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

Leslie O. Dawley and Robert Monster
Ontario Ministry of Transportation

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

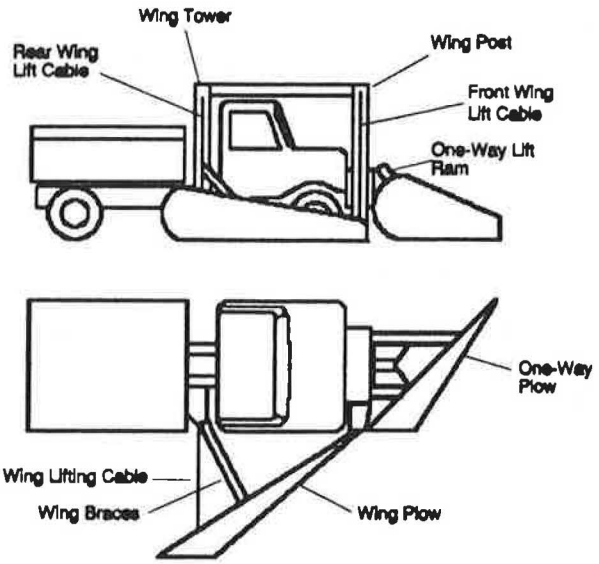

FIGURE 1 Top and side views of a snow plow and wing plow vehicle.

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.