified on all new trucks to improve extended tire wear, driveability and ride.

10. Transmission - Fuller 9 Speed, Allison MT653 or MD-3560P.

11. Wheels - Standardized for <u>size</u> only, 9.0" Front, 8.25" Rear.

12. Wiring System - Truck Lite or Grote. Both totally sealed systems, eliminating corrosion and reduced repair costs. All lights interchangeable.

INTRASTATE FLEET STANDARDIZATION

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North Carolina Department of Transportation

Standardization of North Carolina Department of Transportation's (NCDOT's) equipment fleet may be equivalent to motherhood and apple pie. Everyone supports the idea. NCDOT's experience is that one can sell the concept until individual preferences are violated. The fleet includes an unnecessary variance of functionally equivalent units in the opinion of central equipment staff. It appears that the field forces cannot work without asphalt kettles that include those with capacities that vary from 50 to 300 gallons, six sizes of trailer mounted, diesel oil or bottled gas fired units. It also appears that the required different versions of a ½-ton pickup approach infinity. The various requests include 4-cylinder, 6-cylinder, 8-cylinder engines, compact and full size, 2-wheel and 4-wheel drive, various bed lengths, cab configurations and tire tread patterns.

Advantages of standardization within a state's fleet are numerous and most are obvious. The following are a few that come to mind:

- The fewer the variants within an equipment class, the larger the blocks of units comprising the order. While hard to confirm, it is logical to expect lower prices.
- Reduced inventories and associated lower capital cost of inventory is a measurable advantage to standardization.
- There is an increase in familiarity with the fleet support network and ensure improved communications when dealing with fewer suppliers.
- Reduced difference between successive annual buys reduces required training of operators and mechanics and material problems that might result in absence of appropriate training.

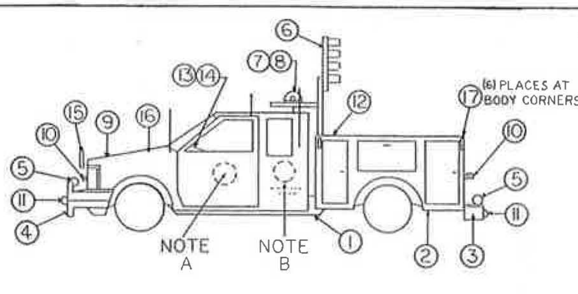
Fleet standardization has associated costs and obstacles. Specification constraints to achieve standardization will undoubtedly restrict competition. A few years ago, specifying radial tires on motor graders to achieve a radial equipped fleet, meant that they would be supplied with Michelin tires as "they were the only act in town." In North Carolina this prevented such a move until Goodyear manufactured such a tire. This is an example where purchasing law or the purchasing organization may encourage or require maximum competition. When allowed and restricted competition is recognized by suppliers, their perception that they are locked into the business may encourage a rise in their prices. Vendors that perceive they are locked out may cause political or legal problems for the organization. Too close a focus on a few suppliers may result in a loss of visibility across the marketplace and cause the buyer to miss innovative changes in the industry by other suppliers. A final obstacle to standardization may be observed when operators, sometimes mechanics, and often engineers that salespersons get to, may have name brand biases. They may identify associated desires as requirements for other than the standard unit. Unhappy operators may communicate their displeasure with other than John Deere motor graders by abusing the Caterpillars.

Early attempts at general standardization in NCDOT were primarily through central unit generated specifications. These specifications presumed an understanding of what field forces needed that was based on informal communications, personal knowledge and the influence of manufacturers' representatives. Ideas from the field that were not addressed resulted in resentment. Field forces were heard to say that "headquarters is telling us how to do our job and what to do it with." To meet this initial communication challenge several years ago, a Specifications Committee was formed that reviewed each significant specification before it was used in an annual procurement. Committee composition ensured field representation and generation of consensus specifications that included user ideas.

Committee members included representation from many groups:

- Division/district Maintenance Engineers,
- Maintenance Supervisors,
- Operators of Specialty Equipment,
- OSHA/Safety Representatives,
- Equipment Maintenance Supervisors;
- Specification Writers, and
- Invited Guests, such as Manufacturers' Representatives.

The representatives from the equipment industry were most helpful in advising what was available in the marketplace and addressing, for unique cases, the



NOTES :

ALL FEATURE ITEMS STANDARD

A: THIS SPACE RESERVED FOR MAP INSIGNIA

B: LOCATE EQUIPMENT NUMBER AND TRISKELION AS SHOWN

C: AMPS: 34.8 LINE-AMPS SINGLE PHASE
VOLTS: 115 V.A.C.
POWER: 4,000 W
FREQUENCY: 60 HZ.

OTHER STANDARD FEATURES INCLUDE:
POWER WINDOWS
POWER LOCKS
AIR BAGS
DUAL FUEL TANKS
TOWING PACKAGE
PRE-WIRED FOR ACCESSORIES

ITEM	NOTE	DESCRIPTION	D.O.T./NCO'N NUMBER
17		HIGH INTENSITY LIGHT	55-23729
16		MAP DECAL	
15		MAP SIGNBOARD	
14		DOT TWO WAY RADIO	
13		PA SYSTEM	
12	C	GENERATOR - HYD. DRIVEN	
11		CENTER PULL HOOKS	
10		JUMP START PLUGS	
9		FRONT MOUNTED HYD. PUMP	
8		WORK LIGHTS	
7		STROBE LIGHTS	
6		ARROW BOARD	
5		WINCH (FRONT + REAR)	
4		PUSH BUMPER (FRONT)	
3		STEEL STEP BUMPER (REAR)	
2		UTILITY BODY	
1		CAB + CHASSIS	

STANDARD EQUIPMENT DRAWING

DESCRIPTION: MAP TRUCK
¾ TON, 4X4, EXT. CAB W/REAR SEATING
AT, PS, ABS, A/C, AM/FM RADIO

DATE DRAWN	REVISED DATE	BUY YEAR	
12/20/93	3/8/94	1994-95	
APPROVED BY	CHECKED BY	CLASS CODE	OPTION
HLM	WD	0210	A

FIGURE 1 Standard equipment drawing for a map truck.

"buildability" of the specified unit. The Committee is often augmented to handle special purpose equipment with specific user groups represented. In this way representative users identify needs, unit safety is considered, a consensus is reached, and recommended specifications are drafted or modified. Resulting specifications, while more detailed, incorporate essentially all desires from the field in a single unit. The improved methods for accommodating users needs into specifications resulted in better detailed and more standard specifications, but these documents did not provide effective communication tools with field forces.

The vehicle used in NCDOT to identify what is available, in other words, to identify the units represented by detail specifications, is the specification drawing book. It provides a drawing that includes all available options for each significant equipment class. The specification drawing book is provided to field forces along with a price list and the division fair share budget allocation for replacement equipment. Resulting prioritized equipment lists are expected to become progressively more standardized among the several organizations. Equipment replacement lists from across the state are collated centrally and the year's consolidated buy list generated.

The cornerstone of NCDOT's standardization program is the drawings that tell the customers up front what is available. In the past, misunderstandings of what the user thought was being ordered caused severe problems many months later when equipment was delivered. The drawing of the class 210 motorist assistance patrol (map) truck is shown in Figure 1. While the detail of this unit may appear to be overkill, it includes needs from all the geographical locations with congestion management teams and this unit is less costly than supplying three or four different versions.

The 1993-94 buy year incorporated NCDOT's drawing catalog in identifying requirements. The buy cycle has been much smoother. While there is plenty of room for further standardization, the improved system discipline will make further efforts easier. There are additional benefits to using standard drawings. Using standard drawings and denoting numbers required by various customers provides a basis for generating definitive production orders, by division, at the central equipment depot. The drawings are used to ensure customers receive units prepared for delivery that reflect accurately their order. Also, responses to inquiries from suppliers receiving purchase orders based upon detail specifications are often easier when shown in a picture of anticipated unit characteristics. Progress toward "intrastate" equipment standardization is slow in NCDOT, but much more deliberate today than it was several years ago.

ADVANTAGES OF STANDARDIZED EQUIPMENT SPECIFICATIONS

Francis E. Allred
Alabama Department of Transportation

The Southeastern Equipment Regional Managers has met for the past eight years. One of the topics on the agenda each year has been to assign a specification for one particular piece of equipment to each of the 12 states. Equipment managers are responsible to research the specification with the other 11 states and compare how their specifications differ. Through this exchange a lot has been learned about why states specify things differently. This exchange has resulted in more uniform specifications. The exchange of this information will continue, and more uniform and improved specifications will be developed. This process has made the meetings very meaningful and each state has gained valuable information from the comparisons.

Alabama DOT has made a good number of changes which have improved the specifications and allowed the purchase of equipment that is better suited for the job, and at a more competitive price in some instances. The ultimate goal is for several states to buy equipment from the same specification and from the same bid. Using this method would give smaller states a great advantage because of the volume of purchasing. Attached is a dated comparison of a motor graders purchased by the different states. If this comparison were made today the specifications would be much closer than what is presented here.

TABLE 1 SOUTHEASTERN STATES EQUIPMENT SPECIFICATION COMPARISON FOR MOTOR GRADER

STATE	MOLDBOAR D LENGTH	TIRES	SCARIFIER	WARRANTY	WEIGHT	TYPE	ENGINE - HP DISPLACEMENT (cu.in.)	TRANSMISSIO N SPEED RANGE (MPH) SHIFT
ALABAMA	12 Ft.	1400 x 24 12 PLY	V Type 5 Tooth	Mfg. Std. Wty. 5 Yr. 5000 Hr. Powertrain & Hyd.	32,000	Articulated	Diesel 6 Cyl 145 hp N/S	4F - 3R N/S Powershift
ARKANSAS	14 Ft.	1400 x 24 12 PLY Brands x,y,z	V Type 9 Tooth	Min 12 Mo. or Vendor Std.Wty.	28,500	Articulated	Diesel water cooled 125 hp	4F - 3R N/S Powershift
FLORIDA	12 Ft.	1400 x 24 12 PLY Radial x,y,z	Option V-9 Tooth	Mfg. Std. Wty.	25,000	Articulated	Diesel 4 cyl 125 hp 359 C.1.	4F - 4R ? Powershift No-converter option
LOUISIANA	12 Ft.	15.5 x 25 8 PLY	V-5 46' Cut	!2 Mo./1500 Hrs. Dealer Service Statewide Required	20,000	Standard	Diesel 85 hp N/S	N/S N/S Powershift
MISSISSIPPI	12 Ft.	1400 x 24 10 PLY Radial	N/S	Mfg. Std.	29,500	Articulated	Diesel Water Cooled 135 hp N/S	4F - 3R N/S Powershift
NORTH CAROLINA	13 FT.	1400 x 24 12 PLY	V-9 46 Inch	12 Mo. or Mfg. Std. if Longer	27,500	Conventional	Mfg. Choise for job performance specified	4F - 2R 3.6 to 8 Powershift
SOUTH CAROLINA	12 FT.	1400 x 24 12 PLY	V-5	12 Months	26,000	Articulated	Diesel Water cooled 135 hp N/S	4F - 4R N/S Powershift
TENNESSEE	12 Ft.	1400 x 24 12 PLY	V Type 9 Tooth	Engine and Drivertrain: 3 Yrs.- 5000 Hrs.	25,390	Articulated	Diesel 125 & 2200 359 C.1.	5F - 4R 2.2 - 23.9 Powershift
VIRGINIA	12 FT.	1400 x 24 10 PLY	Rear Mtd. 9	24 Mos. as Covered Under Mfg. Std. Wty.	27,100	Articulated	Diesel 125 hp N/S	4F - 3R N/S Powershift
WEST VIRGINIA	12 Ft.	Mfg. Std.	V-Type	Mfg. Std.	27,100	Articulated	Diesel - Mfg. std. for unit	N/S Max 20 mph Powershift

SECTION VIII REHABILITATION, PURCHASING, AND LEASING

EQUIPMENT REFURBISHING IN PENNSYLVANIA DOT

Ronald D. Doemland
Pennsylvania Department of Transportation

Refurbishing in Pennsylvania Department of Transportation (PennDOT) started slowly. In 1984, some construction equipment was converted from standard transmission and gasoline engines to hydrostatic drive and new diesel engines. In 1987, PennDOT began a rather aggressive equipment refurbishment program which is still in progress today.

Some advantages of refurbishing equipment are:

- Saves money when compared to purchasing new equipment,
- Allows Capital Budget funds to be used for the purchase of new equipment,
- Provide the opportunity to bring updated technology into the equipment fleet,
- Familiar equipment remains in the fleet, and
- With refurbishing, end users often exhibit new equipment pride.

In PennDOT, refurbishing candidates must meet four criteria:

- The cost should not exceed 40-50% of a new unit,
- The completed unit must not only meet todays needs but tomorrows needs as well,
- The refurbished unit must approach the oife expectancy of a new unit, and
- The end user must be satisfied with the refurnished unit.

Since 1987, PennDOT has refurbished over 600 units at a savings of about $25 million. Equipment which has been refurbished is listed below:

Equipment Type	Quantity	Total Savings, $
Single Axle Dump Trucks	302	$ 12,100,331
Tandem Dump Trucks	52	1,567,500
Road Tractors	14	323,704
Belt Loaders	30	2,215,926
Rubber Tire Rollers	25	953,350
3 Wheel Rollers	118	5,508,000
4-6 Ton Static Rollers	91	2,009,241
Total		**$ 24,678,052**

Some refurbishing projects have been more successful than others and some have been dropped because the cost savings no longer existed. PennDOT remains committed to refurbishing whenever and wherever it is appropriate and we continue to look for new refurbishing projects. As Larry Stewart stated in a recent issue of *Construction Equipment*, "Equipment managers who measure just the right mix of rebuilt machines that work cheaper and new machines that work smarter should be heroes in the years ahead."

TABLE 1 PENNSYLVANIA DEPARTMENT OF TRANSPORTATION'S EQUIPMENT REFURBISHING PROGRAM

Equipment Type	M.Y.	F.Y.	Refurbishment Cost Quantity	Refurbishment Cost , $ (Each)	Retail Price New, $ (Each)	Savings, $ Per (Each)	Total Savings, $
3 Wheel Galion Rollers	62 & 64	86-87	38	$ 16,800	$ 63,000	$ 46,000	$ 1,748,000
	65 & 67	87-88	36	16,000	63,000	47,000	1,692,000
	67 & 68	88-89	22	16,000	63,000	47,000	1,034,000
	70/73/75	89-90	22	16,000	63,000	47,000	1,034,000
International Tandem Dump Trucks	79	89-90	22	15,000	62,500	47,500	1,045,000
	79	90-91	11	15,000	6,500	47,500	522,500
	84	94-95	19*	22,446	65,157	42,711	811,509
International Single Axle Dump Trucks		91-92	146	16,876	53,000	36,124	5,274,100
		92-93	120	20,146	53,000	32,854	3,942,480
		93-94	36	24,706	53,000	28,294	1,018,584
		94-95	59*	24,387	56,000	31,613	1,865,167
Athey Belt Loaders	73	88-89	1	39,500	108,000	68,500	68,500
	73 & 76	89-90	5	33,560	108,000	74,440	372,200
	73 & 76	91-92	6	28,971	108,000	79,029	474,170
	73 & 76	92-93	8	33,288	108,000	74,712	597,696
	76	93-94	3	37,880	109,000	71,120	213,360
	77/78/80	94-95	7*				
Galion Rubber Tire Rollers	70 & 76	91-92	25	17,866	56,000	38,134	953,350
4-6 Ton Galion Static Rollers	76/77/80	92-93	79	8,573	30,500	21,927	1,732,233
	78 & 80	93-94	12	9,916	33,000	23,084	277,008
Road Tractors	81	92-93	3	25,032	53,000	27,968	83,904
	80 & 81	93-94	9	32,800	55,000	22,200	199,800
	81	94-95	2*				
			604 + * 87 units to be refurbished during FY 94-95			Total	$ 24,959,561

EQUIPMENT ACQUISITION CHOICES: MAKING THE RIGHT CHOICE IN TODAY'S FINANCIAL ENVIRONMENT

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As capital budgets continue to come under closer scrutiny and tighter spending reduction pressures, individual agencies and public officials are often faced with having to use alternative equipment acquisition methods to secure needed machines for key maintenance operations. Understanding the true costs of alternative machine acquisition methods can sometimes be confusing. What appears to make sense at the time of bid opening, can often be a very expensive or impractical choice when considered on a long-term or entire fleet basis. Determining which acquisition alternative is the best choice for a particular agency or operation will require detailed study, however, often the best way to start is simply to ask, "Do I have a real need to own the equipment or do I really just need to have use of the equipment?" Depending on local acquisition laws, a public agency can be in an excellent position to truly consider the benefits of paying to "use" a piece of equipment versus paying to "own" a piece of equipment.

There are many choices offered today for acquiring machines. Closed-end leases, open-end leases, municipal leases, residual values, short-term rental, total cost, skip payments, balloon payments, low A.P.R., fixed payments, variable payments, and many other choices. All these different choices, however, can normally be grouped into one of the following six common categories of equipment acquisition methods.

COMMON EQUIPMENT ACQUISITION METHODS

1. Straight Rental of Equipment;
2. Straight Lease of Equipment;
3. Cash Purchase or Rental Purchase of Equipment;
4. Lease Purchase of Equipment;
5. Purchase w/trade or buyback guaranteed; or
6. Any of the five above methods combined with a guarantee of repair, parts, labor, and/or maintenance costs

Paying to Own

When cash purchasing, rental purchasing, lease purchasing, or finance purchasing with a trade or buyback guarantee, you are paying to "own" the equipment. Paying to "own" the equipment, however, often requires the commitment of a higher cash flow than "use" acquisition methods such as straight rentals or operating leases. Buying a machine outright offers the best chance of obtaining a dealer's deepest discounts, but using cash ties up capital that might be better utilized in other investments or areas of budget expenditure. Sometimes simply financing equipment purchases can help invest hard-earned budget cash where it will produce the greatest return. For example, if you put 20% down on a $150,000 machine and financed the remaining $120,000 at 9% percent for 60-months, you would pay more than $29,000 in interest over the term of the note. Paying cash for the machine saves that sum. The problem is, even a very conservative rate of return (if local statutes permit) would produce $155,000 on a $120,000 investment over five years. Comparing the total acquisition costs (TAC), the combined finance charges, down payment, prepayment penalties, fees, other costs, and terms from various lenders will help reduce the impact of borrowing.

Paying to Use

When renting or leasing (often called a straight lease, true lease, or operating lease) a piece of equipment, you are paying for the "use" of the equipment. Often, a purchase option can be provided as part of the rent or lease contract, however, the purchase option when combined with the monthly rental or lease payments will often prove to be a higher "owning" cost than other acquisition methods.

Renting Equipment

The straight renting of equipment normally fills a short-term need rather than putting off a buying decision. Rentals have also become the industry's "try before you buy" test drive. Renters are attracted by the opportunity to get the machine they think they need, earn some equity with it, and (if structured properly) convert it to a purchase, all with no money down. Rental contracts normally have minimum obligations compared with

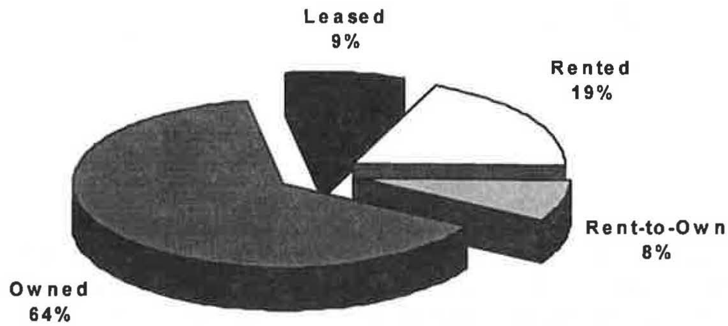

FIGURE 1 Short-term rentals and rental-purchase agreements increased 76% between 1987 and 1991 in the United States. The total universe of America's fleet is 1.28 million machines. Source: Construction Equipment Magazine, April 1994.

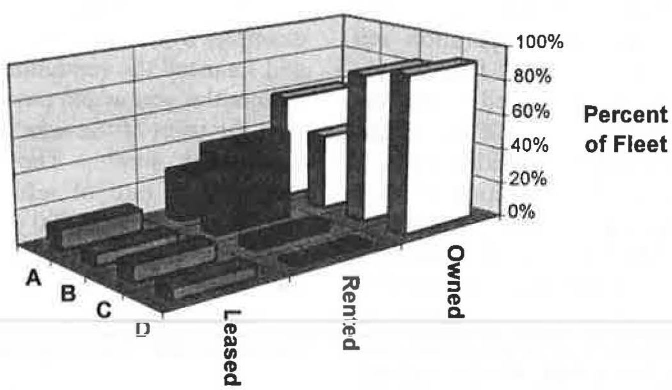

FIGURE 2 Until recently, many government agencies have not been allowed to rent or lease, but budget-conscious fleet managers are making progress revising procurement law to allow rental of low utilization machines. (A=highway and heavy construction firms; B=building firms; C=materials and mining firms; and D=governmental agencies.) Source: Construction Equipment Magazine, April 1994.

other acquisition methods. In a straight rental, the customer is paying for only the "use" of the equipment and not its ownership.

Leasing Equipment

Leasing is an escape hatch for buyers wary of long-term ownership or buyers faced with stretching budgets to cover a variety of acquisition needs. The same cash crunch that encourages agencies to finance, rather than buy machines outright, has also spurred the lease's popularity over conventional financing.

Leasing equipment is normally a good choice for longer-term equipment "use" without making a relatively high investment. The customer usually has a longer term obligation with a lease than a rental, however, the monthly lease payment will normally be lower than a straight rental due to the longer term commitment. Like a rental, with a lease, the customer is paying for the "use," not the "ownership" of the equipment. Low cash flow options are available with leases that can help justify the development of newer equipment fleets or the replacement of higher quantities of machines.

A = Highway & Heavy Construction Firms,
B = Building Firms,
C = Materials & Mining Firms, and
D = Governmental Agencies.

Many terms and options are available with leases, including master lease packages, which can greatly reduce traditional acquisition paperwork and procedures. Leases can also be structured where the agency can blend/balance their options for acquiring the machines at the end of the lease.

For example, a choice can be made at the start of a lease to have the lowest monthly payments and no funds going to reduce the machine's residual value (normally leasing with no intention or obligation to own) or starting the lease with higher monthly payments and some of those funds going to reduce the machine's residual value (normally leasing with intention, but no obligation to own). The flexibility of leasing can allow agencies to almost have their proverbial "financial budget cake and eat it too."

For one month's payment up front, agencies can lease a machine with the option to buy. The value of the money saved on the down payment can reduce the lease's TAC to equal or less than conventional financing. For example, purchase price of machine = $160,000. If an agency puts down 20% ($32,000) and finances the remaining balance over 60-months at 8.5 percent, the loan's TAC is $189,567. Leasing the same machine over 60-months, with a purchase option fixed at 25 percent of the original selling price, would require only a month's payment in advance of $3,258.86. The lease's TAC equals $198,790. The lease cost $9,233 more than the loan in cash flow over the term. However, it leaves $28,741 in your pocket, the difference between the first lease payment the loan's down payment, that you would not have if you financed the purchase. Assuming you could make 10% annually investing that money over five years (if local statutes permit), it would earn more than $18,500. To compare the total cost of the lease to the loan accurately, subtract the $18,500 earnings from the lease's TAC. The adjustment brings the lease's overall cost down to $180,290, about $9,277 less, in this example, than the TAC of the loan.

Cash Purchase of Equipment

Cash on the barrel head is the most common method used today by governmental agencies to acquire equipment. It is the lowest cost method for acquiring a machine that you want to own. When combined with an effective machine repair, parts, and labor coverage contract, cash purchase is also the lowest cost method for owning, operating, and disposing of equipment. Properly structured, cash purchase can be a near ideal method for long-term use of equipment by a governmental agency. The biggest barrier to cash purchase for many agencies, however, is the relatively high initial cash flow requirement.

Lease Purchase of Equipment

Properly structured, a lease purchase contract for a governmental agency (often called a municipal lease purchase contract) normally offers one of the lowest financing costs for owning equipment. As such, lease purchasing is an excellent ownership acquisition tool for matching existing equipment budgets to equipment needs by reducing initial cash flow requirements. Normally the total acquisition cost associated with a lease purchase is much lower than the costs incurred by an agency in issuing a bond for raising capital to pay cash for the equipment. The lease purchase contract can be written so there are no early payment penalties and also provide non-appropriation of funds clause protection for the customer.

Purchase with Trade or Buyback Guarantee

On a long-term fleet management basis, the purchase of equipment that includes a trade or buyback guarantee of those same machines will normally be the highest cost acquisition method for owning, operating, and disposing of equipment. The main reason for its high relative cost is that the customer is asking the bidder to be responsible for costs that the bidder has little control over. To protect himself, the bidder must add some cost cushion to his guarantees. In addition, this method of acquisition normally has extensive customer record keeping requirements, that if not performed, make the contract guarantees null and void. Due to the record keeping requirements, required maintenance, required inspections, required operator maintenance, required mechanic qualifications, instability of some dealers and resultant unenforceable performance bonds, force majeure, and/or a combination of these or other factors; a low percentage of the contracts have the trade or buyback guarantee effectively utilized, which negates any possible "real" benefit of this type of acquisition method.

Along with the high cost, this method normally also has the highest initial cash flow requirements and a limited number of bidders are usually willing to participate. With all these problems, why would an agency want to consider this acquisition method? Although the costs are relatively higher, if dealing with a reputable supplier, the costs are guaranteed and can be accurately budgeted. Accurate budgeting, sometimes, is worth the additional cost to some agencies.

TABLE 1 SAMPLE 2.5 CUBIC YARD WHEEL LOADER

Base Machine Price	$ 85,500
Front axle hydraulic lock	1,100
17.5 x 25 12PR L2 tires	750
Rops Cab w/deluxe cloth seat	4,500
Bucket w/teeth & return-to-dig	6,500
Counterweight, drawbar, and fenders	2,250
M.S.R.P.	$ 100,600
Factory freight	1,100
Prep, insp, del	750
Window Sticker	$ 102,450
Dealer Bid Price	$ 92,500

ANALYZING ACQUISITION COSTS

When considering the six basis acquisition methods, it is sometimes helpful to layout the choices and look at their relative, bottom-line costs. For comparison purposes, assume that a standard four wheel drive wheel loader is being considered for acquisition by a governmental agency.For example purposes, let us assume that the dealer bid price of $92,500 is acceptable and that the customer now wants to consider various acquisition alternatives. The customer in this example is considering the acquisition of twenty-five (25) machines and wants to compare the TAC of various "pay to use" and "pay to own" options.

The following table shows four acquisition methods and compares their first month cash flow requirement, the first twelve month cash flow requirements, and total acquisition cost over 60-month period. Using this approach, a governmental customer can quickly see which plan is the smarter choice in terms of initial cash flow or total investment. The costs for machine repair, parts, and labor are assumed to be the same in each example.

In the above example, if the agency is interested in "owning" the equipment, the lowest total acquisition cost is represented by the lease purchase method (if the agency can recognize return on invested funds). If the agency cannot recognize invested funds, then the straight cash purchase option represents the lowest TAC. If, however, the agency does not have $2,312,500 to purchase the units, they might consider the lease purchase option which only requires $507,273 in cash the first year. The agency could then payoff the amount owed on the lease purchase the next year or continue the contract to its full term.

Another use of the lease purchase contract is to "leverage" an existing capital budget into covering additional items compared with the straight cash purchase method. For example, if the agency had the $2,312,500 in cash to purchase the loaders, but decided to use the lease purchase contract, they would have $1,805,227 left after paying for the first year of the lease. These funds could then be applied to other purchases, capital, or personnel requirements and still have "use" of the twenty-five loaders. The agency could then payoff the amount owed on the lease purchase the next year or continue the contract to its full term.

The rental option also offers the agency "leverage" within an existing capital budget by providing new machines as needed each year for agency "use" with minimum obligation and substantial cash flow savings. For example, if the agency was considering the purchase of the loaders, but trading them for new units after twelve months (commonly calling rolling), substantial cash flow savings ($1,652,500) would be gained by simply renting the machines for the number of months needed (in this example, eight months) with an option to rent new units at the start of the next eight-month period. The agency could also eliminate the administrative paperwork and procedures involved in the buying and selling of a $2,312,500 group of machines annually.

Compared with straight rental, additional cash flow could be saved if the agency committed to a longer-term "use" of the equipment through an operating lease. Although the agency would not own the equipment at the end of the operating lease, they would have full "use"

TABLE 2 FOUR ACQUISITION METHODS AND A COMPARISON OF THEIR FIRST MONTH CASH FLOW REQUIREMENT

Cash Purchase Machines:	Down Payment	=	$ 0.00
	First Month Cash	=	$ 2,312,500.00
	First Year Cash	=	$ 2,312,500.00
	Return on Invested Funds	=	$ 0.00
	Total Acquisition Cost	=	$ 2,312,500.00
Lease Purchase Machines:	Advance Payment	=	$ 39,021.00
	First Month Cash	=	$ 39,021.00
	First Year Cash	=	$ 507,273.00
	Return on Invested Funds	=	$ 461,930.00
	Total Acquisition Cost	=	$ 1,918,315.00
Monthly Rental of Machines:	Advance Payment	=	$ 0.00
***Assumes machines are rented eight months yearly and are turned back each year for new rental units the following year.**	First Month Cash	=	$ 82,500.00
	First Year Cash	=	$ 660,000.00
	Return on Invested Funds	=	$ 311,783.00
	Total Acquisition Cost	=	$ 2,988,217.00
Straight Lease of Machines:	Advance Payment	=	$ 47,101.00
	First Month Cash	=	$ 47,101.00
	First Year Cash	=	$ 612,313.00
	Return on Invested Funds	=	$ 365,543.00
	Total Acquisition Cost	=	$ 2,516,618.00

***Note: Figures shown are for example only and are not meant to represent the best choice available at any given time, on any given bid, in any given area, from any given bidder.**

of the machines for 60-months and would normally not be responsible for major repairs on the units. Operating leases of 36-months may be more attractive than leases of 48 to 60-months which allows the user to return machines more frequently helping keep the fleet newer (fewer breakdowns) and provides the latest in production-enhancing product innovations and features.

It should be noted, however, that users (lessees) will pay a premium for this flexibility. Leasing companies tend to calculate lease payments based on a machine price close to suggested list. There is little incentive for a dealer to offer the deepest possible discount on a new machine that may show up on their used-equipment lot in a couple of years. Lessors also tend to compensate themselves generously for their capital investment by using the interest rate they build into lease payments. Left unchallenged, the rate often approaches the prime rate plus up to six percentage points. While the deck may seem stacked, each of these issues represents a negotiating opportunity.

Maintenance contracts in which the user leaves preventive maintenance and light-repair responsibility with the lessor are increasingly common elements that can add value to the lease agreement.

The machine's residual value (the price the user pays to exercise the purchase option) is a critical component of the lease's total cost. Monthly payments will likely be lower if the residual value is close to the fair-market value and the lease payments are calculated to reimburse the owner for the real value of the machine during its use. A fair-market value lease is based on the actual value (or estimated value) of the machine being established at the end of the lease.

Many users, however, are uncomfortable in signing a lease without knowing the residual value. When the owner presets residuals, they like to set them low and compensate for the difference between preset residual and actual value in the monthly payments. If the user decides to return the machine at the end of the term, the owner has already been paid more than market

TABLE 3 WHICH BID IS THE BETTER CHOICE?

BIDDER A		BIDDER B	
Purchase Price	$ 70,655.00	Purchase Price	$ 80,655.00
Guaranteed Parts/Labor Cost	4,500.00	Guaranteed Parts/Labor Cost	3,500.00
Guaranteed Repurchase Price	no bid	Guaranteed Repurchase Price	40,300.00
Total Cost	$ 75,155.00	Total Cost	$ 43,855.00
Bidder A Claims:		Bidder B Claims:	
Purchase Price Savings	$ 10,000.00	Machine Cost Savings	$ 31,300.00

BIDDER A		BIDDER B	
Purchase Price	$ 70,655.00	Purchase Price	$ 80,655.00
Guaranteed Parts/Labor Cost	4,500.00	Guaranteed Parts/Labor Cost	3,500.00
Available Investment Funds	10,000.00	Available Investment Funds	0.00
Estimated Funds Earnings	5,657.00	Estimated Funds Earnings	0.00
Machine's Used Value	38,860.00	Guaranteed Repurchase Value	40,300.00
Total Acquisition Cost	$ 30,638.00	Total Acquisition Cost	$ 43,855.00
At Contract Termination:		At Contract Termination:	
Funds Left in Bank	$ 10,000.00	Funds Left in Bank	$ 0.00

value in lease income and can unload the used machines quickly.

The practice of low preset residuals obliges many users to buy leased machines to recoup some value of their lease payments. A fair-market value lease helps counter the residual hedge and normally gives the user lower lease payments. Experience is also improving the leasing companies' ability to estimate residual prices closer to fair market value, helping make leases a more viable acquisition method for more governmental agencies.

CAN YOU TELL WHICH BID IS THE BETTER CHOICE?

An agency has asked bidders to provide unit purchase price, plus a guarantee for repair, parts, and labor, and a guaranteed repurchase for a period of five years or 5,000 hours of use. Shown above are two sample responses.

Often the type of bid shown above is called a total cost bid or life cycle cost bid. With only the information shown in the above table, knowing which bidder is the smartest choice is difficult. One might be tempted to conclude, since bidder B had the confidence to provide a guaranteed repurchase price, bidder B might be the smarter choice. Unfortunately, the total cost bid method of acquisition does not cover all of the total machine or acquisition costs. Fuel consumption rates, ground engaging tool wear, and time-value of money are often overlooked or deliberately avoided in the total cost methods of acquisition. To avoid potential pit falls with this method of acquisition, it is often helpful to make a comparison to conventional purchasing techniques to determine total investment costs.

If both machines meet all operational and specification requirements, one technique that can help determine which bidder represents the best choice is to compare the bidders on the time value of money and wholesale equipment value basis.

The available investment funds entry in the above table makes the assumption if the agency is willing to accept bidder B and spend $80,655 purchasing his machine, why not purchase bidder A and invest the purchase price difference and take advantage of the time value of money?

The estimated funds earnings were computed on a $10,000 investment earning 9% annually, compounded monthly, for 60-months. The machine's used value for bidder A was computed by taking equipment bid price and projecting that the machine would have a wholesale value, as-is where-is (in five years or 5,000 hours) of 55% of the bid price ($70,655 x 55% = $38,860). Calculating a machine's expected used value is an important step when comparing bids that include total cost or life cycle cost guarantees. Often agencies forget to include the used value of a machine from a bidder who has not guaranteed a repurchase price when comparing total acquisition cost. Leaving this step out can cause a significant calculation error. An interesting note in this comparison, if the agency selects bidder A and spends the whole amount required ($80,655) to purchase bidder B, the agency saves $13,217 in total investment and has $10,000 remaining in the bank at the end of five years. Even if the used equipment value is off by 30%, the agency would still save more than $1,550 in total investment and still have $10,000 remaining in the bank.

Based on this type of analysis, it would appear that bidder A, even with the higher repair costs, is the smarter choice, provided that

- The machine is capable of performing the work requirements;
- The machine meets agency specification requirements;
- The machine has a proven parts and service support; and
- The machine has a low operating cost.

Making the right acquisition choice will not always be as simple as the examples detailed here. However, it is hoped that armed with some analysis on acquisition choices covered in this report, a public official can better answer, "Do I have a real need to own this machine or would I be better to simply pay for the use of this machine?"

THE FUTURE OF FLEET MANAGEMENT: THE OWNERSHIP DECISION

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Hertz Equipment Rental Corporation

OUTLINE

A. Equipment Ownership

- What are Trends for the 90's?
- What are Budget Implications?
- What effect will the Economic Cycle have?
- What are Relative Benefits of...
  - Renting?
  - Leasing?
  - Ownership?

B. Future Trends

- Short Term Economy - Positive
- Long Term - Uncertain
- Financial Sophistication Improving
- Budget Tips
- Reinventing Government
- Governments
  - Cost Reduction
  - Risk Reduction
  - Efficiency

C. Fleet Decisions

- What has changed?

Pride of Ownership — Renting, Leasing
Financial Sophistication

- Non-Financial

Pride of Ownership — Renting, Leasing
Shorter Term Projects
Diversification/Flexibility
Economic Cyclicality

D. Rent *versus* Buy

Rent

- No maintenance cost - Maintenance cost built into one price;
- No disposal problems;
- Cost accounting - simplified;
- Newness of equipment;
- Flexibility on job planning;
- Labor downtime is less;
- Fixed rate cost - no hidden cost of ownership; and
- No credit line tie up.

Buy

- Build assets on your books;
- Buy equipment to your own needs;
- Pride of Ownership;
- Availability of equipment for use; and
- Interest rates are down.

E. Key Points to Consider

- Budgets;
- True Cost Ownership - Direct / Total Costs;
- Cost of Rental;
- Cost of Leasing;
- Utilization;
- Availability;
- Service & Quality; and
- Equipment Requirements.

F. Cost Implications - Typical Backhoe

Rental	$ 55,000
Discount (16.2%)	- 9,000
Price	46,000
Down Payment (20%)	- 9,200
Amount Financed	36,800
Depreciation (72 months)	639.00
Interest	144.00
Maintenance & Insurance (WAG Method)	300.00
Loss of Income on Down Payment	54.00
Estimated Gain	- 51.00
Monthly Payment	$ 1086.00
	72.4% Utilization
Per Year	$ 13,032.00
Average Rental Rate, $1,500/month x 12 months =	18,000.00

G. Final Analysis

Cost

- Cash Flow;
- Direct *versus* Indirect;
- Budget; and
- Control

Risk

- Damage Reserve;
- Use Requirements;
- Model Improvements; and
- Cyclicality.

SECTION IX INTERNATIONAL EQUIPMENT TECHNOLOGY

JAPANESE AND EUROPEAN WINTER EQUIPMENT TECHNOLOGY

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INTRODUCTION

It has been recognized that snow and ice control operations in the United States differ from those in other countries. A Winter Maintenance Panel was organized and visited Japan and Europe to study these differences. The Panel was sponsored by the U.S. DOT's Federal Highway Administration's Office of International Outreach Programs and the National Cooperative Highway Research Program of the Transportation Research Board. The Panel consisted of six U.S. managers responsible for snow and ice control operations. They came from U.S. federal, state, county and municipal authorities.

General topics of interest to the Winter Maintenance Panel included equipment, anti-icing operations, road weather information systems, weather forecasting services, public information systems, policy, roadway level-of-service criteria, visibility and environmental issues. The Panel visited Japan March 12-19 and Europe (Germany and Austria) March 20-27, 1994. While in Austria the Panel was based in Seefeld and attended the 9th Permanent International Association of Road Congress (PIARC) International Winter Road Congress and the International Road Weather Conference.

JAPANESE WINTER ROAD TECHNOLOGY

Japan deals with very complex winter maintenance problems. Japan's population is half that of the United States, but when those people occupy an area 1/30 the size of the U.S. and 2/3 of that land is covered by mountains, high urban population density results. Hokkaido, the northern island of Japan, receives more than 500 centimeters (200 inches) of snow each winter. Heavy snowfall and high traffic volumes team up to create difficult snow and ice control problems.

Studded tires were introduced in Japan in 1962 to provide winter mobility. Before 1962 mobility was achieved by putting chains over summer tires. By the late 1970s nearly all drivers were using studded tires. These studs were much larger than those used the United States and rapidly eroded the road surface, creating a heavy concentration of dust and causing an air pollution problem. To solve the problem, the Japanese Ministry of Trade and Industry introduced a studless tire in 1982. The government heavily promoted these studless tires by offering rebates on new studless tire purchases and providing winter driving training courses. Very few vehicles have studded tires today.

Snow removal standards had to be established to insure mobility without chains and studded tires. Main trunk roads are kept clear of snow pack while lesser traveled roads are allowed to develop snow pack several centimeters deep. Trucks and plows similar to those found in the U.S. are used on the main roads while motor graders with serrated blades, sacrifiers or milling heads smooth snow packed and rutted local streets. Sand (because of air pollution problems) and salt (because it costs $200 per short ton and caused ground water problems) are used very sparingly.

Japan has developed some unique high performance snow control equipment to mechanically achieve their level of service standards with the 500 centimeters (200 inches) of snowfall they receive each winter. The Hokkaido Development Bureau uses a partnering relationship with private companies, universities and research institutes to produce heavy duty snow removal trucks, plows, blowers and blower/loaders. Their use of *mechatronics* (joy sticks and video cameras) make it possible for one person to operate a three-plow (forward, underbody and rear plows) heavy-duty truck. An open-vane snow blower/auger allows for cutting through hard packed snow. Packed and plowed snow is hauled to snow melting facilities or stored in huge piles outside the city and melted during the following summer.

Japan utilizes advanced global positioning satellite (GPS) system for tracking vehicles and reporting information to their management systems. Nearly all the government vehicles that transported the Panel in northern Japan had GPS and a television monitor reporting our current position and direction of travel on a moving street grid background.

EUROPEAN WINTER ROAD TECHNOLOGY

The Panel visited road maintenance facilities in Germany and Austria. The Panel found roads, bridges, equipment and facilities in both Japan and Europe were of high quality and well maintained. Fuel taxes in excess of two dollars per U.S. gallon and approximately 25 cents per kilometer tolls plus a $1.50 terminal fee provide an excellent funding base for roadway construction and maintenance.

The equipment display at the PIARC Meeting in Seefeld was the largest display and demonstration in Europe. Snow blowers, plows, trucks, loaders and spreaders demonstrated advanced technology and increased capacity to that found in the United States.

The price of salt in Europe is about the same as Japan ($200 per short ton). Both countries use chemicals very sparingly and prewet salt at the spinner with brine or liquid calcium chloride to reduce loss and speed up the melting process. Hopper spreaders with plastic liquid storage tanks designed to tuck into the spreader's sloping undersides are the most common design. Many have fifth wheel sensing for spread rate accuracy.

Snow plows are usually heavier than U.S. plows, often use independent one meter sections that conform to the pavement cross section or varying crown with cutting edge trip actions. They use metal, plastic or rubber blades and have foldout wings for extending the plow width. To reduce snow over spray and increase operator visibility, a canvas snow shield rides about ⅓ to ½ meter above the snow plow. This shield traps the snow spray and forces it under the truck. Both Japan and Europe use advanced road/weather information technology to assist in managing snow and ice control operations and to keep the motoring public advised on road/weather conditions.

TECHNOLOGY TRANSFER

The Panel at the end of the trip prepared a brief interim summary with technology transfer recommendations. The document was prepared to provide those agencies who organized and supported the trip with highlight information on Panel international findings about the state-of-the-practice. A more comprehensive report will be published later. [*NCHRP Research Results Digest No. 204*, "Winter Maintenance Technology and Practices - Learning from Abroad," Transportation Research Board, Washington, D.C., January 1995.]

One of the major proposals will be for the establishment of Winter Maintenance Program (WMP) where technologies imported from other industrialized nations and/or developed in the U.S. can be demonstrated, vigorously evaluated and acceptance tested in an operational setting against the present state-of-the-art. The following items discovered by the Panel will be recommended for WMP evaluation:

- European snow plows;
- European spreaders with prewetting equipment and aerodynamic tailoring;
- Japanese rearward (one-lane) snow conveying rotary plows;
- Improved anti-icing and deicing materials, and application management;
- Improved roadway weather information system technologies; and
- Road user information systems.

It is envisioned the WMP will actively develop research problem statements and provide direction for further winter maintenance research.

EQUIPMENT IN SCANDINAVIAN COUNTRIES

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ABSTRACT

Several Scandinavian countries have been experimenting with new and highly promising techniques and systems which have lead to substantial savings in de-icing chemicals without sacrificing the level of roadway service during the winter. Some of these techniques required the development and utilization of equipment such as brine making plants, spreaders for applying liquid salt, and prewetted salt and slush plows. The equipment is summarized.

INTRODUCTION

In recent years, a number of highway authorities in Scandinavian countries have been warned of the dangers inherent in the overuse of de-icing chemicals. These dangers include damage to the environment, and to vehicles, roads, and bridges. Historically, Scandinavian countries have applied a substantial amount of salt to their roadways to combat the frequent occurrences of black ice, frost, and roadway freezing after precipitation. A number of these countries have been experimenting with new and highly promising techniques and systems which have lead to substantial savings in de-icing chemicals without sacrificing the level of roadway service during the winter.

It has been demonstrated, in some countries, that salt usage can be reduced and the level of service maintained by applying salt quantities as small as 5 g/m^2 (65 lb/lane-mile) to the roadway surface prior to the formation of a strong ice-pavement bond. Once a bond has developed, the ice is very difficult to remove. If a road is pre-salted, snow will not bond strongly to the surface. Typically, the brine formed at the beginning of a snowfall is absorbed by the salt as snow continues with very little free moisture. The snow can be removed by plowing without leaving a compacted snow-ice layer, but a slush that traffic may disperse.

Salt can be applied as a salt brine in liquid application or as prewetted salt. Grain size distribution of salt used by the various road administrations in the Scandinavian countries is much finer than the salt used in the United States. Based on reports from Sweden and Finland road administrations, most of the salt grain size used in winter maintenance range from 0.16 to 3 mm (0.006 to 0.12 in) with a low percentage (maximum 5%) below 0.16 mm (0.006 in) and between 3 and 5 mm (0.12 and 0.2 in).

Some of these new and highly promising techniques required the development and utilization of new kinds of equipment such as brine making plants, spreaders for applying liquid salt, and pre-wetted salt and slush plows.

BRINE PRODUCTION UNITS

With the advent of prewetting salt and using liquid brine, the road authorities had to develop simple brine manufacturing equipment that could operate without any malfunction. There are two types of brine solution plants currently in use for the preparation of the saturated brine. Simple units for a temporary or small scale production can be built from used tanks. Production involves filling a tank with salt and pumping water through the salt until a saturated brine solution is obtained. The production capacity is generally 8 m^3 (2,113 gal) of solution at a time. The same container is used for production and storage.

For a high capacity production, more efficient units were developed. The road administrations working with private enterprises designed a plant where water is forced under pressure through a bed of salt in a large tank. In Finland, they use compressed air with the water. The saturated solution is then allowed to flow over to a 10-m^3 (2,642-gal) storage receptacle. Manufacturing of brine solution is a continuous process and the amount of salt and water is metered automatically.

The Swedish National Road Administration has developed a set of standard specifications for brine manufacturing plants. Three production rates are contained in the specifications (2 m^3/hr (528 gal/hr), 5 m^3/hr (1,321 gal/hr), or 10 m^3/hr (2,642 gal/hr)). All these units can load trucks at the rate of 211 gal/min.

When specifying brine manufacturing plants, the road administration recommends that the following items be considered:

- Plan for additional capacity,
- Adequate sources of water,

- Plant site requirements,
- Adequate pump capacity,
- Possible use of earth heat, and
- Tank overflow control.

There are several brine plant manufacturers in the Scandinavian countries. In Sweden, there are two companies and in Norway, four companies manufacture brine plants. In Finland, there are several prototype plants designed by the road administration in addition to manufactured plants. One of the more known manufacturers is Ab Hanson & Möhring of Stockholm. They manufacture module plants. Their most common plant has a production rate of 10 m^3/hr using a production tank of 8-m^3 (2,113-gal) and a storage tank of 13-m^3 (3,434-gal).

SPREADERS

There are a number of companies that manufacture spreaders for liquid brine and prewetted salt. In addition, the road administrations have either designed liquid brine spreaders or worked with manufacturers in designing spreaders. For effective preventive treatments, spreaders should apply small controlled quantities of liquid brine and/or prewetted salt with precise control of spreading or spraying patterns. The following manufacturers are only the large companies. There are a number of smaller companies that manufacture equipment for the road administrations.

Salon in Finland

Salon Terästyö Oy in Salo, Finland, is a highway equipment manufacturing company that produces spreaders and snow plows. Their equipment spreads liquid solution, prewetted salt, and dry salt and sand. The liquid solution spreader, which is mounted on the rear of a truck using a quick mounting system, is a standard for the Finnish National Road Administration. The unit has two liquid spinners that can be adjusted manually to control the asymmetric/symmetry of the spread pattern. The spread width is 2 to 8 m (7 to 26 ft). The liquid is pumped from the supply tank with two hydraulically operated solution pumps. The pumps are controlled with electric clutches and can deliver 520 l/min (145 gal/min). The supply tank is typically a skid-mounted slide-in tank. Salon employs a unique design for the supply tanks, consisting of a two-wall construction of fiberglass, separated by approximately 5 mm (0.2 in) of polyurethane. This design provides for a very strong tank. The Salon company uses electric remote controls, which are manufactured by Bucher Hydraulik of Klettgau, Germany. These controls, which are custom-designed for the client, provide for ground-speed orientation.

The company also manufactures a combination unit, which can spread either liquid brine or prewetted salt. This unit features a spreading width from 2 to 8 m (7 to 26 ft) and has only one spinner. The liquid pumps discharge up to 260 l/min (68 gal/min) and discharge salt at a rate of 5 to 40 g/m^2 (65 to 520 lb/lane-mile). The unit has a tank capacity of 5-m^3 (6.5-yd^3). The entire system is a slide-in model that can be loaded and operational within 15 minutes. Hydraulic power for the unit is supplied by the truck. The company also manufactures dry chemical spreaders, which are tailgate-mounted on a dump box. Salon works closely with the Finnish National Road Administration in providing and developing equipment for snow and ice operations.

Epoke in Denmark

Epoke in Vejen, Denmark, has been manufacturing spreaders for 65 years and has distribution companies in Germany, Sweden and the United States. This company uses a patented metering and delivery system in all their solid-material spreader equipment. All Epoke's bulk spreaders feature hopper boxes where the bottom is closed off with two rubber flaps. One of the bottom flaps is positioned against the delivery roller by adjusting springs. The delivery roller is equipped with replaceable cams, which allow material to pass between the delivery roller and the rubber flap. The cam size can be adapted for all material types and dosage rates. The tightness of the bottom flap is controlled by springs adjusted with a manual crank at the rear of the machine. A scale with sequential markings for continuous increments of spring base tension shows the relative tension. The delivery roller pushes material out of the hopper and onto a rubber conveyor belt located underneath the hopper. An impeller with spring steel paddles located above the delivery roller, is used to pulverize all lumps, distribute the spreading material in the hopper, and feed it to the delivery roller at a constant rate. The conveyor is geared to the speed of the delivery roller so the quantity of material on the conveyor remains the same regardless of the spreading quantity. The impeller, the feed roller, the conveyor belt, and the spinner are all powered by the road wheel. The drive wheel features a piston-type hydraulic pump, which is mounted directly. The drive wheel is under a downward pressure to prevent sliding on icy surfaces. The amount of downward pressure exerted is controlled automatically by hydraulics according to the power demanded by the spreading function. On spreaders with three- and seven-step gear boxes, the spread width is stated in meters, and the spread quantity is adjusted by change of the stated gears. The spread quantity is also displayed on the control box in grams per square meter. On spreaders with a synchron/9-step gear box, the control box has functions that control both quantity and width. The dosage varies from 5 to 40 g/m^2 (65 to 520 lb/lane-mile) in increments of 5. The spread width can vary from 2 to 12 m (7 to 39 ft) in 1-m (3 ft) increments.

When the spreader is equipped for prewetting, it can apply liquids directly to the material being spread. The system automatically adjusts the flow rate of liquid so that the liquid-to-solid ratio remains constant regardless of change in truck speed, spread quantity, or pattern width. The prewetting system is also equipped with hydraulic controls that automatically reduce the material quantity exiting the conveyor belt by 30% when the liquid system is engaged. Epoke manufactures liquid spreaders incorporating nozzles on a spreading boom. The liquids are sprayed from a low height above the roadway, so that there is negligible influence from air currents or turbulence behind the vehicle that can cause the liquid to blow away. Epoke's SW 2000 model is a tow-behind liquid spreader similar to their TK 12 series truck-mounted liquid spreader. The SW 2000 is designed to be towed by a truck with an existing liquid tank. As the spreader is powered by its own traction-driven wheel, it is road-speed controlled. It can be operated at speeds up to 60 km/hr (37 mph).

Liquid flows by gravity through a clear 75-mm (3-in) plastic hose from the tank to the spreader, where two liquid pumps provide liquid chemical to each nozzle. These two pumps, which are a diaphragm type featuring six diaphragms each, share a common inlet filter. The main spray bar, which is 2,264-mm (89-in) long, is equipped with six nozzles -- three large and three small. The spray bar's main nozzles can achieve 3.5 m (11.5 ft) of spraying coverage. At low speeds, the smaller nozzles are engaged. As the truck's speed increases and the need for liquid increases, the smaller nozzles disengage and the larger nozzles are engaged without a break in spray pattern. As the truck slows, the reverse process occurs and the smaller nozzles engage again. Three additional stainless steel nozzles mounted on the left end of the main spray bar are adjustable so that a spray pattern in the left lane can be maintained. With the side nozzles engaged, a spraying width of 7 m (23 ft) can be obtained. Each side nozzle is pressure regulated for a smooth and even flow, even at slow speeds.

To provide the liquid spreader with a maintenance-free environment, the liquid pumps, valving and electrical components are housed in a steel enclosure. The top covers, which open to provide for inspection and service, are rubber gasketed to prevent contaminants from entering. Also, the steel members of the spreader are sandblasted, zinc dust-primed, second-primed, and surface-coated with two-component polyurethane paint.

Kupper-Weisser in Germany

Kupper-Weisser, one of the three leading manufacturers of winter maintenance spreader equipment in Europe, is controlled by Kellner (KG), a holding company. Kupper-Weisser has designed and manufactured spreader equipment using modular systems. Because of the multiple capabilities of this system, they can accommodate all multi-use vehicles including trucks, LVDs, Unimogs, narrow-track vehicles and trailers to towed vehicles. Kupper-Weisser manufactures highway chemical spreader equipment (dry, prewetted, and liquid material), pumps and controls for mixing salt brine, and modular diesel engine with hydraulics. The typical winter maintenance spreader sizes that are manufactured by Kupper-Weisser are salt hopper boxes (6 to 9-m^3 (8 to 12-yd^3)) and liquid salt tanks (2,500-l (660-gal)). The size of the spinner is based on the desired spread width: 12 m (39 ft) spread needs an 800-mm (32-in) disk; and, 2 to 6 m (7 to 20 ft) spread needs a 600-mm (24-in) disk. If chemical is to be applied to three lanes (16 m (53 ft)) at once, dual spinners are required. Material is metered by a large, open steel helical auger. Parallel to the auger is another shaft with fingers to break up lumps. The material is delivered to a chute at the rear where it is dropped onto a spinner disk. The patented spinner has a series of three different radii that give the disk an almost triangular configuration. This shape provides different lengths of curved vanes or fins that control spread patterns on the roadway. The chute and spinner assembly is rotated to change the direction of the pattern.

Air turbulence behind the spreader vehicle may cause drifts and swirls in the salt leaving the spinner disk. To address this problem, Kupper-Weisser has a patented wind deflector mounted just behind the hopper box and projecting above it. The slip stream is deflected onto the roadway behind the spreader vehicle. Besides spreaders that can prewet salt, the company offers a unit that can be switched from prewetting to spreading of liquid chemicals. This unit has a hopper box with a capacity of 6-m^3 (8-yd^3) and two polyester tanks mounted underneath the side walls of the hopper, with a total capacity of approximately 2,000-l (528-gal). The range of the spread density for liquid application is 10 to 15 g/m^2 (130 to 195 lb/lane-mile), and the spread width is 2 to 7 m (7 to 23 ft).

SNOW PLOWS

There are many varieties of plows including one-way front plows, reversible plows, underbody plows, side wings and slush removal plows. All of the plows are hydraulically controlled. It takes only minutes to mount and unmount the plows using the quick-change buffer system. Hydraulically extendable plows have recently been developed in Finland. The width of the plow can be extended on the left or right-hand side, depending on the manufacture. These plows are best suited to roads that vary in width. The extendable plow allows width adjustment between 2.8 and 3.5 m (9.2 and 11.5 ft). Side wing plows can be attached to trucks and motor graders. The one-way front plow and the underbody plow can be used simultaneously with the side wing. The side wings are used when the width of the roadway is more than 7 m (23 ft). The side wing is also used for lowering snowbanks and for pushing the banks away from road surfaces.

Motor graders utilize a large variety of accessories such as side wing plows, snow cast extensions and smaller main blade extensions to cast snow over snowbanks, side ditch cleaning wings for lowering snow banks, bulldozer blades to clean intersections, snow blowers to cast the windrow over the snowbanks, snowstop flanges to prevent windrows at intersections and driveways, and blades for slush removal.

The Swedish National Road Administration tests and evaluates both front and side wing plows. They are tested by plowing snow depths of 30-cm (12-in), 60-cm (24-in) and 120-cm (47-in) at speeds varying from 20 to 40 km/hr (12 to 25 mile/hr) at temperatures of 0° C (32° F) and -2° C (28° F). The height and length of the throw are measured. Also, the plows are evaluated as to sound level, splash protection, handling, and ease of hooking up the plow to the unit.

SLUSH PLOWS

During the winter months in these countries, they experience long periods when the sun hardly rises in the sky and the relative humidity stays between 93 and 99 percent. Under these conditions, the roadway tends to stay wet. When slush develops from salting and plowing, the slush does not dry and must be plowed. Therefore, the combination of the rutting of the roadway surface by studded tires and salting has made the slush plow very important. Roads with slushy conditions are more dangerous for the traveling public than bare and dry conditions. These conditions require slush removal equipment consisting normally of double blade and/or rubber blade plows. The double blade plows are very good when the consistency of slush varies from wet to dry. Rubber blades can only efficiently remove wet slush. The wetter the slush, the thicker the rubber blade can be. The slush blades are either spring loaded or hydraulically controlled to maintain pressure on the road surface regardless of the deep ruts. These plows cannot remove wet or compacted snow because the rubber edges cannot withstand the pressure. Normal plows, motor grader blades, and underbody blades can be equipped with rubber edges.

The Norwegian Public Road Administration has developed a slush trailer that is very effective in clearing slush from the roads. This trailer has been equipped with ice blades, slush blades, and a brush. The brush is powered from a diesel engine mounted on the trailer. This produces a clean road surface. Traditionally, slush removal was accomplished with front-mounted truck equipment. However, the results from this trailer are so effective they are now building additional units. Plans include the attachment of a rear salt sprayer fed from a tank on the trailer. The only negative aspect of this new type of slush plow is its size and that it needs plenty of room to turn. However, this equipment is primarily intended for use on highways where its size will not be a problem.

ACKNOWLEDGMENTS

Information reported herein is part of the findings collected during a winter maintenance technology scanning and assessment survey authorized by Sections 6003 and 6005 of the 1991 ISTEA Act. These sections provide for federal support of state and other agency personnel visits to other countries to study their organizations and technology and assess which of these technologies may be applicable to winter maintenance operations in the U.S. The complete scanning and assessment findings are to be presented in a final report to the FHWA and subsequently shared with other agencies and interests in the United States and Canada.

SECTION X REPORTS FROM REGIONAL EQUIPMENT MANAGERS MEETINGS

WESTERN STATES EQUIPMENT MANAGERS WORKSHOP

Greg Phillips
Oregon Department of Transportation

SUMMARY

The Western States Equipment Managers Workshop was held in Albuquerque, New Mexico, in August 1993. There was a great deal of quality information sharing between states and support to try new approaches. This is truly a professional group. The proof is in the efficiency gains at the individual state level. The next western states' conference will be held in Salt Lake City, Utah, the fourth week in August 1994.

The 1993 conference included representatives from Arizona, Nevada, Colorado, Oregon, Texas, Idaho, Montana, Wyoming, New Mexico, Utah, Washington and Missouri. Key discussion topics included the following cost controls and efficiencies, recycling and environmental protection, preventive maintenance, repair shop productivity, optimum time for replacement, and sharing of equipment specification.

- *Cost Controls and Efficiencies.* Information was presented with discussions on the following topics: ODOT's reorganization; full service tire contracts in Oregon with service provided statewide at 80-outlets; after market statewide OEM contracts; tire wear to find the best tire at the best cost; electronic fuel injection engines and their performance; and automatic transmissions in dump trucks and their performance. These discussions were aimed at finding the best product and service.
- *Recycling and Environmental Protection.* Topics in this area included recycling antifreeze; synthetic oils and lubricants; alternative fuels and how are they performing; solar powered arrow boards and variable message signs; and cleaning of spray bars to avoid hazardous material spills. There is true interest in protecting the environment.
- *Preventive Maintenance.* The fleet topics in this area included customized inspections; pre-trip inspections; performance measures to insure proper preventive measures occurs; service intervals; and operator abuse. The theme is to implement new techniques to prevent problems before they occur.
- *Repair Shop Productivity.* The questions in this area included: where can gains be made; what training is needed as a basis for mechanics and as a follow-up; and how are states measuring performance. There was also discussion on employee motivation and employee efficiency gains.
- *Optimum time for equipment replacement.* This area included discussion and examples on leasing verses acquisition; life-cycle costing in the bid process; life-standards between states; automated fleet management systems; and equipment resale.
- *Sharing of Equipment Specifications.* This topic included discussions on significant changes in standard specifications; successes and failures in new specification design; and a discussion of multi state purchasing of equipment and potential savings.

The information sharing in these workshops is excellent and critical to continued successes. Representatives from the states are enthusiastic and eager to share successes and failures, and to try new ways of doing business.

1994 MIDWESTERN STATES EQUIPMENT MANAGEMENT CONFERENCE

Richard W. Hunter
Illinois Department of Transportation

SUMMARY

The 6th Midwestern States Equipment Managers Conference was held June 6-8, 1994 in Arlington Heights, Illinois and hosted by the Illinois Department of Transportation (IDOT), Division of Highways. The following is a brief summary of discussion topics and information reported during the meeting.

● *Alternative Fuels Update.* Illinois has several ethanol flex-fueled automobiles for pool use. Kansas has several flex fuel cars and light trucks for use in metro areas. Minnesota recently purchased 20 E85 Chevrolet Luminas and is using propane fueled pickup trucks. These have had problems with poor performance and hard starting in cold weather. Iowa is operating 25 alternative fuel vehicles, 21 were purchased this year. They are a combination of Ethanol and slow-fill CNG. Several medium duty highway maintenance trucks have been equipped with an injection system that mixes 20% soy oil and 15% ethanol. The after-market system costs $9,500.00 but appears to work. South Dakota is using some alternative fueled busses, primarily bio-diesel. North Dakota has no alternative fuels in use. They must be provided as an OEM product to be considered. Missouri is operating 30 dual fueled vehicles. GMC is in the process of retrofitting their CNG vehicles with gasoline engines. They are still operating several propane powered vehicles and will begin using soy-diesel powered trucks in the near future. Ohio is using 20 dual fuel (CNG powered) pickup trucks in the Cleveland area. They are constructing quick-fill facilities. Indiana is operating four CNG Chevrolet S10 pickup trucks. Fuel sources for these vehicles is a problem.

● *Color Standardization - Are We Any Closer Today?* Indiana, Missouri, and South Dakota use yellow for their vehicle fleet. They will allow some "off-road" equipment in manufacturers standard color. The rest of the states use a variety of oranges. Kansas purchases all orange with no deviation.

● *Automatic Transmissions - Experiences with Allison MD Series. What Manual Transmissions Are Currently Specified?* Illinois purchased 190 trucks with Allison World Transmissions both the 3060 and 3560 models. The only problem experienced with the World Transmission has been RF interference on the low band FM radio frequency. This interference locks the radio receiver until a stronger signal is received and can override the interference. Indiana and Kansas have purchased several of the MD series transmissions for evaluation. Ohio, North Dakota, and Missouri purchase mostly manual transmissions. Iowa and South Dakota trucks are equipped with standard or automatics based on the use of the truck.

● *Anti-Lock Brakes for Medium and Heavy Duty Trucks - Experiences and Expectations.* Only Kansas and Ohio have vehicles with anti-lock brakes. The cost for this feature is approximately $1,200.

● *Discussion of Fleet Management Systems.* The consensus of the group was to carefully determine what costs and records are essential for the operation. The most important function is the planning of the system. Then purchase only what is needed.

● *Equipment Fleet Size and Utilization Expectations for Government Fleets.* Missouri makes the rental of major equipment "easier" for field forces to accomplish. Ohio purchases only "core" equipment and encourages the rental of other major pieces. Kansas is under going a three phase program to reduce the amount of state owned equipment. They are currently in phase two of the program. Iowa requires 12,000 miles per year utilization or the vehicle is reassigned. They use a lane mile formula to assign snow removal trucks.

● *Re-Refined Lubricants and Fluids - Who Is Using What?* Iowa requires military specifications and American Petroleum Institute standards be met. Several states have purchased machines to recycle their own fluids. All states agreed they have had no failures of major components due to the use of recycled material.

● *Discuss the "Pros and Cons" of Remanufactured Engines, Transmissions and Other Major Components.* Kansas uses remanufactured components with warranty protection. The Illinois Tollway purchases mostly new components but does rebuild some engines and transmissions in-house if practical.

● *Discuss the Purchase and Use of Electronic Diagnostic Tools for Servicing Diesel Engines.* Minnesota has purchased these tools for their shops. They can be used for most engines. The Illinois Tollway is planning to acquire this type equipment in the coming year.

● *Discuss the Inventory Control Practices for Tools and Small Equipment.* Illinois and Missouri begin formal numbering procedures at $100; South Dakota at $300; Iowa and Kansas at $500; and, North Dakota $750. Kansas uses a decal "Property of" for all major equipment items. Several states commented that the limits for these item may be going to increase. Indiana has taken recent disciplinary action against employees for inventory discrepancies.

● *Mechanic Classification - Is Any State Using a Classification Similar to "Lead Mechanic" Similar to Shop Supervisor Position Between the Highway Mechanic and the Mechanics Job Description?* In Minnesota one mechanic gets higher grade classification. Iowa has small shops. Each has only three mechanics. No difference in grade is provided. Indiana uses a Mechanic II position in its larger facilities.

● *How Are Other States Handling Welding Fumes in Their Shops?* Missouri uses an air circulation system and is beginning to use positionable vacuum devices at designated welding areas. Minnesota is having similar problems with paint. Iowa has a manual that outlines the wastes generated by their sites and the steps to take for the treatment and disposal of these items. They perform the employee training and continually update the manual.

● *Presentation of Illinois Modification to the Minnesota "Gordon Stanley" TMA Hitch.* The modified hitch mounts in the same "over-the-tailgate" fashion as the original hitch. The modification extends the upper and lower arms to provide clearance for an under-tailgate salt spreader. This addition makes the use of the attenuator easier during winter months when immediate responses to snow removal are necessary. The extended arms and additional gusseting weldments are available in a kit to modify the older "Gordon Stanley" hitch.

● *General Discussion of Dump Body Specifications.* Most states are using conventional dump bodies on their snow removal fleets. Iowa has successfully used the "Western" style dump body . They lowered the dump body height 3.5 inches. Illinois has 12 trucks ordered this year with this style body.

● *Use and Experiences with Track-Type Hydraulic Excavators. For What Operations & What Sizes Are Purchased?* Kansas, Iowa, Minnesota and Ohio purchase larger (40,000 pound) track machines. Illinois, Illinois Tollway, Indiana, and Missouri primarily use rubber tired machines. The track machines are used for ditch work, major pavement patching and in soft-soil conditions. The rubber tired machines are primarily ditching machines. Illinois has purchased several small track hoes to use for ditch maintenance in place of larger rubber and track type units. Missouri has purchased a large self-propelled rotary ditcher.

● *Review of "Under-body" Plow Specifications.* Each state is using a limited number of under-body plows in a variety of applications and styles. Primarily used for ice scraping.

● *Ground Speed Spreader Controls - Who Is Using and from Where Are They Purchasing?*

● *Presentation on a Cooperative Purchasing Venture by Minnesota.* Dave Strage described the program Minnesota uses to assist other governmental entities in the state to purchase equipment and supplies. This program includes the use of Department staff as consultants in generating specifications and allowing local units of government to attach to existing bids and contracts. This cooperation results in better relationships amongst agencies and lower operating costs for government. This concept could possibly be expanded to allow other states to participate in the purchase of like pieces of equipment or other goods and services. If this type of purchasing is implemented, it must be simple, easily understood and easy to use. The local units of government must be convinced they have input into the purchase and selection process.

● *Discuss the Application of SHRP Products by the Participating States.* Minnesota has received a $750,000 annual research grant for all forms of projects including equipment. Minnesota is currently operating two remote control trucks for work zone protection and one remote control slope mower. The use of the SHRP snowplow has not worked out. They could not make the scoop portion of the plow work. Iowa also found the snow scoop design plow unsuccessful the first time tried. It is being tested again in a different area of the state. North Dakota has run a SHRP snow scoop for two years with poor performance reports.

HOST STATE FACILITY AND EQUIPMENT TOUR

A portion of the meeting was spent touring some of the Illinois Department of Transportation and Illinois Toll Highway Authority facilities in the Chicago area. Highway maintenance equipment was displayed on the tour that included the IDOT Emergency Traffic Patrol Headquarters. This facility is the home of the "Minutemen" that patrol the Chicago Expressway system assisting stranded motorists and responding to expressway emergencies. Their equipment ranges from 30,000 GVW rated wrecker-type trucks to large rotating 50-ton wreckers mounted on chassis in the 80,000 GVW range, and specialized equipment used to lift and upright semi-trailers.

PLANS FOR FUTURE MEETINGS

Several suggestions were made for future meetings. They included video taping the conference; changing the schedule; advantages of hosting and the additional attendance for the host state; the minutes from the Western States Meeting; documenting the benefits from the conference; and, send the three most important to potential host state executives.

Iowa agreed to host the meeting, possibly on the border with Nebraska. Ohio agreed to host the 1996 meeting pending upper management approval. Several state representatives commented on this being their first opportunity to attend this meeting and where pleased with the worthwhile information and sharing of ideas and experiences relating to highway maintenance equipment.

8TH ANNUAL SOUTHEAST EQUIPMENT MANAGERS MEETING

Francis E. Allred
Alabama Department of Transportation

SUMMARY

The 8th Annual Southeast Equipment Managers Meeting was held in New Orleans on April 12-14, 1994. The Louisiana Department of Transportation hosted the conference. Some of the topics on the agenda are listed below.

- An Alternate Fuel Update — presented by TxDOT;
- Update On The Equipment Buy-Back — presented by Arkansas DOT;
- Conspicuity Stripping — presented by 3M Corporation;
- New Electronic Engines — presented by Detroit Diesel;
- Specification Comparisons — presented by each state represented; and
- Performance Base Specifications — presented by John Deere.

South Carolina Department of Transportation will host the 1995 conference in Charleston, June 19-22, 1995.

PROPOSED NORTHEASTERN STATES EQUIPMENT MANAGERS GROUP

Edward G. Fahrenkopf
New York State Department of Transportation

SUMMARY

This group has not formed as an identifiable and stand-alone group; however, some states do participate in an equipment program that has been included in the New York-New England Highway Maintenance Meeting. This annual meeting usually is held in New Hampshire in September of each year.

Mr. Fahrenkopf, with support from other members of TRB Committee A3C08, are pursuing the formation of a regular New England States Equipment Managers Group. The potential member states include New York, Pennsylvania, Connecticut, Delaware, New Jersey, Vermont, Maine, Massachusetts, Rhode Island and New Hampshire.

APPENDIX A FINAL PROGRAM

Sunday, July 31, 1994

3:00 - 7:00 p.m. REGISTRATION

6:00 - 8:00 p.m. RECEPTION (cash bar)

Monday, August 1, 1994

7:00 a.m. - 5:00 p.m. REGISTRATION

7:00 - 8:30 a.m. CONTINENTAL BREAKFAST

8:30 - 9:00 a.m. **OPENING SESSION**

Doug Nielsen, *Arkansas State Highway and Transportation Department*, and *Chairman of TRB Committee on Equipment Maintenance*, presiding

Welcoming Remarks

- Donald E. Forbes, Director, *Oregon Department of Transportation*
- Dwight R. (Dick) Berkey, Fleet Operations Manager, *Oregon Department of Transportation*
- Robert W. Kuenzli, (Retired) *Oregon Department of Transportation*

9:00 - 10:00 a.m. **IMPACT OF CLEAN AIR ACT AMENDMENTS ON DIESEL FUEL**

Edward G. Fahrenkopf, *New York State Department of Transportation*, presiding

Fuel Supplier Views, Manuch Nikanjam, *Chevron Research & Technology Center*, Richmond, California

Engine Supplier Views, Ralph Nienas, *Navistar International Transportation Corporation*, Portland, Oregon

10:00 - 10:30 a.m. BREAK

10:30 - Noon **WASTE MANAGEMENT**

Ronald D. Doemland, *Pennsylvania Department of Transportation*, presiding

South Carolina's Tire Recycling Project, H. Lee Hax, *South Carolina Department of Highway and Public Transportation*

Waste Management at Bus Transit Maintenance & Fueling Facilities, Douglas Lowell, *Acurex Environmental Corporation*, Mountain View, California

Effect of Regulations on Bus Maintenance Facility Design, Dorr Anderson, *KCM Consulting Engineers*, Seattle, Washington

Noon - 1:00 p.m. LUNCHEON

1:00 - 3:00 p.m. **ALTERNATIVE FUELS**

Thomas H. Maze, *Iowa State University*, presiding

California DOT Fleet Experience, Dale Phillips, *California Department of Transportation* (Invited)

Alternative Fueled Buses, Gary Brentano, *Portland Tri-Met Transit District*, Portland, Oregon

Safe Operating Procedures for Alternative Fuel Buses, Douglas Lowell, *Acurex Environmental*, Mountain View, California

A-55 Technology Fuel, Peter Gunnerman, *A-55 Limited Partnership of North America*, Reno, Nevada

3:00 - 3:30 p.m. BREAK

3:30 - 5:30 p.m. **EQUIPMENT OF THE FUTURE**

Arlen T. Swenson, *John Deere National Sales*, presiding

Dump Truck and Snow Plow Applications - Specifications for the Twenty-First Century, Richard W. Hunter, *Illinois Department of Transportation*

Listening to the Customer on Truck Ergonomics, Gene Valley, *Minnesota Department of Transportation*

Ergonomic Factors in a One-Person Operation of Snow Plows with Attached Wing Plows, Leslie O. Dawley, *Ontario Ministry of Transportation*

Improved Underbody Plowing, Wilfred Nixon, *University of Iowa*

Tuesday, August 2, 1994

7:00 a.m. - Noon REGISTRATION

7:00 - 8:00 a.m. CONTINENTAL BREAKFAST

8:00 - 10:00 a.m. **HUMAN RESOURCE MANAGEMENT**

Richard W. Hunter, *Illinois Department of Transportation*, presiding

Equipment Operator and Mechanic Training Program, James B. Bretz, *Pennsylvania Department of Transportation*

Productivity Measurement, Craig Holt, *Oregon Department of Transportation*

Maintenance Technician Training: An Investment in the Future, Ladell G. (Dell) Wood, *Texas Department of Transportation*

Self-Directed Teams, Dale Allen, *Oregon Department of Transportation*

10:00 - 10:30 a.m. BREAK

10:30 a.m. - Noon **EQUIPMENT MANAGEMENT**

Francis E. Allred, *Alabama Department of Transportation*, presiding

Role of GPS in Equipment Management, Dennis Harlow, *Rockwell International*, Cedar Rapids, Iowa

Cradle to Grave Truck Radio Maintenance System as Part of a Maintenance Management System, Richard W. Hunter, *Illinois Department of Transportation*

Repair Parts Management System, Edward G. Fahrenkopf, *New York State Department of Transportation*

Noon - 1:00 p.m. LUNCHEON

1:00 - 3:00 p.m. **TOWARD EQUIPMENT STANDARDIZATION**

Edward H. Adams, *Kentucky Transportation Cabinet*, presiding

Should There be a Uniform National Color for DOT Vehicles?, Edward L. Kocan, *North Carolina Department of Transportation*

Panel Discussion

ADVANTAGES AND DISADVANTAGES OF STANDARDIZED EQUIPMENT SPECIFICATIONS

- Ronald D. Doemland, *Pennsylvania Department of Transportation*
- John M. Burns, Jr., *North Carolina Department of Transportation*
- Francis E. Allred, *Alabama Department of Transportation*
- Arlen T. Swenson, *John Deere National Sales*, Moline, Illinois

3:00 - 3:30 p.m. BREAK

3:30 - 5:00 p.m. **REHABILITATION, PURCHASING AND LEASING**

John M. Burns, Jr., *North Carolina Department of Transportation*, presiding

Equipment Refurbishing in Pennsylvania DOT, Ronald D. Doemland, *Pennsylvania Department of Transportation*

Leasing Considerations from a Manufacturer's Perspective, Arlen T. Swenson, *John Deere National Sales*, Moline, Illinois

Purchasing or Leasing, Bud Howard, Vice President, Sales, *Hertz Equipment Rental Corporation,* Park Ridge, New Jersey

5:30 p.m. **NORTHWEST EVENING AT THE WORLD FORESTRY CENTER**

(Buses depart Hotel at 5:30 p.m. and return at approximately 10:00 p.m.)

Wednesday, August 3, 1994

7:00 - 8:00 a.m. CONTINENTAL BREAKFAST

8:00 - 9:00 a.m. **INTERNATIONAL EQUIPMENT TECHNOLOGY**

Walter J. Tennant, Jr., *Cortland County New York Highway Department*, presiding

Equipment in Japan and Austria, Leland D. Smithson, *Iowa Department of Transportation*

Equipment in Scandinavia Countries, Paul Keranen, *Minnesota Department of Transportation*

9:00 - 10:00 a.m. **REPORTS FROM REGIONAL EQUIPMENT MANAGERS MEETINGS**

Leland D. Smithson, *Iowa Department of Transportation*, presiding

Reports will be given by regional representatives on topics discussed and results obtained from the Western, Midwest, Southeastern and Northeastern Regional Equipment Manager's Meetings.

10:00 - 10:30 a.m. BREAK

10:30 - 11:30 a.m. **EQUIPMENT RESEARCH ISSUES**

Doug Nielsen, *Arkansas State Highway and Transportation Department*, presiding

All participants are invited to offer and discuss technical and operational issues that might be resolved through applied research efforts.

11:30 - 11:45 a.m. **CLOSING REMARKS**

Doug Nielsen, *Arkansas State Highway and Transportation Department*, and *Chairman of TRB Committee on Equipment Maintenance*

Dwight R. (Dick) Berkey, Fleet Operations Manager, *Oregon Department of Transportation*

1:30 to 4:30 p.m. **POST-WORKSHOP TOUR**

Freightliner Corporation

Portland, Oregon

(Buses depart from Hotel at 1:30 p.m. and return at approximately 4:30 p.m)

ACKNOWLEDGMENTS

Oregon Department of Transportation Planning Committee: Dwight R. (Dick) Berkey, chair, Robert W. Kuenzli, Pat Crawford, Bud Davis, David Evenhus, Shellee Lowery, Sue Smittcamp, and Betty Jo Strauch

Technical Program Committee: Leland D. Smithson, chair, Dwight R. (Dick) Berkey, Robert W. Kuenzli, and Thomas H. Maze

TRB Committee A3C08, *Equipment Maintenance*: Doug Nielsen, chair, Edward H. Adams, Francis E. Allred, Dwight R. (Dick) Berkey, William J. Buglass, John M. Burns, Jr., Ronald D. Doemland, Edward G. Fahrenkopf, Richard W. Hunter, Robert W. Kuenzli, Thomas H. Maze, L. David Minsk, Gerald L. Ray, Leland D. Smithson, Arlen T. Swenson, Walter J. Tennant, Jr., Thomas Wald

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