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An Evaluation of Highway Mowing Procedures for the Reduction of Mower Thrown Object Accidents

Michael R. Istre and Kurt M. Marshek

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16. Abstract

Control of roadside vegetation is achieved primarily through mowing operations and the use of herbicides. An unfortunate side effect of mowing operations to manage vegetation growth is the occurrence of mower thrown object (MTO) accidents. The most significant effort to reduce mower thrown object accidents is for mowers to travel opposite traffic flow. A computer database of mower accidents was developed to determine the effectiveness of mowing against traffic on the severity and frequency of accidents. A detailed analysis of the underlying concepts related to thrown objects and mower direction was performed. Surveillance of mowing operations showed the degree and ease of implementation of mowing against traffic. Modifications to the mowing against traffic requirement are presented along with other recommendations on increasing safety on Texas roadways for both mower operators and motorists and increasing the efficiency of highway mowing.

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AN EVALUATION OF HIGHWAY MOWING PROCEDURES FOR THE REDUCTION OF MOWER THROWN OBJECT ACCIDENTS

by

Michael R. Istre
and
Kurt M. Marshek

Research Report Number 1441-1F

Research Project 0-1441
Mower Thrown Object Accidents

conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

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by the

CENTER FOR TRANSPORTATION RESEARCH
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THE UNIVERSITY OF TEXAS AT AUSTIN

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IMPLEMENTATION STATEMENT

The intent of this project (1441) is to provide new knowledge with regard to the current mowing specification that requires the orientation of large rotary mowers so that they move against traffic. The project identifies (1) the safety issues associated with preventing mower thrown object accidents and (2) the measures for reducing mower thrown object and related mower accidents. The project report proposes changes to the current State of Texas mowing specifications for (1) better effectiveness of the mow against traffic requirement and (2) adoption of a highway mowing safety standard. Additional research is proposed to further increase the safety of the public, the safety of mower operators, and the efficiency of highway mowing.

Prepared in cooperation with the Texas Department of Transportation
and the U.S. Department of Transportation, Federal Highway Administration

DISCLAIMERS

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

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Kurt M. Marshek, P.E. (Texas No. 39519)

Research Supervisor

Michael R. Istre, E.I.T. (Louisiana No. 14509)

Research Engineer Associate

for the Center for Transportation Research
The University of Texas at Austin

ABSTRACT

Control of roadside vegetation is achieved primarily through mowing operations and the use of herbicides. An unfortunate side effect of mowing operations to manage vegetation growth is the occurrence of mower thrown object (MTO) accidents. The most significant effort to reduce mower thrown object accidents is for mowers to travel opposite traffic flow. A computer database of mower accidents was developed to determine the effectiveness of mowing against traffic on the severity and frequency of accidents. A detailed analysis of the underlying concepts related to thrown objects and mower direction was performed. Surveillance of mowing operations showed the degree and ease of implementation of mowing against traffic. Modifications to the mowing against traffic requirement are presented along with other recommendations on increasing safety on Texas roadways for both mower operators and motorists and increasing the efficiency of highway mowing.

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SUMMARY

Highway mowing is a necessary and vital roadway maintenance activity for the safety of Texas motorists. Mower thrown objects are unfortunately inherent to this activity and cannot be completely eliminated from all highway mowing. While the foldable wing rotary mower is prone to mower thrown object accidents, it is still the best available mower to perform highway mowing. This is due to its ease of use, lower initial cost, lower maintenance cost, and higher productivity when compared to other available equipment.

Mowing against traffic was most effective in reducing the severity and frequency of mower thrown object accidents when conducted on roadways where at least two adjacent travel lanes are traveling in the same direction. Since objects can be thrown over two travel lanes on average, mowing against traffic is not as effective as originally perceived on two lane roadways where the lanes are traveling opposite each other. Modifications to the current mowing specifications and a highway mowing safety standard are provided to allow implementation of the resulting conclusions.

Future research is proposed to increase the efficiency of highway mowing operations. The increased efficiency will allow mowing to be completed in less time thereby reducing the motorists' exposure to mowers and risk of accident.

CHAPTER 1: INTRODUCTION

The Texas Department of Transportation (TxDOT) is the state agency primarily responsible for providing the people and commerce of Texas with efficient and effective air and surface transportation systems. This responsibility has three principle aspects: (1) formulating plans and policies for the location, design, construction, maintenance, and operations of a comprehensive infrastructure, (2) planning for, fostering, and assisting in the development of intra-city and inter-city public and mass transportation, and (3) assisting general aviation with funding and technical expertise.

Nearly one fourth of the department's budget is dedicated to the construction and maintenance of Texas highways. Of the $2.4 billion received in 1993 from the Texas State Legislature, $560 million went to the Division of Construction and Maintenance (DMC) of TxDOT. The DMC is responsible for overseeing the physical upkeep, repair and expansion of existing highways. Included under these activities is the control and preservation of vegetation growing along Texas roadways. This control is achieved primarily through mowing operations and the use of herbicides. Mowing operations constitute the majority of these efforts and has an annual cost of approximately $27 million.

An unfortunate side effect of mowing operations to manage vegetation growth is the occurrence of mower thrown object (MTO) accidents. These accidents occur as a result of a foreign object being struck by the blade, discharged from the blade encasement, and then striking passing vehicles or other property usually causing minor damage. While the cost of MTO damage is generally small with respect to the overall mowing expense, there have been several litigation cases involving serious injury to the vehicle occupant by a mower thrown object. In 1990, the passenger of a passing vehicle was killed when a steel leaf spring thrown by a mower broke through the windshield causing fatal head injuries.

Fortunately, serious injuries are a rare occurrence. However, the MTO problem is severe enough that the Texas Department of Transportation collaborated with the Center for Transportation Research (CTR) in 1986 to develop solutions to this problem. The CTR research teams investigated literature and patents, reviewed filed accident reports, contacted other states, studied alternate equipment and safety modifications, and conducted field experiments. Recommendations were made to reduce mower thrown object accidents. However, no consideration was given to the implementation of these recommendations, especially with respect to traffic safety. Nonetheless, recommendations from the research were apparently used to modify the Texas state mowing standards and procedures; this being that mowing be performed against the flow of traffic in the nearest travel lane in order to reduce the relative velocity between an object thrown from the rear of the mower and a passing vehicle. This recommendation may introduce extra time and expense into the mowing operation and its effect on traffic safety is unknown.

Consequently, this report features an in-depth review of the "mow against traffic" recommendation and provides new developments in safety procedures that address MTO problems, primarily related to the foldable wing rotary mower. The foldable wing rotary mower (see Figure 1.1) is generally the mower of choice for highway mowing because of its lower initial cost, ease of use, low maintenance cost, and high productivity. This type of mower is, however, responsible for the majority of MTO accidents.

Objectives

The primary objective of this research is to increase the overall safety of highway mowing operations by reducing the number and severity of accidents involving mowers. Since MTO accidents represent the significant portion of mower involved accidents, much of this research addresses the reduction of mower thrown objects by developing new mowing procedures rather than require contractors to purchase new equipment. The primary effort to reduce MTO accidents has been in the implementation of the "mow against traffic flow" requirement recommended in 1986 [Ref 17]. Unfortunately, since its implementation the cost of mowing has significantly increased (approximately 35% increase per acre [Ref 14]).

This research will focus on evaluating the "mow against traffic requirement". The primary assumptions behind the requirement will be tested to determine the feasibility of mowing against traffic. These assumptions include the following:

(1) Mowing against traffic will decrease the frequency and severity of accidents.

(2) Mowing against traffic decreases the relative velocity between the thrown object and a passing vehicle.

(3) Objects are not likely to be thrown over one lane of traffic, therefore the far lane is considered safe.

Modifications to the requirement will be presented along with other recommendations on increasing mower safety on Texas roadways for both mower operators and motorists.

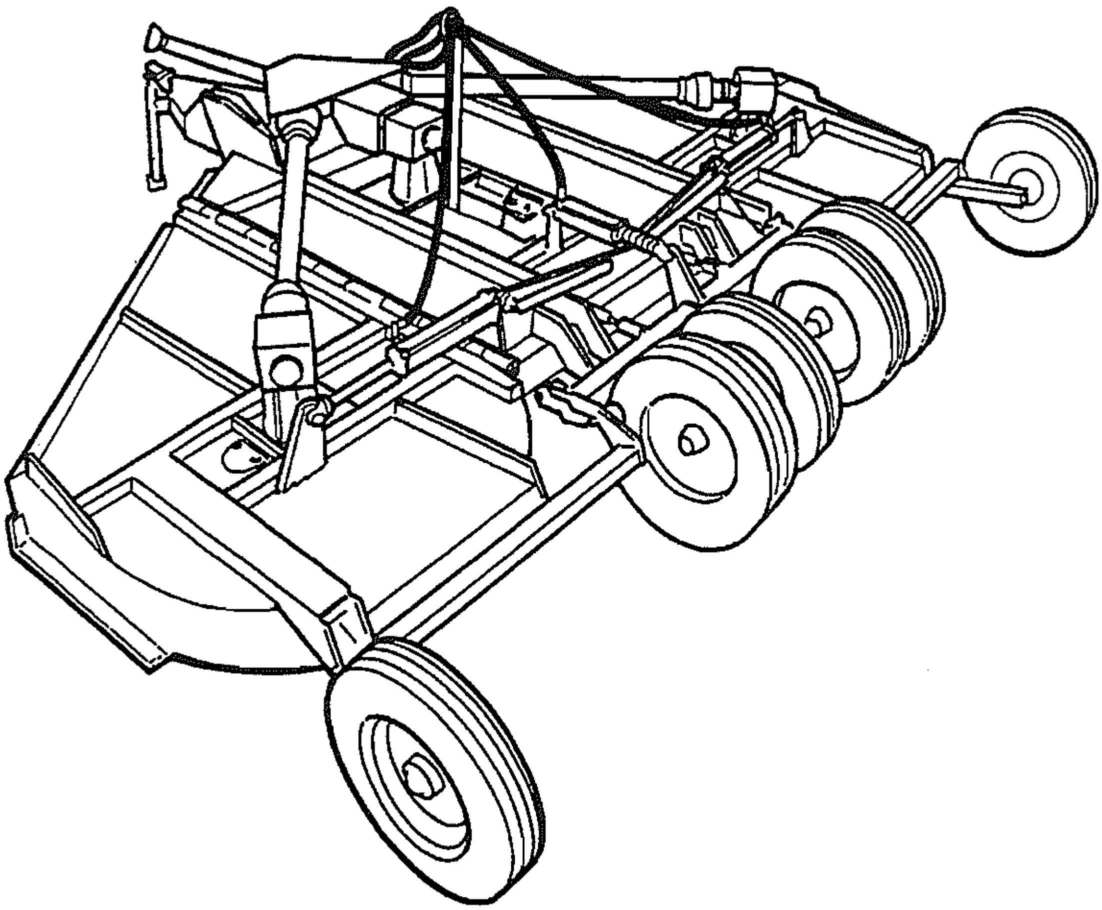

Figure 1.1: A foldable wing rotary mower [Ref 1]

Scope and Organization

Chapter 1: Provides an introduction to this report.

Chapter 2: Provides background information of mowing operations.

Chapter 3: Discusses innovations in mowing equipment and procedures, traffic concerns, industry safety standards and the development of a state safety standard and training.

Chapter 4: Analyzes a database of MTO accident reports.

Chapter 5: Analyzes the relative velocity assumption in mowing against traffic.

Chapter 6: Presents the results of a field investigation of highway mowing operations.

Chapter 7: Presents the conclusions and recommendations.

CHAPTER 2: REVIEW OF HIGHWAY MOWING

This chapter provides a review needed to understand highway mowing operations. It includes mowing objectives and vegetation maintenance goals and the procedures used to meet those goals. The three primary mower types are described and the advantages and disadvantages of each is discussed along with the definitions of some terms to be used in this report. Previous reports done by the Center for Transportation Research and the preliminary reports done on this project are also discussed. Finally, problems encountered with privatization due to changes in the mowing specifications are examined.

Background

The Texas Department of Transportation has categorized mowing into four distinct types: strip, full width, spot and transition mowing.

Strip mowing (Type I) involves mowing the area from the edge of the shoulder to a distance of 1.5 to 4.6 meters (5 to 15 feet) (Figure 2.1). Strip mowing also includes the following conditions: (1) mowing from the pavement edge or shoulder to the right-of-way line next to developed areas, (2) mowing around all signs, delineators, guardrails, culvert headwalls, etc. that are within the designated strip, (3) mowing the entire width of narrow medians and outer separations and (4) mowing full width, from right-of-way to right-of-way for drainage where appropriate.

Full width mowing (Type II) includes all unpaved rights-of-way, except for designated non-mow areas where the slope is too steep or the area is covered with desirable plants. The frequency of full width mowing depends on the level of maintenance assigned to the roadway by TxDOT.

Spot mowing (Type III) is performed when and where necessary to maintain adequate sight distances for inside curves, on and off ramps, intersections, private entrance signs, delineators, and other appurtenances (Figures 2.2, 2.3). Spot mowing is generally required when safety needs arise between scheduled strip mowing cycles.

Whenever two areas require different mowing width, **transition mowing** is used to provide a gradual shift to visually blend the two areas (Figure 2.4). Transition mowing

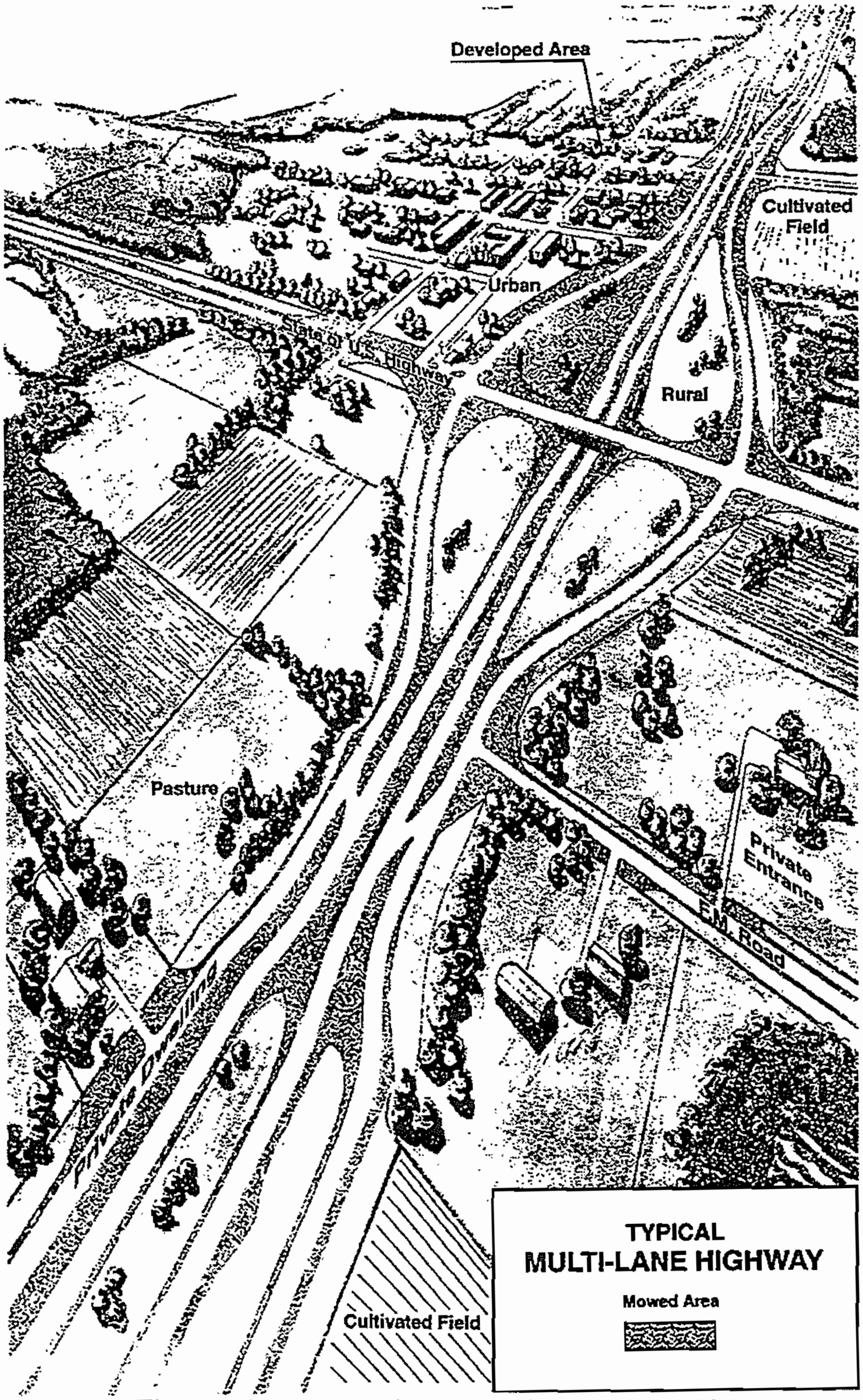

Figure 2.1: Strip mowing on a typical multi-lane highway
[Ref 23]

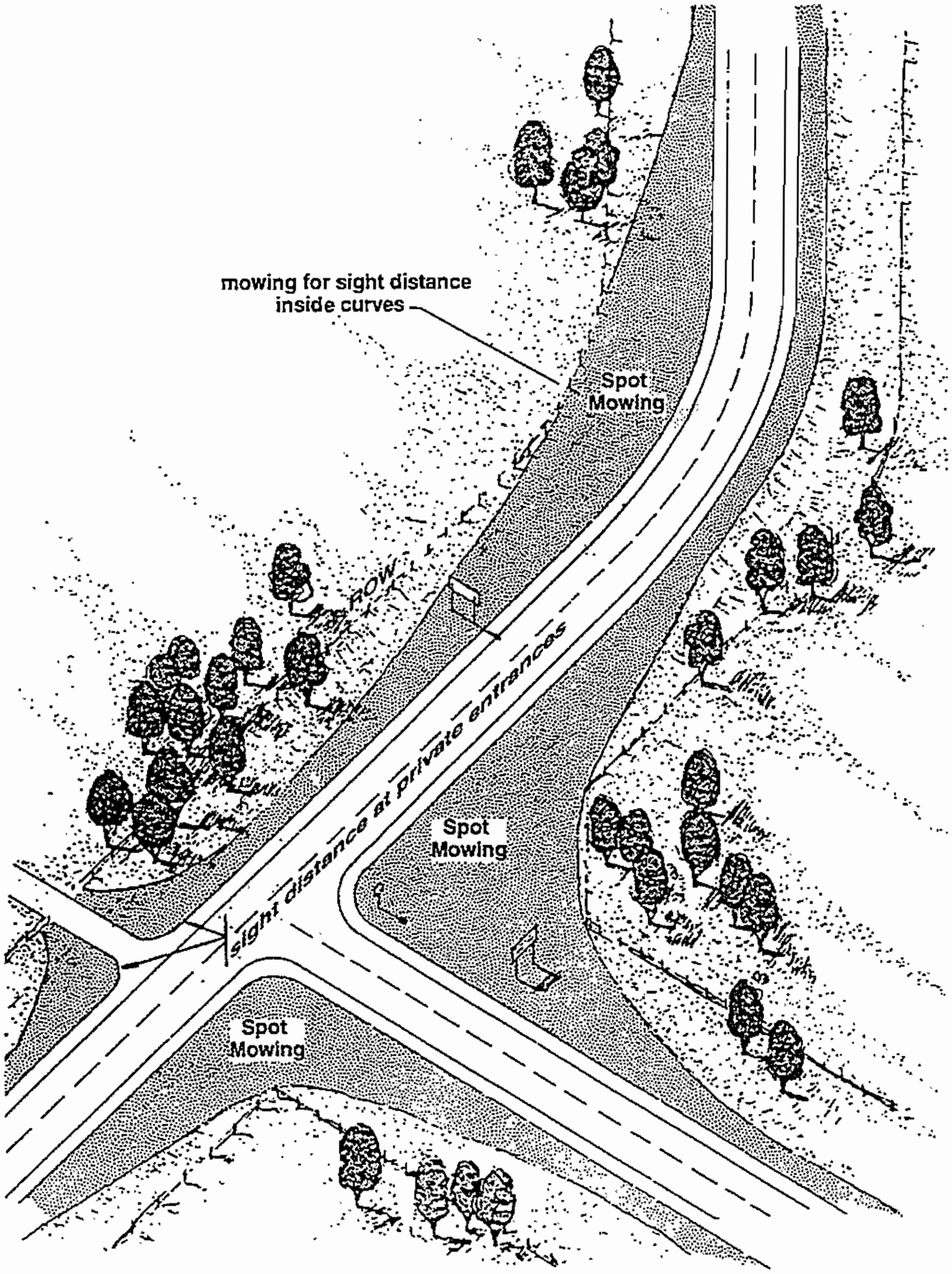

Figure 2.2: Spot mowing on inside curves
[Ref 23]

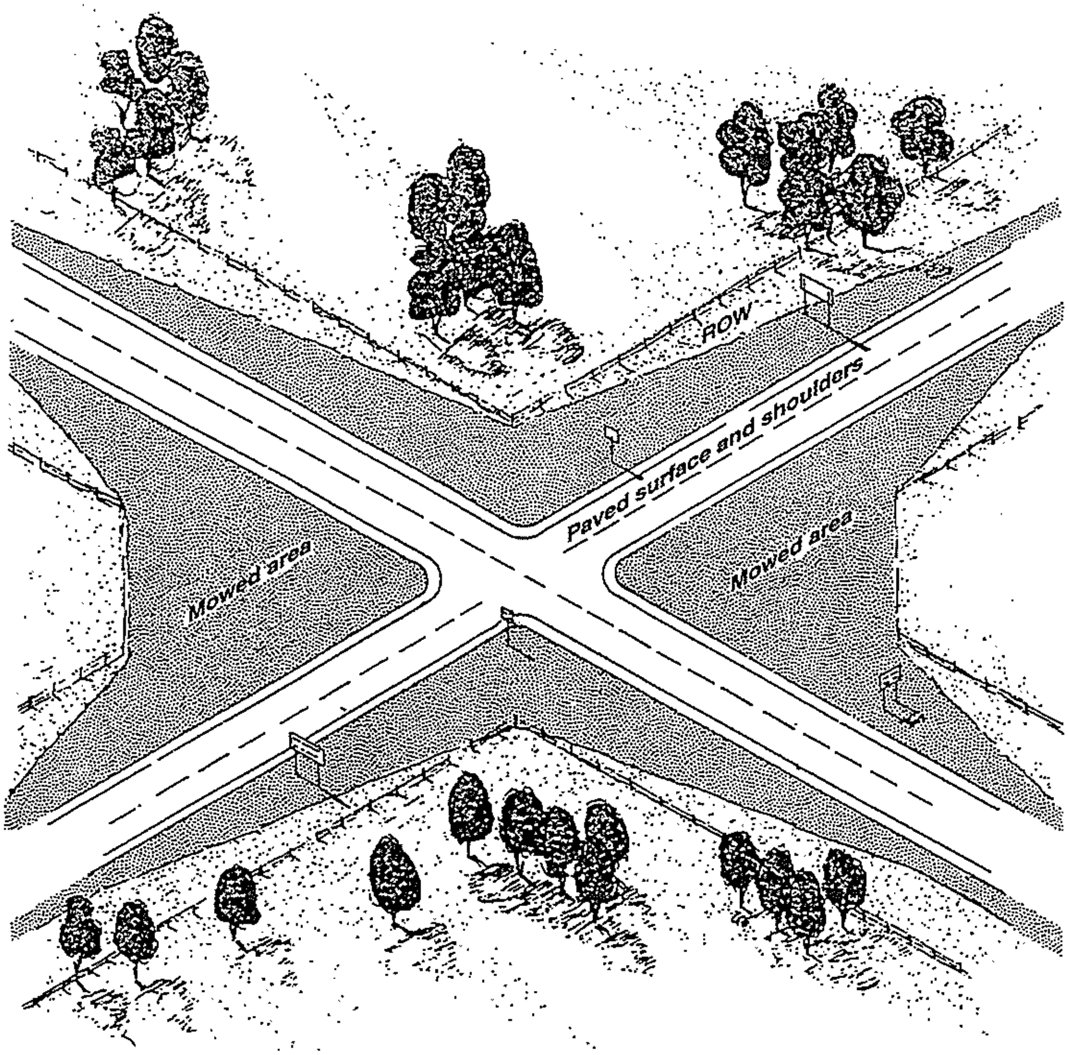

Figure 2.3: Spot mowing at an intersection

[Ref 23]

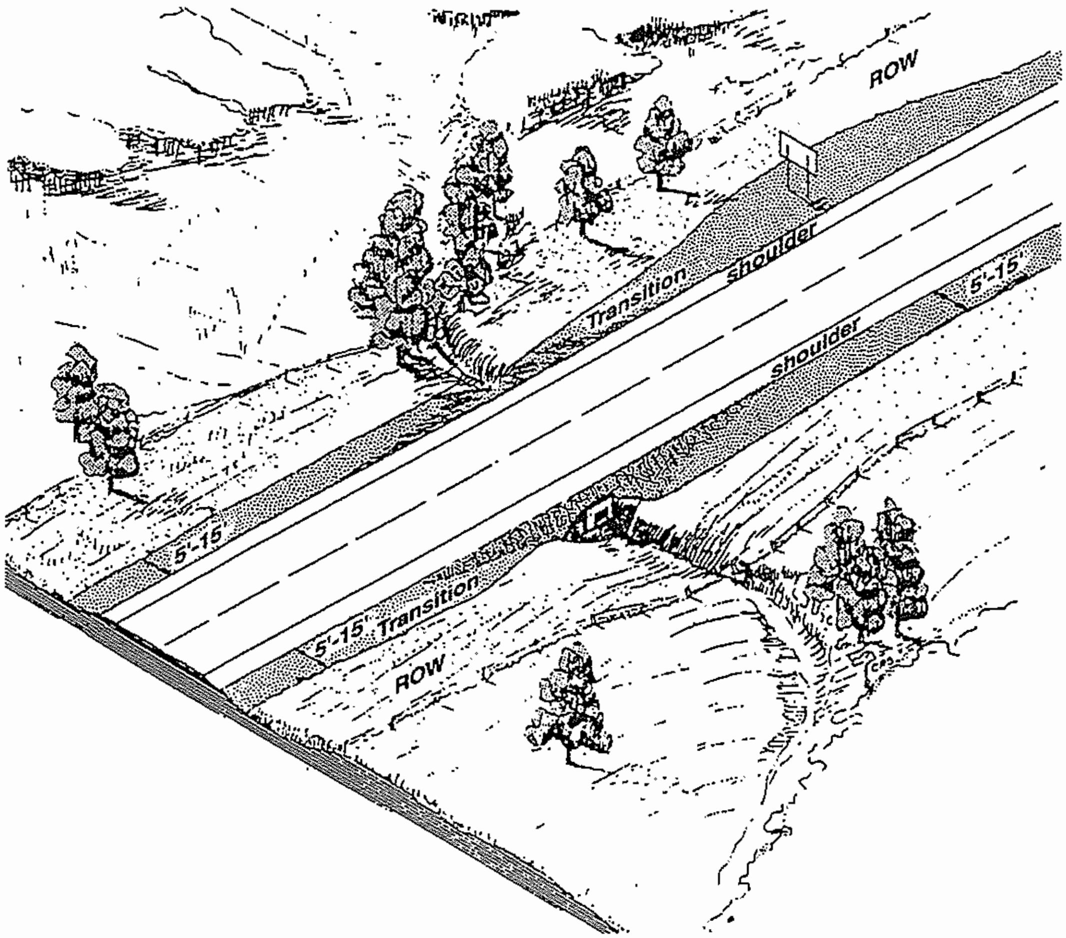

Figure 2.4: Transition mowing around signs and ditches

[Ref 23]

is necessary between the following locations: (1) an area that is mowed full width and a non-mow area, (2) the designated strip mowing width and the greater width required around a sign, and (3) the designated strip mowing width and the extra width required to maintain sight distances at a curve, driveway, or intersection.

In addition to serving a cosmetic function, the maintenance of vegetation along Texas roadways ensures the safety of the traveling public, enhances environmental protection, promotes and preserves wildlife habitats and native grasses throughout the state and mitigates erosion. Wildflower preservation has gained significant importance since the introduction of Texas wildflower seeding by Ladybird Johnson. The presence of wildflowers along Texas state roadways is popular with both residents and tourists. **Preservation mowing** is necessary to prevent mowing equipment from damaging or killing native flowers before they can seed. In areas where full width mowing is necessary, mowing is deferred until the early spring flowers have mature seeds. During this defer period, mowing is restricted to a single pass adjacent to the road (Figure 2.5).

Mowing Equipment

The mowing equipment used can be classified into three basic types: rotary, flail, and disc. Preferred overwhelmingly by mowing contractors, rotary mowers rank as the most common type of mowing equipment used to maintain vegetation along Texas roadways. Because of their popularity, inherent characteristics and high usage, rotary mowers also have the highest MTO accident rate. In 1984, 98% of all reported MTO accidents in the state were caused by rotary mowers [Ref 17]. Rotary mowers are defined as a power mower in which one or more functional components cut by impact and rotate about a vertical axis. Rotary mowers come configured as average garden mowers, riding mowers with fixed undercarriages, and tractor pulled mowers. The type of rotary mower responsible for nearly 60% of MTO accidents is the foldable wing rotary mower (Figure 2.6) [Ref 17]. This mower generally consists of three rotating blade assemblies, with two blade assemblies contained in side "wings" able to tilt to match the slope of the terrain, the third blade assembly is in the center of the mower. The unit is powered by and towed behind a tractor.

The flail mower has been used since the 1950's. Flail mowers contain a set of many small blades attached to a rotating horizontal shaft (Figure 2.7). The blades strike the plant at such high velocity that the inertial forces of the plant resists rapid acceleration. This resistance is sufficient enough for the blade to generate failure stresses before the blade velocity is imparted to the free material. These mowers cause fewer MTO accidents than

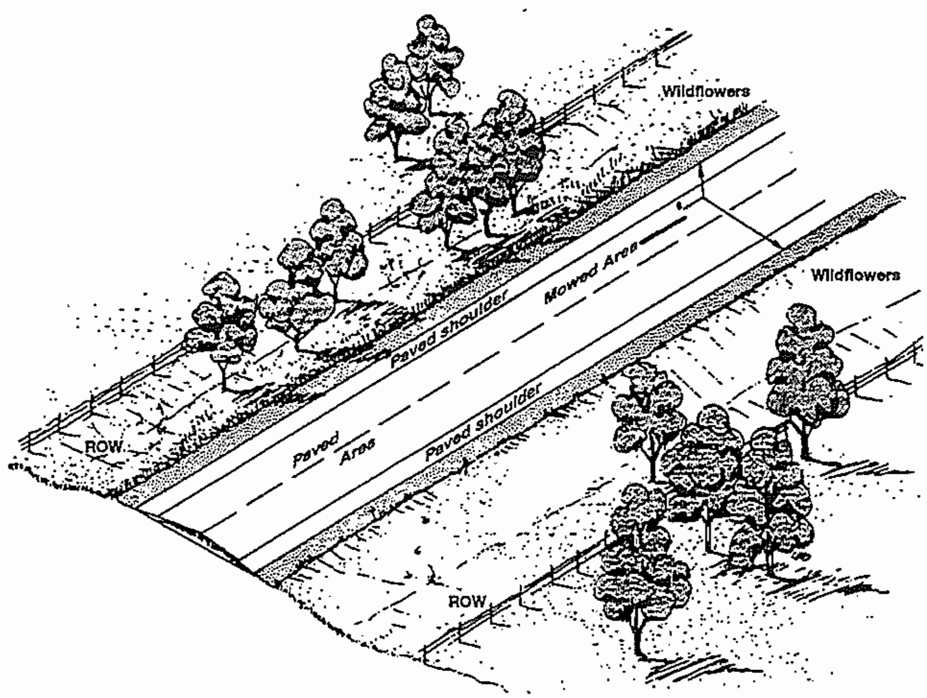

Figure 2.5: Preservation mowing for wildflower protection

[Ref 23]

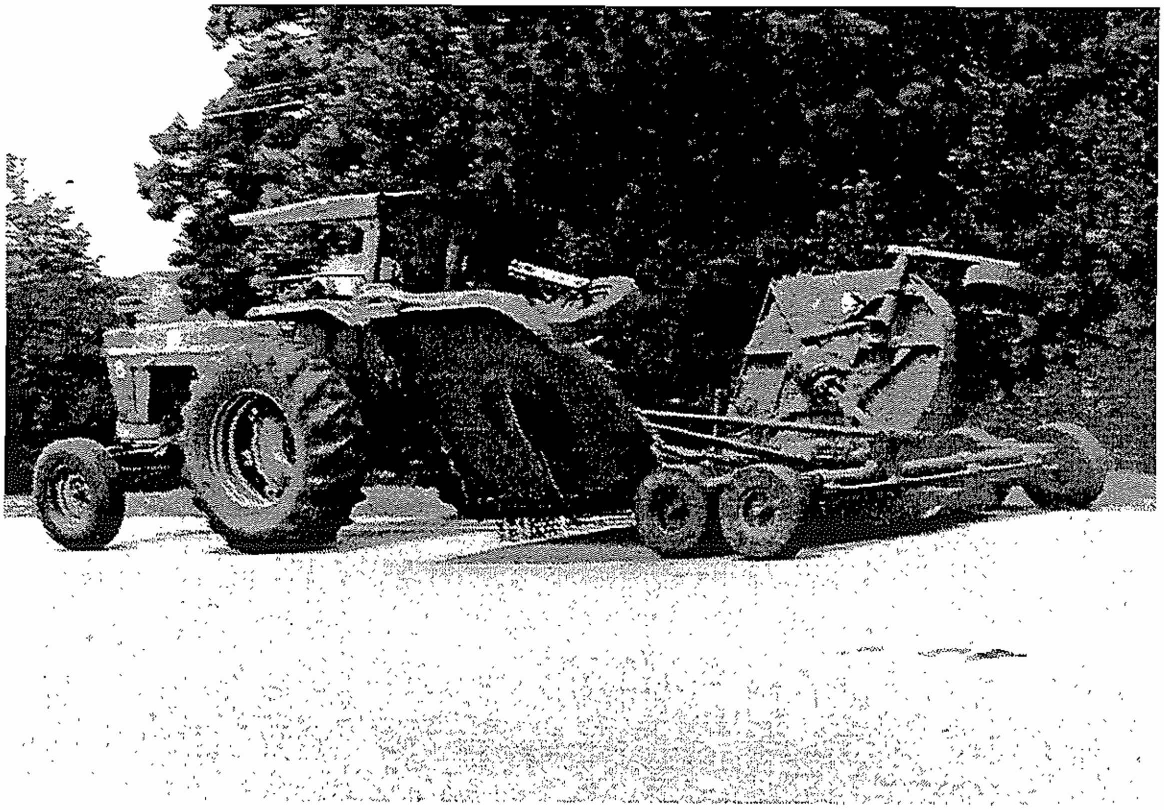

Figure 2.6: Foldable wing rotary mower with wings raised

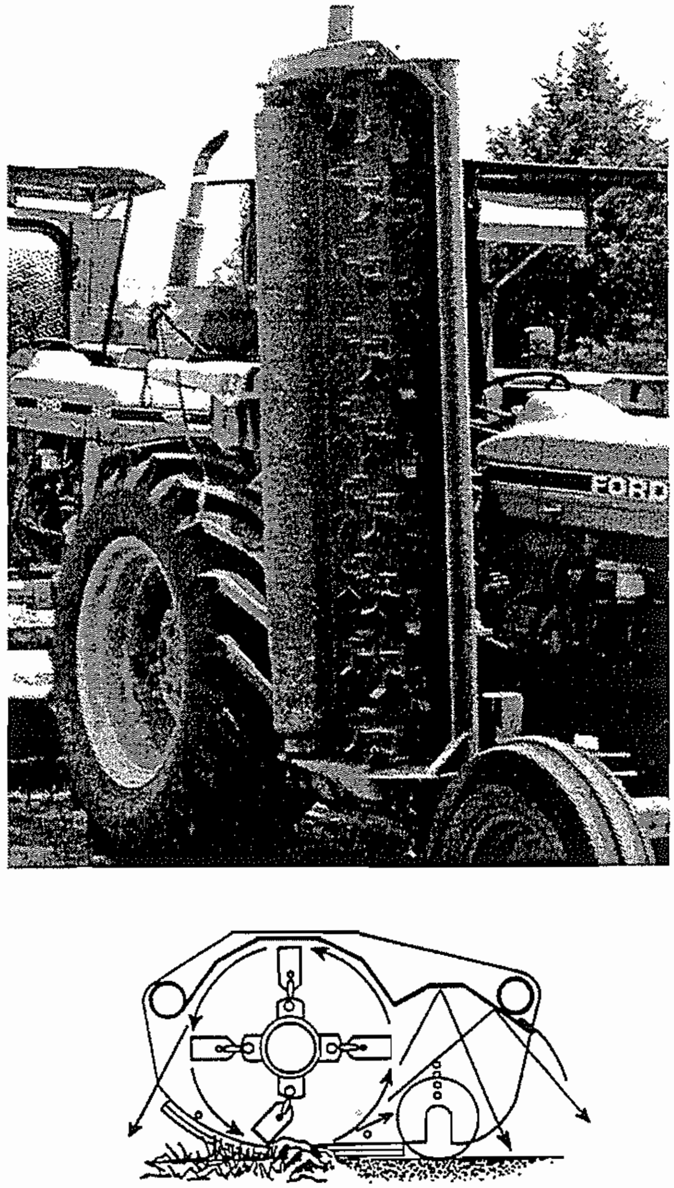

Figure 2.7: Flail mower and schematic

rotary mowers because the vertical motion of the blades direct debris downward rather than out. Unfortunately, flail mowers are ineffective in cutting taller grasses. Flail mowers are also notorious for requiring constant maintenance because of the large number of moving parts and therefore cost more to operate.

Disc mowers represent the latest development in mowing technology, utilizing a series of triangular shaped counter-rotating discs (Figure 2.8). Disc mowers offer a variety of advantages over other mowers including improved productivity, lower maintenance costs, and safer operation. VICON, the American manufacturer, claims that speed up to 13 kph (8 mph) can be attained (compared to 5 to 8 kph (3 to 5 mph) for rotary mowers) and mowing can be done in almost any weather condition. The Minnesota State Highway Department reports that the frequency of MTO accidents is the least with disc mowers and that 95 to 130 kilometers (60 to 80 miles) of mowing with a 2.1 m (7 ft.) mower can be achieved during a normal 8 hour work day including breaks [Ref 17].

Definitions of Terms

There are some terms that are used extensively in this report that may have ambiguous meanings and/or may be unique to this project and should therefore be defined so that the reader will understand their use.

The term **efficient mowing** will be used to describe mowing done to: (1) minimize the number of times the blade(s) is disengaged, (2) minimize the number of times the travel direction is changed, and (3) maximize the amount of grass cut for a given time and terrain condition.

The term **safe mowing** will be used to describe that mowing which is done to: (1) minimize the number of times the mower must enter the roadway and (2) minimize the hazards to the operator and the passing motorists.

A **mower thrown object, MTO**, is any foreign object struck by the rotating blade of a mower and thrown out of the blade encasement that may cause property damage and/or personal injury. Discharged grass is not considered a mower thrown object.

The **right-of-way, ROW**, is the unpaved area between the shoulder of a roadway and the boundary to private property. The right-of-way is considered to be public land.

Deadheading is a mowing practice where no productive cutting is performed. Deadheading occurs when mowers move from one spot to another without cutting any grass.

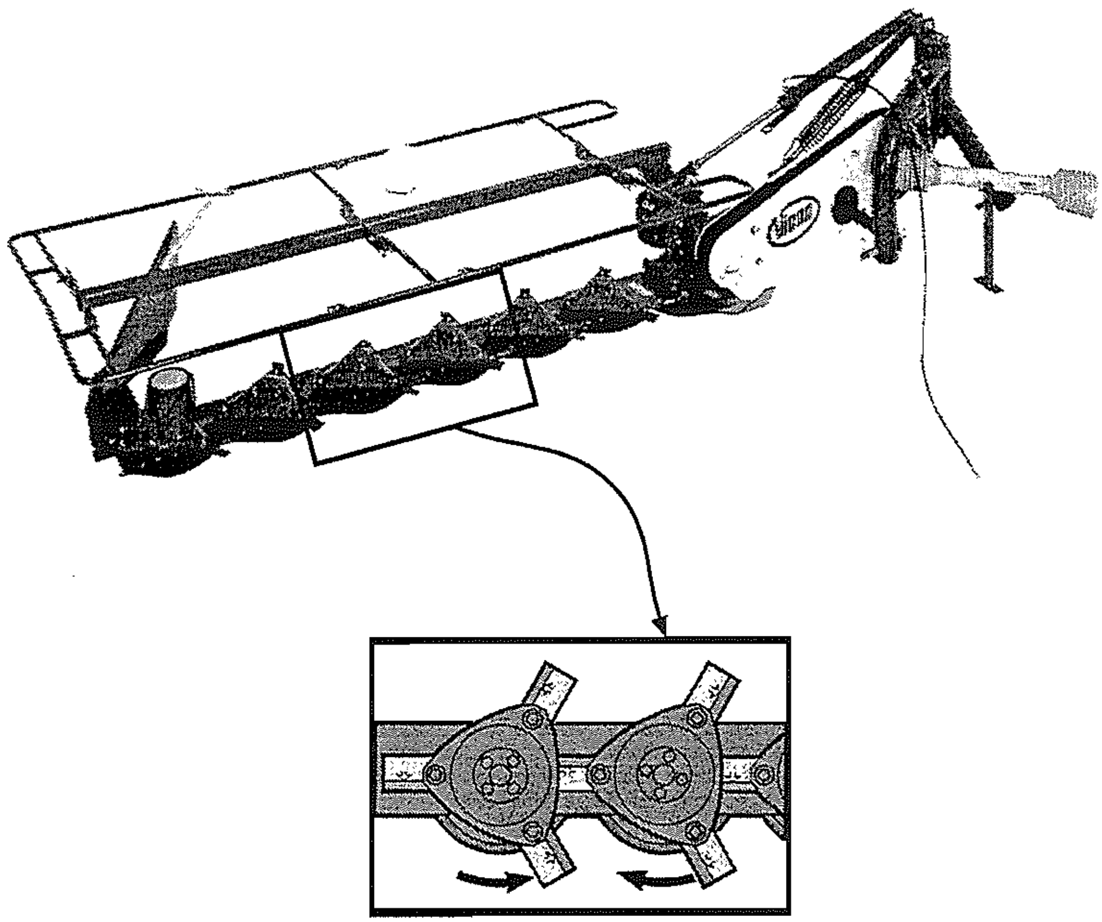

Figure 2.8: Disc mower with close-up of cutting blades [Ref 25]

Previous Research

In 1986, TxDOT commissioned the Center for Transportation Research to investigate problems associated with MTO phenomenon [Refs 16,17]. The research included a literature review, an investigation into mower design modifications, an analysis of MTO accident reports, and perfomance of field experiments. Six recommendations were submitted to TxDOT for reducing mower thrown object accidents. The six recommendations were:

1. Herbicides and non-rotary mowers should be used in areas with a high risk of MTO accidents.
2. Adopt the use of disc mowers.
3. Raise the cutting height to 15 cm (6 in.) (this height has recently been raised to 18 cm (7 in.)).
4. All mowers should be fitted with a double row of safety chains.
5. Operators should be notified of difficult terrain conditions.
6. Mowing should always be done against the flow of traffic in the nearest lane.

The sixth recommendation (mowing against traffic) was developed from the results of field experiments. In these experiments, fifteen objects were placed in a staggered array and driven over by a foldable wing mower (Figure 2.9). The objects used were 9 cm by 9cm by 10 cm (3 1/2 in. by 3 1/2 in. by 4 in. pressure treated wood blocks of about 0.45 kg (1 lb) and 7.5 to 12.5 cm (3 to 5 in.) limestone rocks with a mean weight of about 2.3 kg (5 lb). The tests showed that most objects exit from the rear of the mower. The CTR researchers concluded that, because most objects exited from the rear, the risk of MTO accidents would be reduced if the mower traveled in the direction opposite traffic flow. This would reduce the relative velocity between the thrown object and the moving vehicle and therefore reduce the severity of the impact.

Privatization

The privatization of Texas state mowing operations began in 1988 and has rapidly accelerated under the direction of Governor Ann Richards. Currently, mowing contractors account for approximately 80% of all mowing operations. TxDOT has a goal of reaching 95% privatization in the near future [Ref 14]. Competition for contracts has significantly reduced the expenses associated with vegetation maintenance and privatization is considered to be a successful venture.

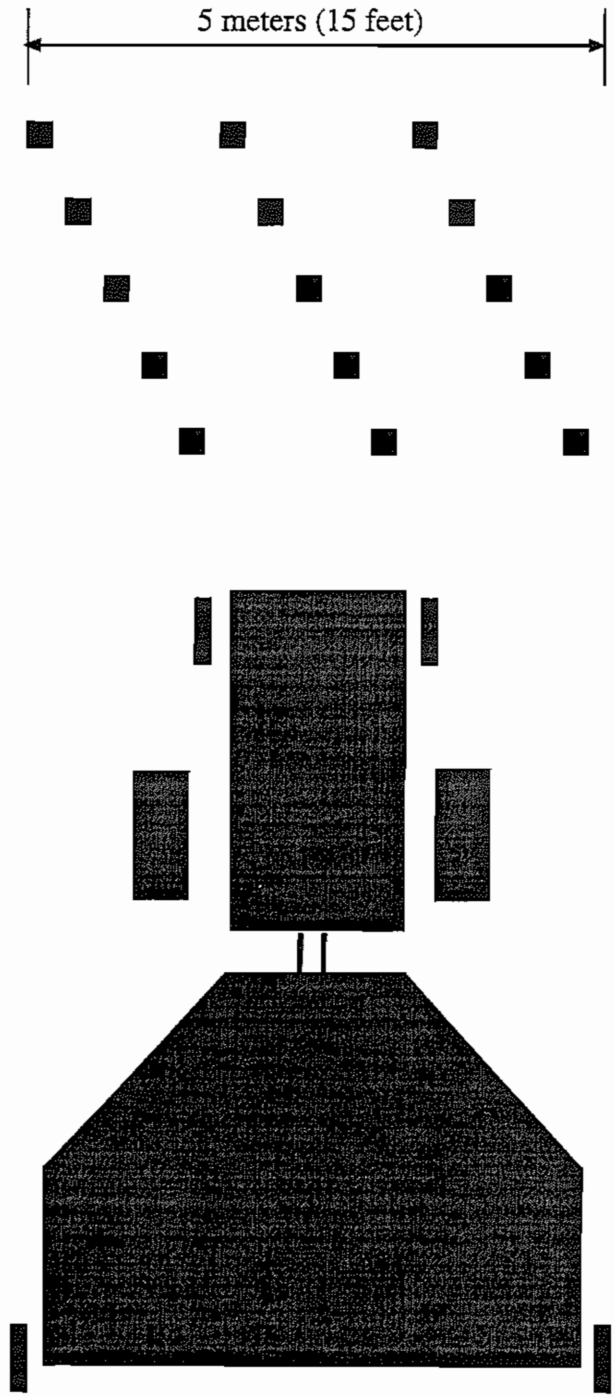

Figure 2.9: Experimental setup from 1986 experiment

CHAPTER 3: MOWING EQUIPMENT, PROCEDURES, REGULATIONS, AND STANDARDS

This chapter presents recent innovations in both mowing equipment and vegetation control practices. This chapter also presents the general safety issues associated with mowing including interpretation of the Texas Traffic Laws [Ref 22], industry standards related to mowing equipment safety, federal regulations for operator safety, and the mower manufacturers recommended safe operation practices. The development of a safety standard for highway mowing is presented.

Equipment Innovations

A patent search of new mowers and mower shields and guards was performed. The objective of the search was to find any new equipment which would reduce the frequency or severity of mower-thrown-objects. Only patents since 1986 were examined since previous MTO studies performed a similar search in 1986 [Ref 7].

The Komatsu Zenoah Company of Japan was granted four patents on a mower which has two pivotal cutting wheels slidably superposed with each other. The wheels have many teeth along their circumferences, and they rotate in opposite directions relative to one another through a given angle (see Appendix A). This design apparently produces few if any thrown objects, however, the productivity of this mower is unknown and the complexity of the design would require higher maintenance.

Three other patents deal with changes to the blade design of rotary mowers. U.S. Patent 5,271,212 consists of a center blade section and two jointed outer blade sections. These joints can yield both upward and backward upon striking an object. Otherwise, centrifugal force keeps the outer blades in cutting position. U.S. Patent 5,233,820 has circular blades attached to the ends of a rotary blade bar which can pivot if an object is struck. U.S. Patent 4,936,884 attaches flexible tines to the distal ends of a rotary blade. An airfoil along the blade provides upward suction of the grass (see Appendix A for patent descriptions and figures).

Mower manufacturers are constantly improving their products to increase the safety of their equipment. Terrain King has begun experimenting with steel rollers and internal baffles in order to reduce mower thrown objects. The initial testing shows that steel rollers mounted along the rear opening of smaller mowers not only provides a consistent cutting height, but also significantly reduces the number of objects discharged from the blade encasement. Terrain King hopes the steel rollers can be incorporated into larger mower designs [Ref 9].

Recommended Mowing Practices and Alternatives to Mowing

Examination of journal articles and periodicals provided information on recommended mowing practices and alternatives to mowing. The Toro Company with St. Paul Fire and Marine Insurance Company developed a safety program for mowing. Many of the safety recommendations were general and did not specifically address highway mowing. The safety procedures mentioned included (1) policing the area for objects before mowing, (2) making certain safety guards are in place, (3) shutting off the equipment and inspecting the situation after hitting an object, and (4) becoming familiar with the equipment's controls. Another article stated that 25% of tractor fatalities occur while being driven on public roads and highways. Therefore, it is important to take precautions such as attaching slow-moving vehicle signs to the equipment and putting out warning flags which mark the mowing area [Ref 21].

While only a small number of articles address the mowing of roadside vegetation, many present the use of herbicides to control vegetation. The Better Roads article "Herbicides Stretch Budget in Louisiana" describes the impact of herbicides along Louisiana highways [Ref 10]. Before the use of herbicides, Louisiana right-of-ways required five or six mowings per season. The Louisiana Department of Transportation and Development saved nearly $4.5 million in one year. In Philadelphia, fifteen plant growth regulators were tested. By mixing the growth regulators with herbicides, grass and weeds can be controlled without mowing. One article, "Roadside Vegetation: Player or Pest?", questions the necessity of controlling vegetation [Ref 19]. The use of herbicides, however, remains uncertain. Proper use mandates training and special care must be taken to insure environmental safety. Observations along Louisiana highways show the cosmetic considerations which may need to be addressed to satisfy the public. Herbicide use on Interstate Highway 10 through Louisiana can be identified by the brown strips of grass along the shoulder contrasted with the lush green in the center of the median and the remaining areas of the right-of-way.

Traffic Regulations

During the initial data collection and interviewing, it was reported that some operators, following TxDOT's requirement to mow against traffic, were given citations for traveling the wrong way on a roadway [Ref 15]. This has led to an investigation of the Texas Traffic Laws and interpretation of those regulations by the General Counsel for the Texas Department of Transportation. When the mowing against traffic recommendation was first presented, there was no research to determine its legality.

In response to questions submitted about mowing procedures, the General Counsel for TxDOT provided the following interpretations [Ref 26]:

1. Driving on the shoulder is restricted for most vehicles, but during mowing operations, mowers are allowed unlimited use of the shoulder.
2. On the job site, whether on or off the roadway, mowers are considered road maintenance equipment and not vehicles.

With this interpretation, a mower should therefore be exempt from traffic laws regarding direction of travel while involved in safe mowing operations. The Texas Traffic Laws apply to "vehicles" and not road maintenance equipment (see Appendix B for Texas Traffic Laws, Article VI). Therefore, mowing against traffic flow is allowable, especially if confined to the shoulder, median, and side right-of-way.

Industry Safety Standards

Published mower safety standards usually fall into three categories: (1) product safety, (2) operational safety, and (3) manufacturer's recommended practices.

Product safety standards

Organizations such as the American National Standards Institute (ANSI), the Society of Automotive Engineers (SAE), and the American Society of Agricultural Engineers (ASAE) provide testing methods of mowing equipment to insure the safety of the product under adverse conditions to both the operator and bystanders. Mower manufacturers are generally not required by law to meet these standards. Most manufacturers voluntarily test their equipment to insure they meet industry standards in order to reduce accidents as well as the possibility of product liability litigation. Interviews with mower manufacturers confirmed they are concerned with product safety and they consider the ability to meet industry standards an important asset [Refs 6, 9, 18].

SAE J232 is the standard most appropriate to foldable wing rotary mowers. Included in this standard (and also the ANSI and ASAE standards) is a thrown object test.

In this test, six-penny nails are dropped through holes drilled in the top of the blade encasement (Appendix C). The entire mower is surrounded by a cardboard enclosure to detect the number and impact penetration of nails thrown from the blade encasement. Manufacturers generally agree that this is not a particularly reliable, realistic or accurate test of safety for thrown objects. Other disadvantages of the test include:

(1) Projectile size. The nails do not accurately reflect the type and size of object most likely to be hit, i.e. rocks.

(2) Time and Effort. The standard requires each blade assembly be tested in eight different areas. For foldable wing mowers, this would require dropping over 10,000 nails, one at a time.

(3) Expense. At least one mower must be sacrificed to perform the test in addition to the expense of the personnel require to perform the tests.

A member of the committee presently rewriting the ASAE standard, said new tests are always being developed but as yet none are as feasible, statistically accurate, and most importantly repeatable as the nail test [Ref 18].

Operational safety manuals and standards

Another way manufacturer's attempt to insure the safety of their equipment is by developing their own safety practices and including them in the operator's manual. Warning decals are also placed on the equipment warning both the operator and bystanders of potential dangers. Unfortunately, the operator's manuals are not readily made available to the operators. All known mower manufacturers provide replacement decals free of charge.

The Operational Safety and Health Administration (OSHA) under the Federal Department of Labor provides safety guidelines to insure the safety of the operators of machinery. There is no section of the OSHA code that directly addresses industrial mowers, however OSHA 1928.57 provides safety and training guidelines for farm field equipment [Ref 20]. Since industrial mowers are often used as farm equipment, these guidelines can easily pertain to industrial mowers. Section 1928.57 of the code discusses the type and frequency of training that employers must give employees who are involved with farm field equipment. It discusses some of the basic safety guidelines that are normally covered in the manufacturer's operator's manuals. Additional safety for the operators is provided by requiring the employer to make safety guidelines available to anyone who works with this equipment (see Appendix C).

Development of a Safety Standard for Highway Mowing

There are industry standards which insure the safety of mowing equipment and federal guidelines and manufacturer's recommended practices which insure the safety of the operator. Unfortunately, no safety standards for mowing incorporating all the ideas of highway mowing safety have been found. A product of this research is a **safety standard** providing both contractors and operators with the information necessary to perform highway mowing as safe as possible while still being able to mow efficiently. Adoption of this type of standard will be significant in bringing the safety hazards associated with highway mowing to the attention of those who are directly involved in these operations -- the contractors and especially the operators.

Three sources of information were used in developing this **safety standard**: (1) present industry and federal standards, (2) previous and present research on mower safety, and most importantly, (3) input from mower manufacturer's. A first draft of the document was sent to Alamo Group (manufacturer's of Terrain King and Rhino mowers), Continental Belton, John Deere, and Bush-Hog. The response was extremely favorable, supporting the effort to increase mower safety. Many of the ideas and recommendations made by these manufacturers were included in the final version of the document found in Appendix D.

The SAE and OSHA standards were used to give an appropriate format for the document. Since the OSHA standards do not directly apply to industrial rotary mowers, minor language modifications were made to incorporate OSHA guidelines into the new document. The language change made was to make the term "farm field equipment" include rotary mowers. As defined in OSHA 1928.57, farm field equipment means "tractors or implements ... or any combination thereof used in agricultural operations" [Ref 20]. Since the term "agricultural operations" is not defined, it is interpreted to cover vegetation maintenance which includes highway mowing.

A central idea in the highway mowing safety standard is training. Presently, operators of mowing equipment receive little safety training. The **safety standard** would require safety instruction be given prior to mowing at least annually. The material to be covered would be provided by the contractor and would be in the form of a video or brochure. A **safety brochure** based on the ideas presented in this report and information gathered from mower manufacturers has been prepared and is given in Appendix E. The **safety standard** for highway mowing as well as the **safety brochure** incorporates the results of an accident database analysis, thrown object velocity analysis, and field investigation discussed in the following chapters.

CHAPTER 4: DEVELOPMENT AND ANALYSIS OF THE ACCIDENT DATABASE

This chapter deals with the development and analysis of a database compiled from mower thrown object accident claims. The analysis presented will test the assumption that the direction of mowing can affect the frequency and severity of MTO accidents. Using the computer database, trends will be developed to show the effect of *direction of mowing* on MTO accidents. Correlation between MTO accidents, geographic regions of the state, and type of roadway will also be investigated.

Data Collection

Between 1987 and 1992, the Insurance Division of the Texas Department of Transportation received 406 accident reports dealing with mower thrown objects. These reports only represent accidents involving State of Texas owned mowers and not those owned by contractors. Due to the privatization of mowing operations, a significant portion of accident claims are reported directly to the mowing contractor and are paid by the contractor. No information is provided to the state by the contractor.

Because of the limited number of reports available, it was necessary to calculate the number of reports required to have a statistically valid sample. Assuming all the reports are randomly sampled, it was calculated that 385 reports would be necessary to give a 95% (± 5%) level of confidence. Therefore, the 406 reports available would suffice [Ref 5]. The initial development of the database is presented in Clothier, Smitherman, and Wilkins [Ref 7].

Direction of Motion Analysis

The parameters selected for evaluating the database were chosen to specifically address the mowing against traffic recommendation. The objective of each parameter is given in Table 4.1. The range of each parameter is presented in Table 4.2. A diagram outlining the direction an object is thrown was also developed to eliminate any further ambiguities in the data collection process (Figure 4.1).

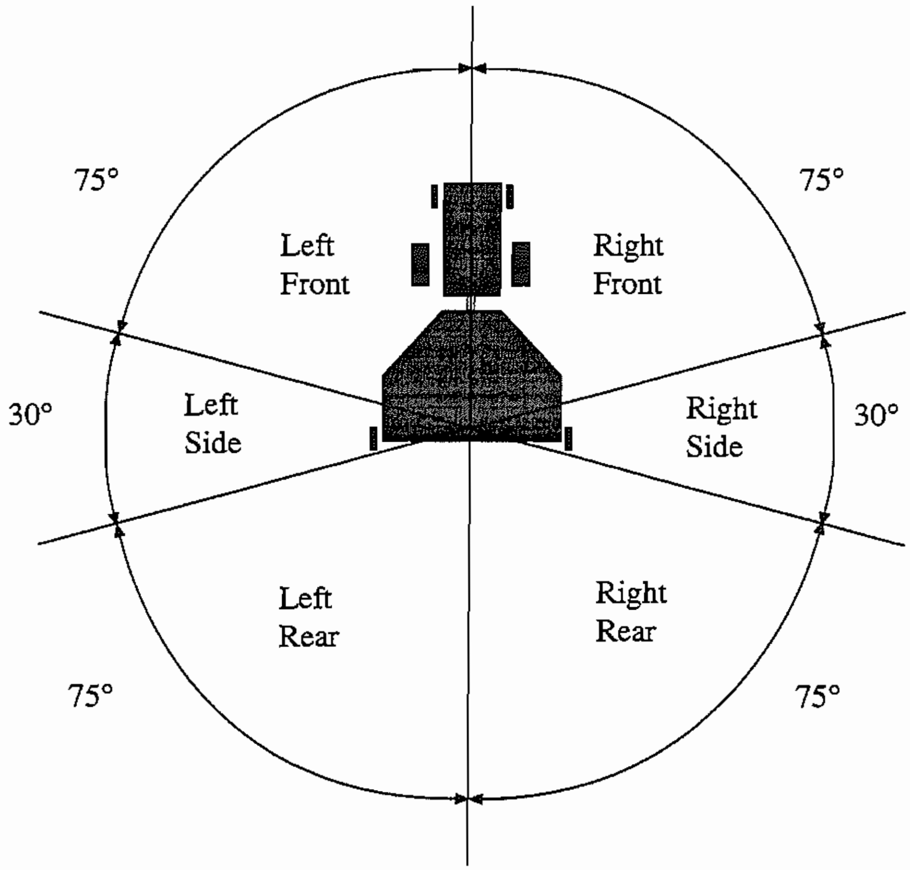

Figure 4.1: Thrown object direction diagram

Table 4.1: Objectives of Database Parameters

Parameter	Objective
Time	To identify which times of day pose the highest risk of MTO accidents
Date	To identify which times of year pose the highest risk of MTO accidents
Location	To identify Texas counties with higher numbers of MTO accidents
Equipment Type and Manufacturer	To identify which equipment brands pose higher risks of MTO accidents
Equipment Class	To identify which type of mowers pose higher risks of MTO accidents
Road Class	To identify road types which pose higher risks of MTO accidents
Road Surface	To determine the effect of road surface characteristics on MTO accidents
Road Characteristics	To identify road types where which pose higher risks of MTO accidents
Speed Limit of Road	To determine the effect of speed on MTO accidents
Mower Position	To determine which mower orientations pose higher risks of MTO accidents

Table 4.1 (continued): Objectives of Database Parameters

Parameter	Objective
Mower Direction	To determine the effect of mowing direction on MTO frequency and severity
Vehicle Position	To determine the approximate distance the MTO traveled
Vehicle Direction	To determine the orientation of the vehicle with respect to the mower
Direction Object Was Discharged	To determine the tendency of a mower to throw objects to one side
Cutting Height of Mower	To determine the relationship between cutting height and MTO accidents
Installed Safety Devices	To evaluate the effectiveness of safety devices
Signs and Warnings	To evaluate the effectiveness of the current warning system
Location of Vehicle Damage	To indicate regions where MTOs most frequently strike vehicles
Amount of Vehicle Damage	To indicate the effect of mowing direction on MTO accident severity and frequency
Motion of Mower	To determine if mowing in reverse increases the risk of MTO accidents

Table 4.2: Range of Database Parameters

Parameter	Range of Values
Time	Hour and minute; Unknown
Date	Day, month, and year; Unknown
Location	Texas county; Unknown
Equipment Type	Push mower; Riding lawn mower; Tractor-pulled mower; Unknown
Equipment Class	Rotary; Flail; Sickle; Disc; Other; Unknown
Equipment Manufacturer	Make and model of equipment; Unknown
Road Class	Interstate highway; US highway; Texas highway; Farm to market road; Ranch road; Urban street; Parking lot; Other
Road Surface	Concrete; Asphalt; Gravel; Dirt; Brick; Other
Road Characteristics	One-way; Two-way; Number of lanes per direction; Other characteristics
Speed Limit of Road	Posted speed limit; Unknown

Table 4.2 (continued): Range of Database Parameters

Parameter	Range of Values
Mower Position	Side of road; Median; Ditch; Slope; Other; Unknown
Motion of Mower	Forward; Reverse; Stationary; Unknown
Mower Direction	Against traffic in near lane; With traffic in near lane; Perpendicular to traffic; Other; Unknown
Vehicle Position	Near lane; Far lane; Other; Unknown
Vehicle Direction	Opposite mower; Same as mower; Perpendicular to mower; Other; Unknown
Direction Object was Discharged	Front right; Front left; Rear right; Rear left; Right side; Left side; Other; Unknown
Cutting Height	Measurement in inches; Unknown
Installed Safety Devices	Chains; Cable reinforced chains; Floating side skirts; Stand-off deflectors; Dragging canvas; Rubber skirt; Other; Unknown
Signs and Warnings	Advanced warning signs; Reduced speed signs; Arrow board; Flashing lights; Flags; Cones; Other; None; Unknown
Location of Vehicle Damage	Body location; Window location; Other
Amount of Vehicle Damage	Final dollar amount paid

To provide an accurate evaluation of mowing against traffic flow the following must be known and combined with all possible configurations of the mower and the vehicle: (1) the mower direction, (2) vehicle direction, and (3) the direction the object exited the mower. The analysis is for mowing along the side right-of-way of a road with only one side of the mower exposed to traffic. Mowing the median places the mower in-between both directions of traffic and unless the median is large, the analysis does not apply because (1) more than one side of the mower is exposed to passing traffic and (2) there would be a different mower/vehicle configuration for each side of the mower.

In order to perform the frequency and severity analysis with the database information the MTO direction was needed. An insufficient number of reports contained the MTO direction so a modified parameter was established to represent the relative motion of the mower and vehicle. Figure 4.2 shows the four direction parameters -- same/right, same/left, opposite/right, opposite/left. Two other parameters are also included to cover all possibilities: (1) moving toward (perpendicular to) the road and (2) moving away from (perpendicular to) the road. Figure 4.3 shows the number of MTO accidents versus the relative direction parameters created.

To determine the effect of direction on the severity of MTO accidents, the damage cost for each of the direction parameter was calculated and totaled. This provides the most objective and effective method of determining the effect of mowing direction on the frequency and severity of MTO accidents.

Results and Discussion of Direction of Motion Analysis

The total cost of MTO accidents versus mower direction is shown in Figure 4.4. The same/right category represents mowing with traffic whereas the opposite/right category represents mowing against traffic. Figure 4.4 shows that mowing against traffic does have an effect on mower thrown object accidents. The higher total cost of the same/right category compared to the opposite/right category shows that mowing against traffic tends to reduce the severity of MTO accidents. While the average cost in mowing against traffic is comparable to the other direction parameters (Figure 4.5), the high total cost indicated in the same/right category implies that mowing against traffic also reduces the frequency of MTO accidents.

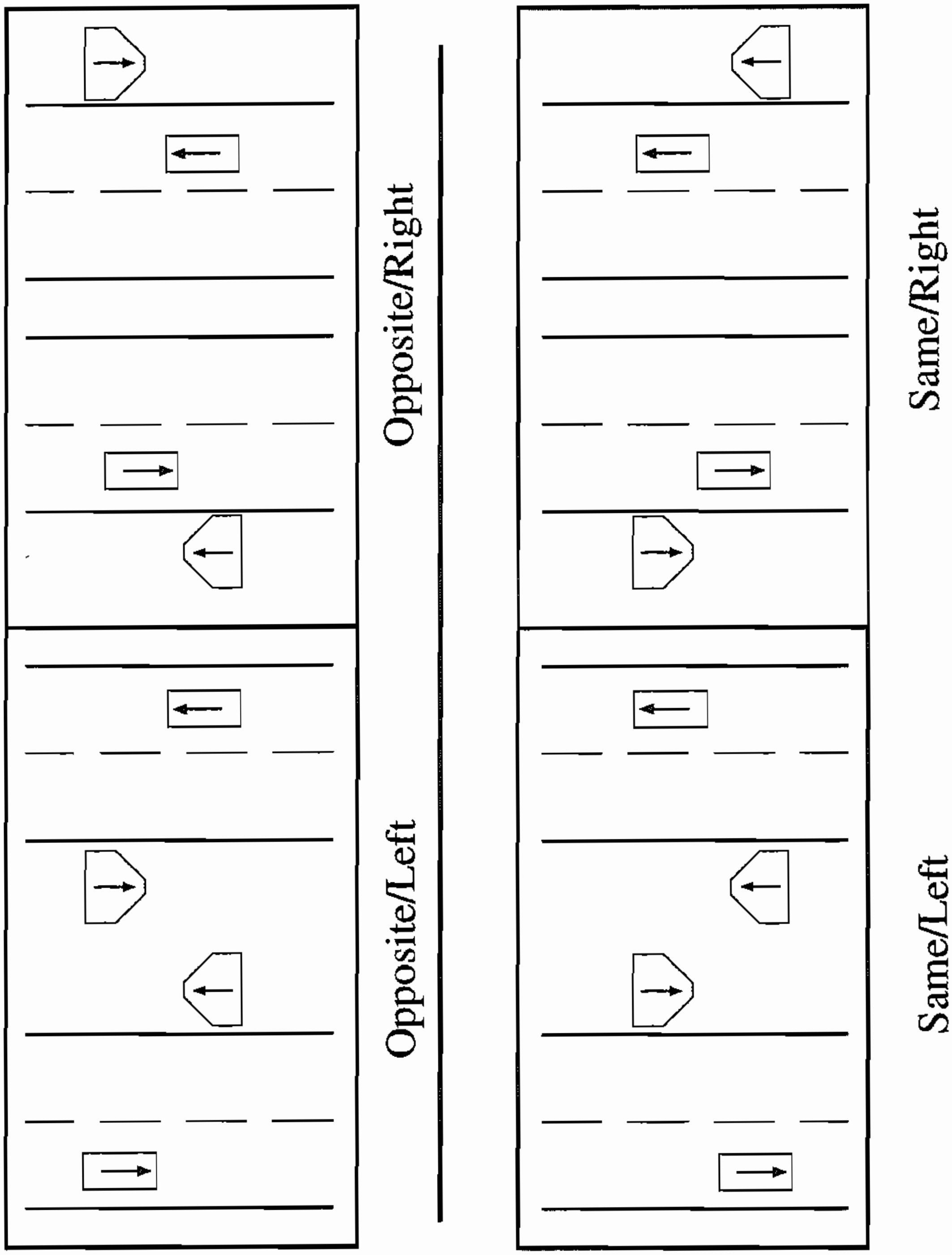

Figure 4.2: Relative direction database parameters

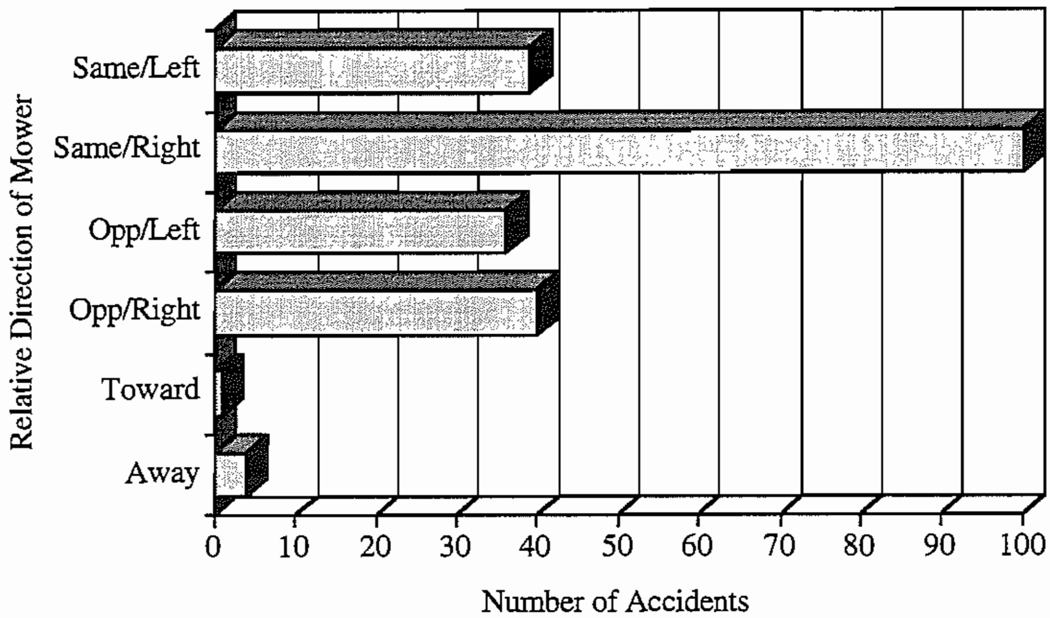

Figure 4.3: Number of MTO accidents vs. mower direction

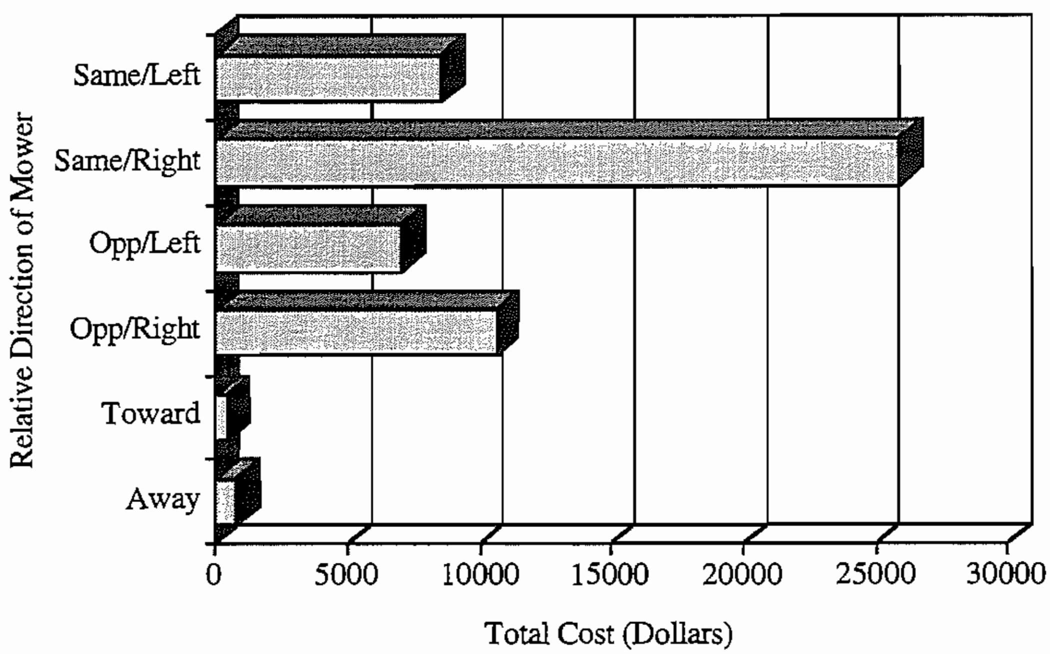

Figure 4.4: Total cost of MTO accidents vs. mower direction

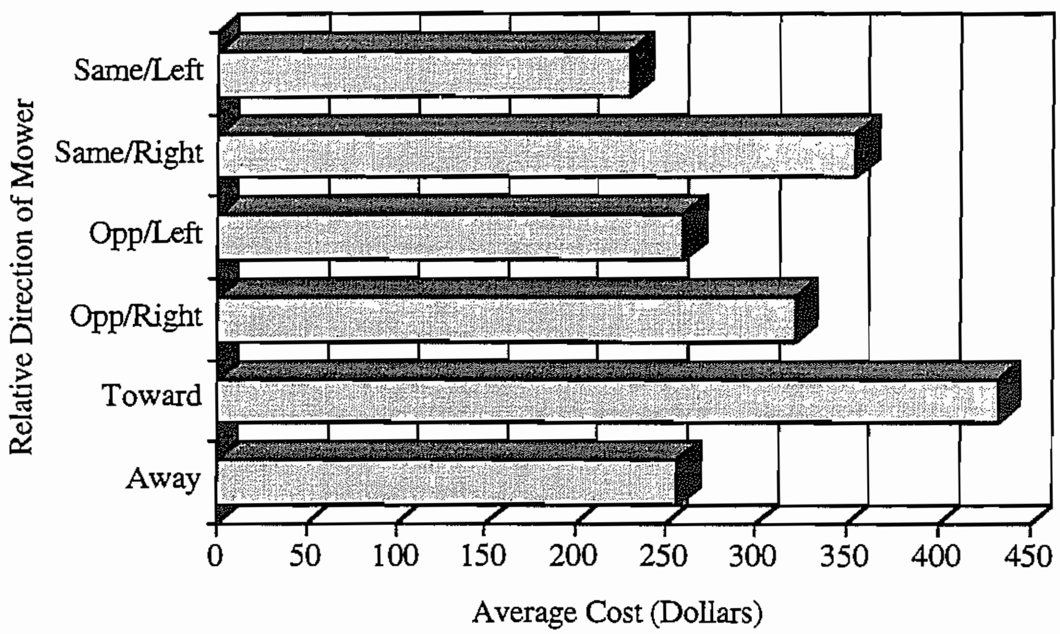

Figure 4.5: Average cost of MTO accidents vs. mower direction

Geographic Location Analysis

A geographic analysis of the data was performed to determine if the reported MTO accidents were confined to a region or regions of the state. The accident reports were also analyzed by roadway type. The categories used were (1) US Highway, (2) Interstate Highway, (3) Texas State Highway, (4) Farm to Market Road, and (5) Ranch Road. These categories were also divided as rural or urban (within city limits). Parking lots and city streets were also included for completeness and are considered urban areas.

Results and Discussion of the Geographic Location Analysis

The geographic analysis did not lead to any new insights as far as identifying a particularly hazardous region of the state. Of the 254 Texas counties, 48% (123 counties) reported at least one MTO accident between 1987 and 1992. Common to all the counties reporting accidents is an interstate or US highway. Common to the counties reporting 10 or more MTO accidents (2.5 % of the counties) is a city with a population over 75,000 people and west of Interstate Highway 35. These counties make up over 35% of the total MTO accidents reported. The only exception is Hutchinson county which has neither a major population area nor a US highway. Deduction tells us that the more traffic the greater the possibility that an accident will occur. Figure 4.6 shows the number of MTO accidents by TxDOT District. The occurrence of more accidents west of IH 35 (see Figure 4.7, Fort Worth, Wichita Falls, Amarillo, Odessa, Laredo, and Childress districts) is also easily explained. The rockier terrain in west Texas increases the probability that an object will be hit and thrown. Combined with major highways and population areas and the possibility of an MTO accident occurring is greatly increased.

Figure 4.8 shows the number of MTO accidents based on the roadway categories given. Of the reported accidents, 59% occurred on urban roadways and 41% on rural roadways (Figure 4.9). Also, 56% of MTO accidents occurred on US and Interstate highways (Figure 4.10). Once again, the higher population concentrations in urban areas and higher traffic on US highways will lead to an increased probability that an accident will occur. [An interesting side note is related to the parking lot accidents. All but one of the parking lots where accidents occurred were at Texas Department of Transportation Maintenance Offices.]

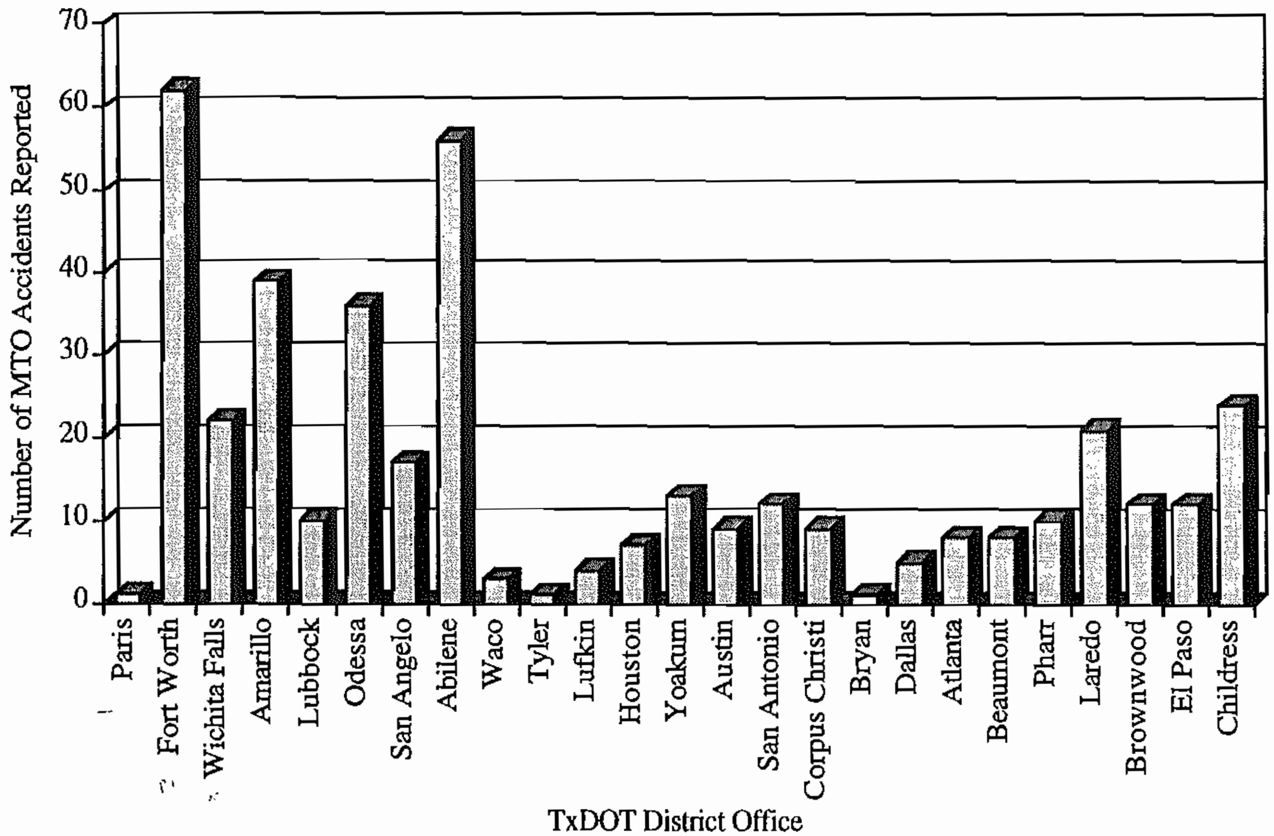

Figure 4.6: Number of MTO accidents vs. TxDOT district

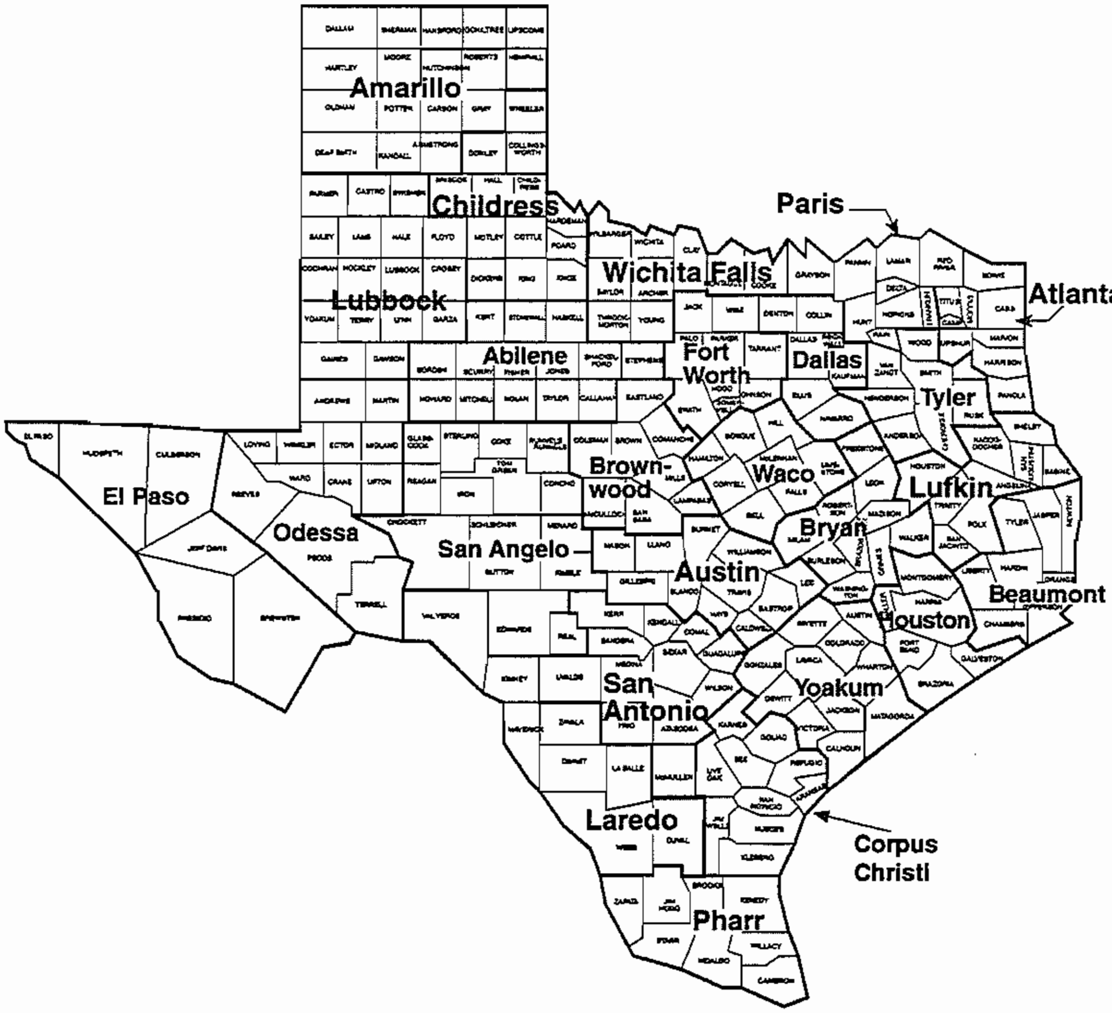

Figure 4.7: Map of Texas Department of Transportation districts

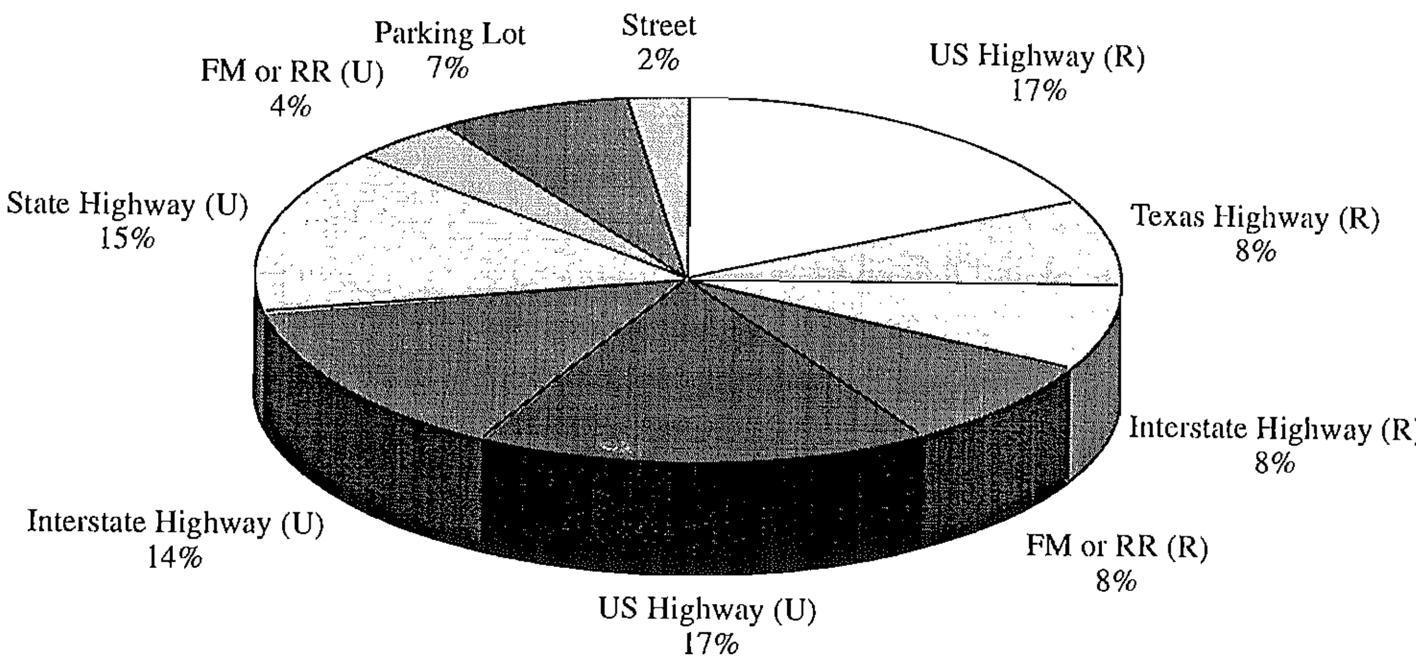

Figure 4.8: MTO accidents by roadway type

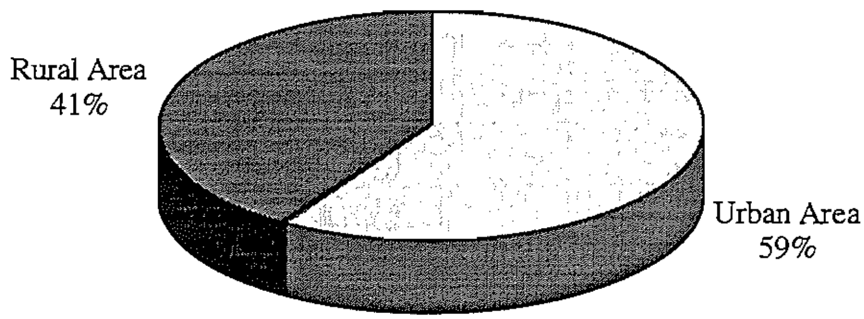

Figure 4.9: MTO accidents on urban vs. rural roadways

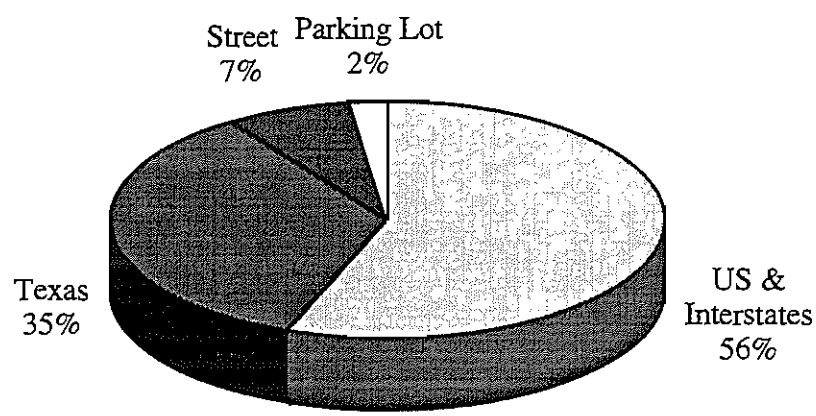

Figure 4.10: MTO accidents on U.S. vs. Texas state highways

Recommendations

With about 80% of all mowing being done by contractors, any trends developed cannot be taken as being reliable. It is recommended that a new data collection system be developed using a new accident data collection document. An improved data collection sheet (Appendix F) was developed and incorporates the details necessary to complete any future studies on mower thrown object accidents and develop more realistic trends.

The completed data collection sheet should be submitted to TxDOT with any accident involving a state-owned or contracted mower. Ideally, each MTO related accident will result in two reports being submitted to TxDOT, one from the vehicle driver and one from the mower operator. Mower operators should be informed that all accidents must be reported. The Department of Public Safety should also inform TxDOT of any reports of MTO accidents. Requiring mower operators to complete these data sheets serves two purposes. First, it will provide data for future studies. Second, the act of filling in the form will raise the awareness of the mower operator to mower safety.

Due to a higher percentage of accidents in urban areas and high traffic areas, it is recommended that additional safety precautions be taken when mowing Level 1 and Level 2 areas as defined in Roadside Vegetation Management, Chapter 1, section 3 (see Appendix G). Level 1 and Level 2 areas are defined as developed urban areas and high traffic roadways, respectively. Additional precautions such as better signing and flagging, flashing lights, and /or a following vehicle will give passing motorists a better awareness of mowing operations and better visibility of the mowers. Better mower visibility should provide the motorist more time to react to the mowing operations and avoid potentially hazardous situations.

CHAPTER 5: THROWN OBJECT VELOCITY ANALYSIS

Experimental results from the 1986 CTR studies on mower thrown objects showed a majority of thrown objects leave the blade encasement from the rear. Based on this information, it was recommended that mowing should be performed against the flow of traffic in the lane closest to the mower. The principal reason being that a reduction in the relative velocity will reduce the amount of damage to the vehicle or lessen the chance of occupant injury.

This chapter presents a detailed analysis of mower thrown object velocities. Determined are the relative velocity between a thrown object and a vehicle as well as the probability a vehicle will be hit by a thrown object. Using the experimental data of the 1986 CTR reports, a probabilistic approach will be taken to evaluate if a thrown object can travel into the far travel lanes. Simple kinematics will be used to determine the relative velocity between a thrown object and a passing vehicle on a typical two lane roadway. In addition, safety rankings are assigned for various mower/travel direction configurations.

Data Collection

The basic assumption for recommending mowing against traffic flow is it decreases the relative velocity between the thrown object and the passing vehicle. However, this assumption was never tested statistically in previous mower thrown object accident studies. Using the experimental data from the 1986 CTR studies along with data from mower manufacturers, the relative velocity, distance thrown probability distribution, and hazard regions were determined.

The CTR 445-1 [Ref 16] study provided the analytical results of the momentum exchange between an experimental mower blade and an object. Those results were used to verify the calculations of the thrown object velocity using current blade assemblies and masses. The CTR 445-2 [Ref 17] study provided experimental data of thrown object distances. This experiment involved mowing over wooden blocks and limestone rocks with a Terrain King bat-wing mower. The distance each object was thrown was then measured. This data was used to determine the probability distribution of thrown objects and used to determine the region of a two lane highway most likely to be hit by a thrown object -- the "danger zone". This data was also used to verify the thrown object velocity calculations. Data gathered from manufacturers' brochures, interviews, and operating manuals provided blade tip velocity, blade assembly mass, and blade length -- all used to calculate the momentum exchange between the blade and a foreign object.

Analysis

Using the SIMAN statistical software package [Ref 27], three probability distributions were formed for the experimental data: (1) thrown rock distances, (2) thrown block distances, and (3) a combination of block and rock thrown distances. Figures 5.1 a and b show the probability distribution curves for the thrown rocks and blocks. Figure 5.1c shows the probability distribution curve when the distances of rocks and blocks are combined. These curves give the probability that an object will travel a certain distance if struck and thrown by a mower. Using the distributions and a typical two lane highway, the danger zone was calculated.

Figure 5.2 shows the four possible mower/travel direction configurations with a single mower and a typical two lane roadway. The mower is shown on the right side of the roadway since there is a general tendency for more objects to be thrown to the left. This tendency, however, depends on the mower model. This tendency may be related to the rotation direction of the center blade assembly. Further study is recommended to better understand the effect of mower make and model on the distribution of thrown objects. For this analysis, the blade assemblies are assumed to be rotating in the following manner: left wing, clockwise; center wing, counter-clockwise; right wing, counter-clockwise. This is the standard setup for Terrain King, Rhino, and Continental Belton mowers, the majority of mowers used in Texas.

Using basic linear momentum calculations and the experimental distance thrown data, the average velocity of a thrown object was calculated. Other assumptions used in determining the relative velocity are:

Cars are traveling at 97 kph (60 mph)

The object is thrown at a 45 degree angle to maximize both components of velocity

The object strikes both vehicles with the same velocity

Air resistance is neglected

Each of the four cases was ranked from the least hazardous (rank = 1) to the most hazardous (rank = 4) with respect to the relative velocity at impact. In the cases where the impact velocities were equal, the case which had the greatest relative velocity striking the

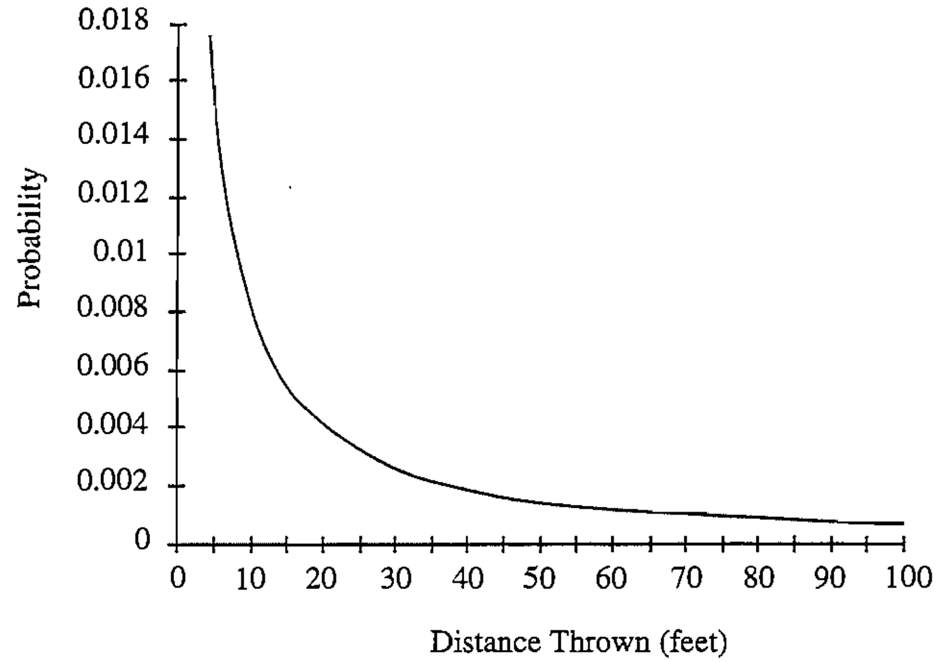

Figure 5.1a: Probability distribution for distance rocks are thrown

Figure 5.1b: Probability distribution for distance blocks are thrown

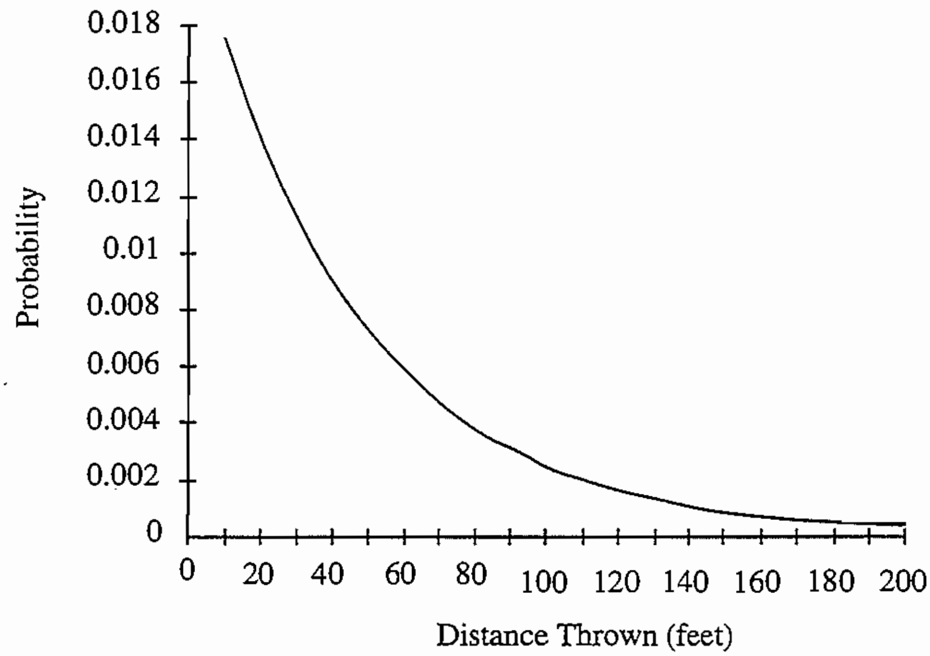

Figure 5.1c: Probability distribution for distance rocks and blocks are thrown

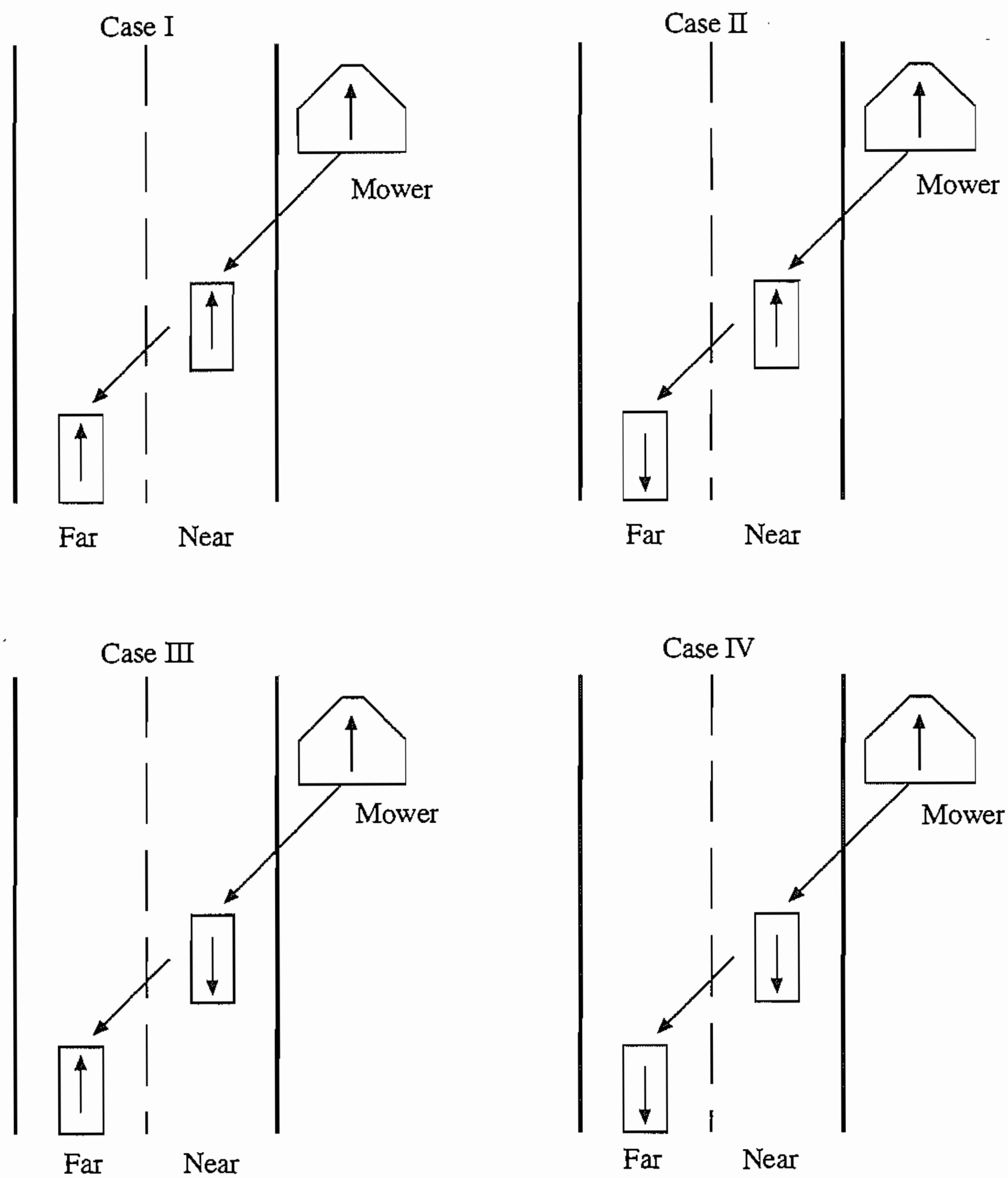

Figure 5.2: Possible mower/travel direction configurations

nearest lane was determined to be more hazardous. This is based on the probability distribution showing a greater probability of an object being thrown into the near lane than the far lane.

Using the probability distributions shown in Figures 5.1 a, b, and c, the probability of a vehicle being hit in each lane was calculated for a thrown rock, thrown block, or a combination of both. It was assumed that for a vehicle in the nearest lane to be hit, the object must be able to travel 2.4 m (8 ft.) {1.5 m (5 ft.) over the shoulder plus 1 m (3 ft.) into the travel lane} or more. In order for a vehicle in the far lane to be hit, the object must be able to travel 6.1 m (20 ft.) {1.5 m (5 ft.) over the shoulder plus 3.7 m (12 ft.) over the near lane plus 1 m (3 ft.) into the far lane} or more.

The calculations performed are summarized and presented in Appendix H.

Results

The average thrown object velocity was calculated to be approximately 138.6 m/s (455 ft/s) or 500 kph (310 mph). Table 5.1 lists the relative velocity between an average thrown object and a passing vehicle for the four mower/travel direction cases. The table also gives the safety ranking of each case.

Table 5.1: Relative Velocity Between Thrown Object and Vehicle and Safety Rank

CASE	VELOCITY m/s (ft/s) Near Lane	Far Lane	RANK (1=safest)
I	158.7 (521)	158.7 (521)	4
II	158.7 (521)	121 (396)	3
III	121(396)	158.7 (521)	2
IV	121 (396)	121 (396)	1

The probability of a passing vehicle being hit by a thrown rock or block regardless of the travel direction is given in Table 5.2. This probability represents the minimum distance an object must be thrown in order for an impact to occur.

Table 5.2: Probability a Vehicle Will Be Hit by a Thrown Object

OBJECT	LANE	
	Near Lane	Far Lane
Rock	33.9%	24.5%
Block	86.9%	70.4%
Either	84.0%	64.6%

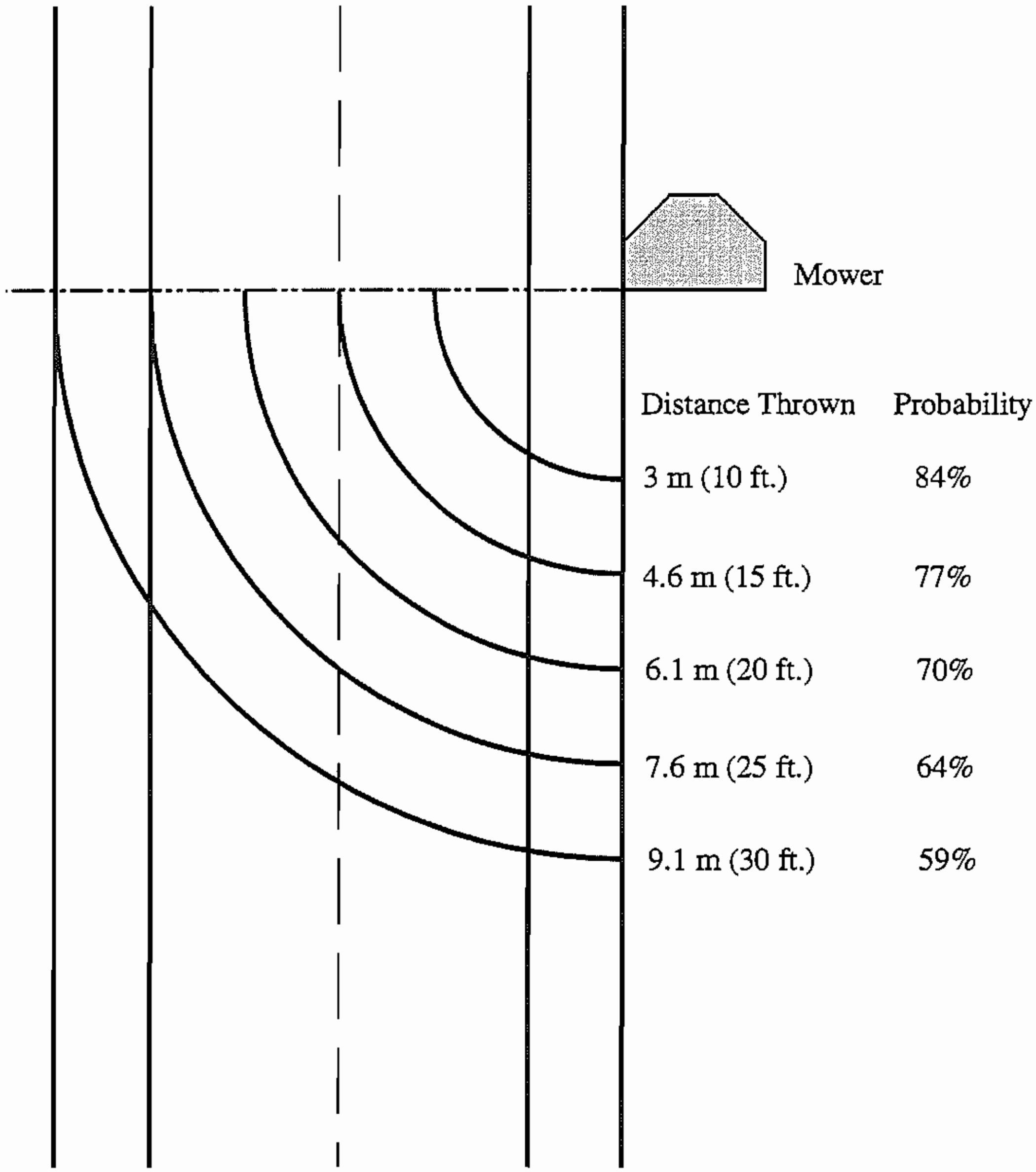

Figure 5.3a: Probability of the distance blocks are thrown

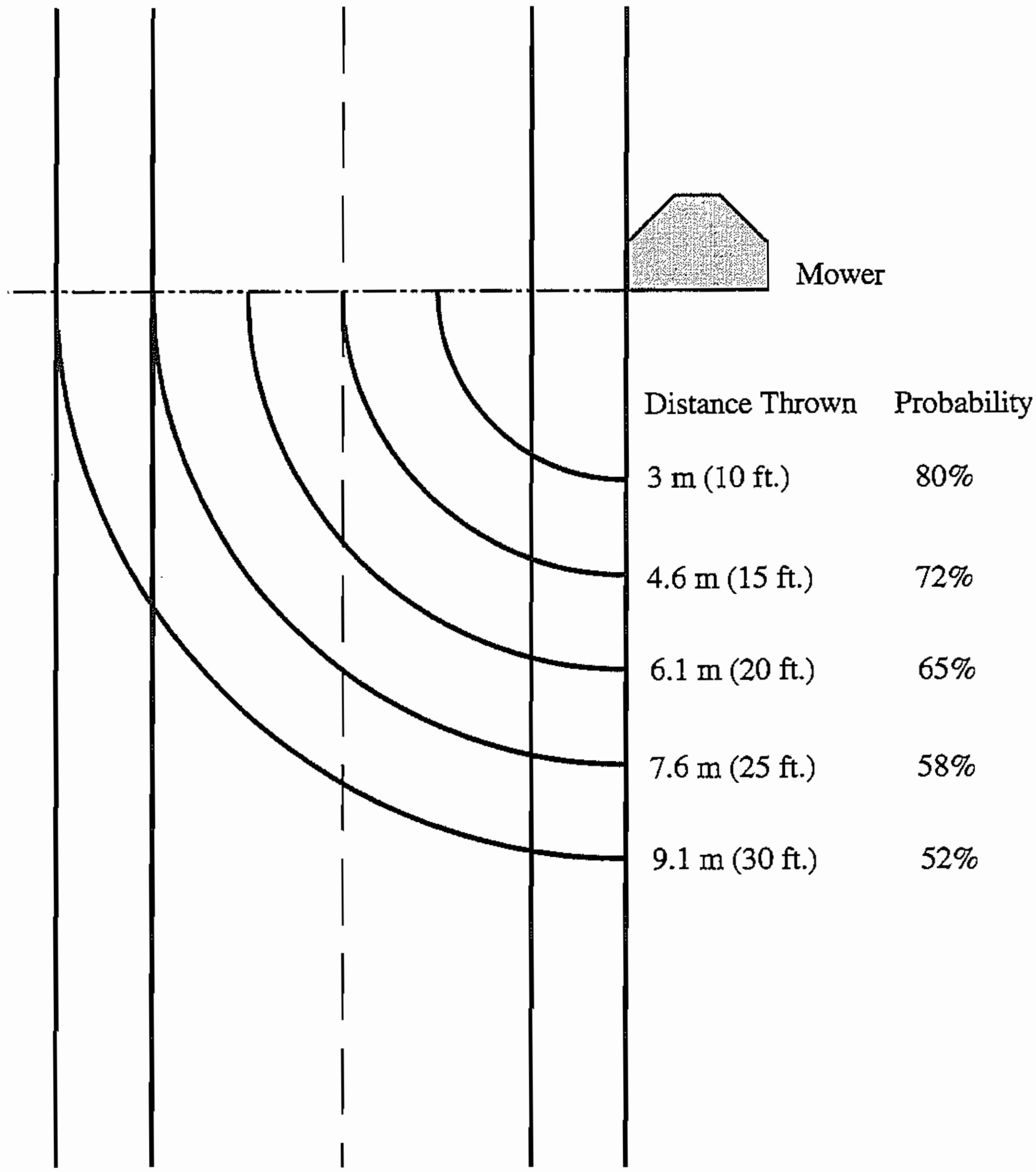

Figure 5.3b: Probability of the distance either blocks or rocks are thrown

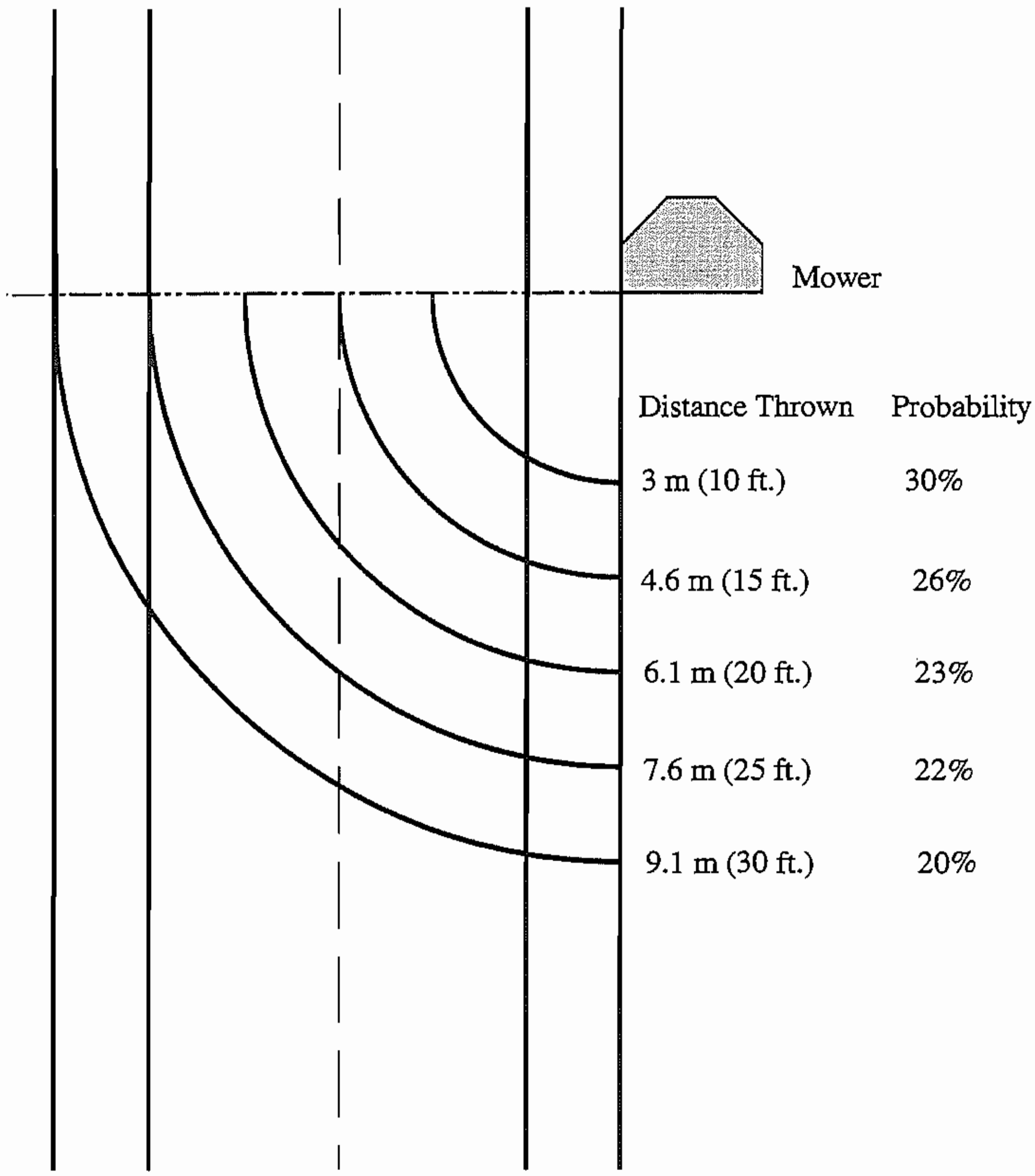

Figure 5.3c: Probability of the distance rocks are thrown

Figures 5.3 a, b, and c show the probability an object can be thrown a certain distance onto the roadway. The outermost distance defines the edge of the danger zone for that roadway.

Discussion of Results of the Thrown Object Velocity Analysis

The graph of the danger zone (Figures 5.3 a, b, and c) shows there is a good probability that an average thrown object can cross over two lanes of traffic. While the calculations for Case III show that mowing against traffic flow does reduce the relative velocity between the thrown object and the passing car in the near lane, the relative velocity is increased for the car in the far lane. This configuration would be typical for many state highways, farm to market roads, and ranch roads in the state. Mowing against traffic flow in this situation would not significantly reduce the severity or frequency of MTO accidents. Operators should be allowed to mow in the safest, most efficient manner possible for these road types. Mowers should mow against traffic flow whenever possible, however, it is realized that certain terrain and traffic conditions may require mowers to travel with traffic flow. The present travel direction requirements should be eased to allow for mowing in the direction of travel for less than ideal conditions.

In cases where both lanes of traffic are moving in the same direction - Cases I and IV, it can be seen that mowing against traffic flow does reduce the relative velocity of the thrown object and the passing car. Operators should continue to always mow against traffic flow for these roadways. This would include divided highways and non divided highways with a center turning lane.

For full width mowing or where more than one strip may be required, the strip nearest the roadway should be mowed against traffic flow and if possible, mowed last. Mowing this strip last may allow the uncut grass to serve as a shield if any objects are thrown while mowing the inner strips. This practice should be followed for all roadway types where full width or multiple strip mowing is required.

The amount of time a motorist is in the danger zone of a mower is related to the probability of an MTO accident. A vehicle can travel in the danger zone for an extended amount of time while following the mower or waiting for an opportunity to pass. The most dangerous situation is when a vehicle, traveling in the same direction as the mower, does not have enough room to pass the mower. Figure 5.4 shows cars waiting for a mower to leave the roadway so they can move in the turning lane the mower is blocking.

Figure 5.4: Mower in travel lane blocking traffic

CHAPTER 6: INVESTIGATION OF MOWING ACTIVITY

This chapter presents the results of the investigation of mowing activity performed during the 1994 summer mowing season. The field investigation was divided into three parts: (1) interviews of mowing contractors, (2) interviews of mower operators, and (3) surveillance of mowing activity. Table 6.1 shows each activity with the document used to collect the data. These documents are given in Appendix I.

Table 6.1: Investigation Activities and Documents

Activity	Document
Interviews of Mower Operators	Questions for Mower Operators
Interviews of Mowing Contractors	Questions for Mowing Contractors
Surveillance of Mowing	Observation of Mowing Checklist

The primary objective of the investigation of mowing activity was to determine the degree of implementation of the mowing against traffic requirement. Other objectives focused on determining:

(1) the type of safety equipment used,
(2) the functionality of mowing against traffic,
(3) the operator's awareness of mower thrown objects,
(4) the willingness of contractors and operators to participate in safety training,
(5) the method of processing accident claims, and
(6) the possible traffic law violations.

Using the above objectives, the documents listed in Table 6.1 were developed to insure consistency in the data collection.

Contractor Interviews

Mowing contractors were interviewed by telephone so a wider cross section of the state could be covered in the shortest amount of time and at the least expense. Table 6.2 lists the names of the contractors interviewed and the county they are contracted to mow.

Table 6.2: Interviewed Contractors

Name of Contractor	Date Interviewed	County Contracted
Randall & Blake, Inc.	June 30, 1994	Tarrant
J & J Services, Inc.	June 30, 1994	Erath
Chemical Control Products	July 12, 1994	Stephens
Nor-Tex Environmental	July 12, 1994	Tarrant
C.R. Buddy Smith Constr.	July 19, 1994	Erath
Jerry Hamilton Contractor	July 19, 1994	Lime Stone
Brownsboro Enterprises	July 21, 1994	Caldwell
Blackwell	July 21, 1994	Caldwell
Varner Mowing Services	August 5, 1994	Harris
G.W. Dill	August 5, 1994	Nolan

Mower Thrown Object Accident Claims

An accurate assessment of the number of MTO accidents is important for determining the effect of mowing procedures. Presently, the only MTO accident data available are contained in claims made to the TxDOT Insurance Division. These claims represent only those accidents involving state owned mowers (about 20% of the total number of mowers). Other claims are made directly to the contractor. Since most claims are usually less than the contractor's insurance deductible, these claims are paid directly by the contractor and not reported to the TxDOT Insurance Division.

Figure 6.1 shows that 60% of the contractors interviewed receive two or more accident claims per mowing season. Assuming one contractor per county is responsible for highway mowing, this indicates there are over 600 MTO accidents per mowing season. This is about double the number expected based on the number of claims submitted by Texas state maintenance personnel.

Safety

Most of the contractors interviewed did provide some type of safety training for their employees. Figure 6.2 shows 50% of the contractors use hands-on training where a new employee accompanies an experienced operator in order to learn how to use the

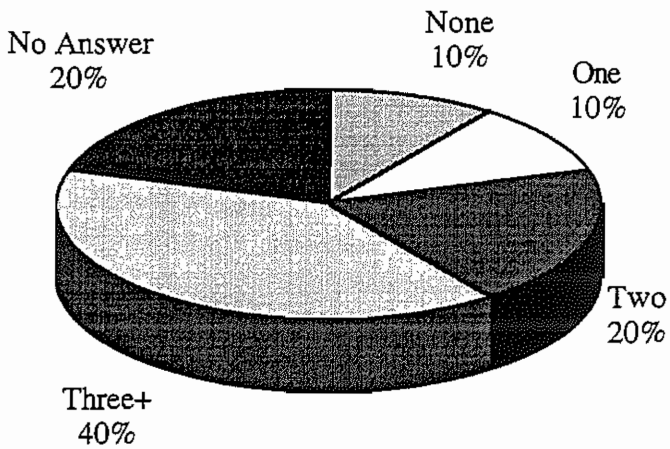

Figure 6.1: Number of MTO accident claims per mowing season

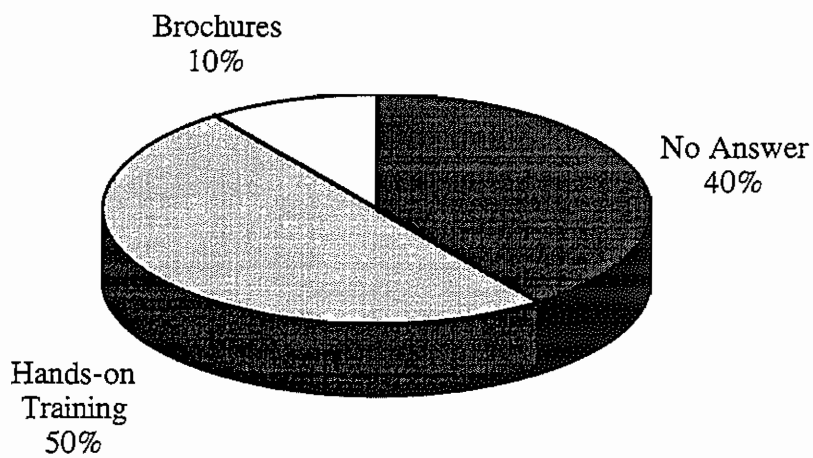

Figure 6.2: Type of safety training provided by mowing contractors

equipment. Contractor published brochures were used by 10% of the contractors to illustrate additional safety issues.

All those interviewed indicated they would be willing to provide safety training to their employees if materials were made available.

Mowing Against Traffic

One of the objectives of the contractor interviews was to determine the functionality of mowing against traffic. When asked what problems mowing against traffic creates the only negative comment received was that mowing against traffic at all times slows the mowing operation due to frequent "deadheading". However, the TxDOT Contract for Highway Maintenance only requires mowing against traffic for the pass nearest the roadway and not at all times. Positive comments about mowing against traffic included:

- No operational problems are introduced by mowing against traffic.
- Mowing against traffic decreases the number of MTO accidents.
- Mowing against traffic in urban areas gives the operator better eye contact with oncoming motorists.

Litter and Debris Control

Contractors were asked for any ideas or suggestions for TxDOT concerning mowing. It was discovered that litter and debris on the roadside is a serious problem. All of the interviewed contractors suggested a better litter control process be implemented. The contractors stated that trash on the roadside contributes greatly to the occurrence of mower thrown objects.

Operator Interviews

Mowing operators were interviewed in person since it was felt this would yield the best results. The operators were interviewed on-site either during the lunch break or at the end of the day. This allowed the interviewer to observe mowing and interview the operator. Table 6.3 lists the employer of the operators interviewed and the county they were mowing.

Table 6.3: Interviewed Operators

Operator Employer	Date Interviewed	County Interviewed
Keith Wilson	June 24, 1994	Travis
Not Available	June 24, 1994	Blanco
Not Available	June 24, 1994	Travis
The Paige Mowing	July 1, 1994	Harris
Not Available	July 1, 1994	Bastrop
Universal Services	July 7, 1994	Harris

Mowing Against Traffic

In order to determine the degree of implementation of the mowing against traffic requirement, operators were asked how often they mowed against traffic. The most common answer was "when possible" indicating certain terrain and traffic conditions do not allow mowing against traffic. Figure 6.3 shows that 33% of those operators interviewed prefer mowing against traffic while 50% prefer mowing with traffic. Those preferring to mow with traffic stated it allows for easier movement on and off the travel lanes when mowing around obstacles. The operators also stated that mowing against traffic often increases the time required to mow some areas (Figure 6.4).

Mower Thrown Objects

The distance objects are thrown is a key factor in determining the effectiveness of mowing against traffic. The analysis in Chapter 5 showed mower thrown objects can be thrown across two lanes of traffic. Of the operators interviewed, 20% said objects are usually thrown across more than two lanes (Figure 6.5).

A concern of this research has been whether or not the operators are aware of an object being hit and thrown. According to the interviews, 17% of the operators are usually aware of an MTO occurrence (Figure 6.6). The operators stated they could hear the impact noise from the blade striking the object. However, in high traffic areas, the operators stated they are not able to hear the impact noise.

Litter and Debris Control/Speed Zones

Operators were asked for any ideas or suggestions for TxDOT concerning mowing. The suggestion repeated by each operator is to perform a litter pickup before mowing takes place. In urban areas where the litter problem is greater, non-profit organizations are hired to perform a litter pickup. However, it has been reported that litter crews do not perform

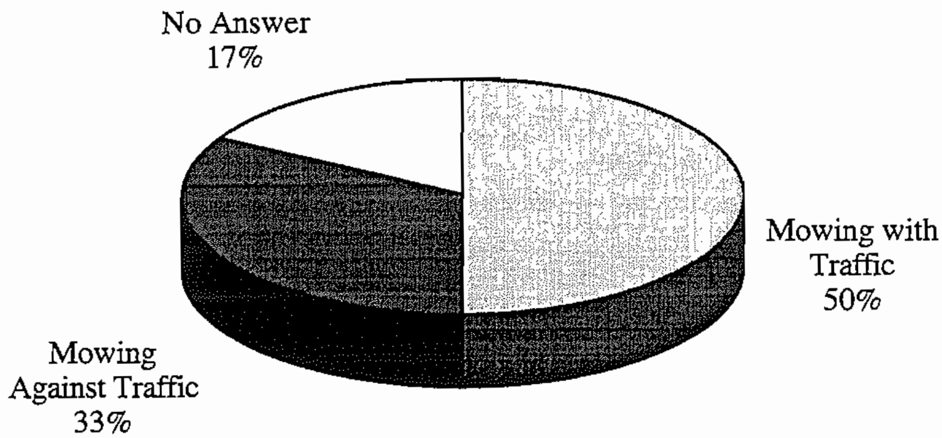

Figure 6.3: Operator preferred mowing directions

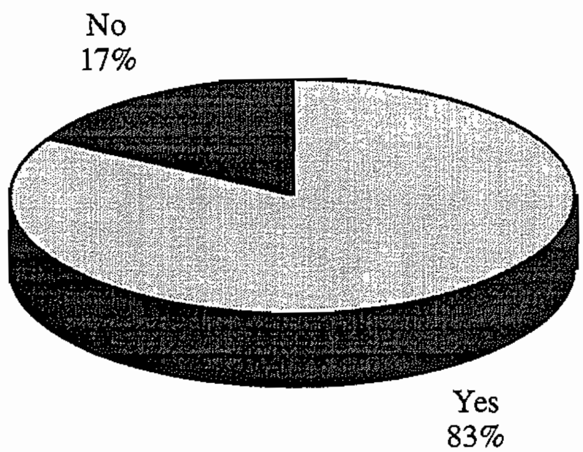

Figure 6.4: Operator response to question: Does mowing against traffic increase mowing time?

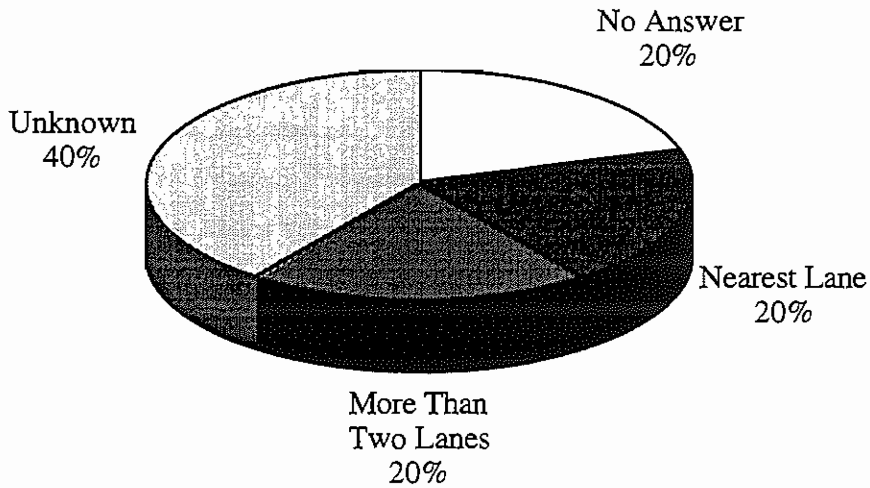

Figure 6.5: Distance mower thrown objects are thrown

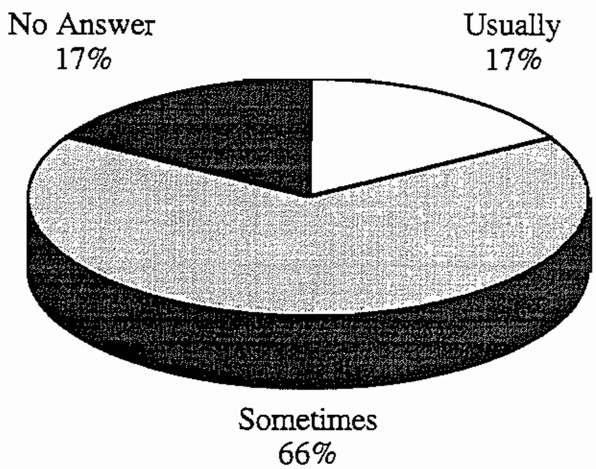

Figure 6.6: Operator's awareness of objects hit by mower

the job adequately. These crews tend to avoid the taller grass areas that are notorious for hiding litter and potentially dangerous objects that could be thrown.

The operators made other suggestions for possible guidelines related to their own safety. These included reduced speed zones around mowers and leaving the mowing direction decision to the operators.

Surveillance of Mowing Activities

Mowing operations were observed in a total of eight counties in Texas, mostly in the Austin area. Mowing was also observed in Louisiana, Oklahoma, Wisconsin, and Colorado. The mowing schedules for the various counties in Texas were provided by the TxDOT county offices. In addition to the "Observation of Mowing" checklist, each mowing operation was photographed and/or videotaped to provide a visual record. The mowing sites observed are given in Table 6.4. The roadway types listed in the table are consistent with those presented in Chapter 4.

Causes of Mower Thrown Objects

Observations were made as to the causes of mower thrown objects. Some of the causes found were:

- Debris and litter on the right-of-way
- Ground strikes caused by uneven terrain
- Improper cutting height
- Improper use of the mower wings

A portion of MTO claims have resulted from roadside trash and other debris along the right-of-way -- additional details are presented in Reference 23. Aluminum cans, bottles, old tires, and mailboxes are the most common types of debris found along the roadside. Tree limbs and rocks are also hit. As previously stated, both contractors and operators consider roadside litter to be the primary source of MTO accidents, yet observations showed that operators seldom make efforts to avoid most roadside litter.

The risk of ground contact is increased due to uneven terrain that separates the right-of-way from the pavement (Figure 6.7). In order to mow around roadside obstacles such as signs, guardrails, and culverts, an operator is often forced over uneven terrain onto the pavement. Blade contact with the ground is also caused by the slopes around driveways and ditches as well as ruts and mounds on the right-of-way. It was observed that driveways are one of the primary sources of ground contact due to the steep slopes on either side (Figure 6.8). The uneven terrain reduces the ground to blade distance (effective cutting height), increasing the probability of hitting and throwing small objects.

Another cause of mower thrown objects was improper cutting height. The current cutting height required in the General Notes and Specification Data section of the Contract for Highway Maintenance is 18 cm (7 in.). Observations indicated the cut height of grass was usually less than the standard height. The cut height of the grass on level terrain was generally around 10 to 13 cm (4 to 5 in.). This cutting height may provide a more aesthetic appearance, but it may increase the possibility of the cutting blades striking the ground and hitting an object.

Table 6.4: Observed Mowing Sites

Date	County	Roadway Type	No. Mowers
June 15, 1994	Hays	State Highway (R)	2
June 15, 1994	Bastrop	State Highway (R)	2
June 17, 1994	Bastrop	US Highway (R)	3
June 17, 1994	Travis	Ranch Road (R)	1
June 17, 1994	Travis	US Highway (U)	1
June 17, 1994	Travis	US Highway (U)	1
June 20, 1994	Travis	State Highway (U)	1
June 20, 1994	Travis	State Highway (R)	1
June 23, 1994	Blanco	US Highway (R)	1
June 23, 1994	Blanco	Farm to Market (R)	1
June 23, 1994	Travis	Farm to Market (R)	2
June 24, 1994	Travis	Farm to Market (R)	1
June 24, 1994	Travis	US Highway (U)	3
June 24, 1994	Blanco	US Highway (R)	1
June 24, 1994	Hill	Interstate Highway (R)	1
June 24, 1994	Bastrop	US Highway (R)	2
June 25, 1994	Travis	Farm to Market (R)	3
June 29, 1994	Kerr	Farm to Market (R)	4
June 29, 1994	Travis	US Highway (U)	3
July 1, 1994	Bastrop	US Highway (R)	4
July 1, 1994	Harris	Interstate Highway (U)	3
July 7, 1994	Harris	Interstate Highway (U)	5
July 17, 1994	Williamson	State Highway (R)	2

R - Rural Roadways : U - Urban Roadways

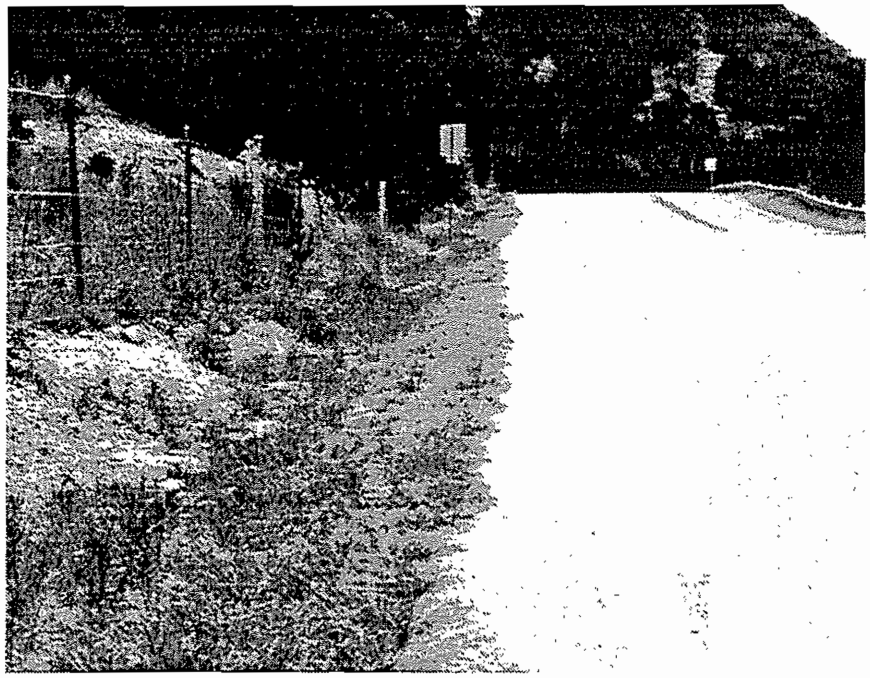

Figure 6.7: Uneven terrain between the pavement and right of way

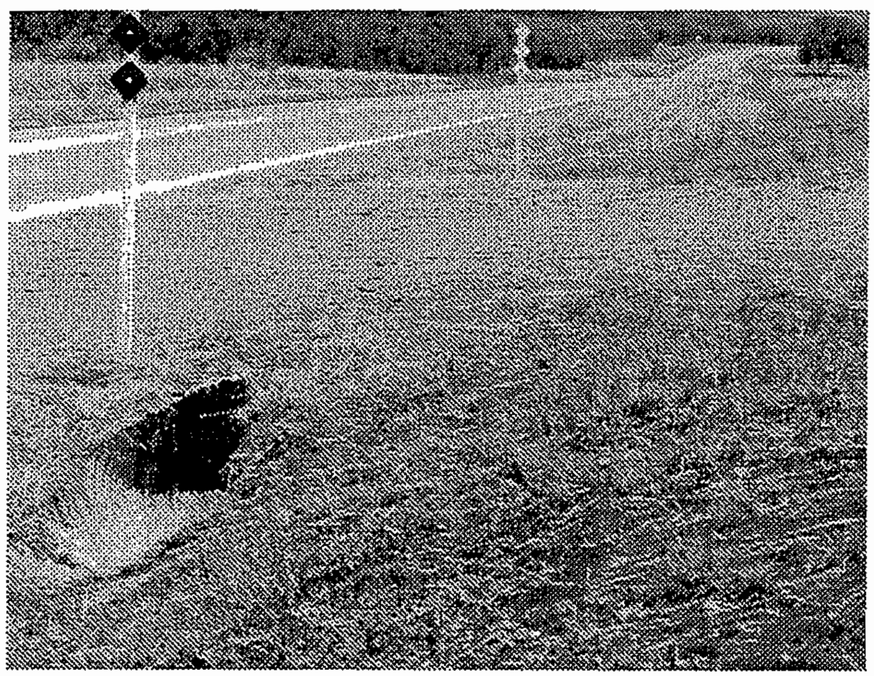

Figure 6.8: Steep slopes on the side of a driveway

Uncontrolled lowering of the side wings of the mower can also cause blade contact with the ground and produce a thrown object. The wings of the mower are hydraulically controlled by the operator. The raising and lowering of the side wings is done to mow over uneven terrain and around obstacles.

Mowing Around Obstacles

According to the contractor and operator interviews, a complaint about mowing against traffic is the increased time it takes to cut some areas. Field surveillance also identified other procedures employed by operators which decreases the efficiency of the mowing operation, regardless of the mowing direction. Road signs and delineator poles slow down the mowing operation when the operator stops and attempts to completely mow around all sides of the obstacle. Figure 6.9 shows the observed methods used to mow around obstacles. Mowing completely around obstacles often forces the mower onto the travel lane (Figure 6.10). The time required to cut the area is also increased if the operator must wait for traffic to clear before entering the roadway. It was observed that some contractors used a second employee with a line trimmer to cut the area around obstacles. This allows the mower to continue cutting without having to enter the roadway.

Results and Discussion of the Observation of Mowing Activity

Field observations showed that 41% of the mowing operations consistently mowed with the flow of traffic, while 38% mowed against the flow of traffic (Figure 6.11). In areas with narrow roadways and limited sight distance, most operators mowed with traffic to avoid possible collisions with on-coming traffic. Because most of the observations were made in the Austin area where narrow roadways are common, these percentages may not accurately reflect the remainder of the state.

The number of thrown objects and those mowing procedures that produced thrown objects were primary concerns. In 46% of the observations, at least one mower thrown object occurred. Of that percentage, 12% of the cases involved two or more objects being discharged from the mower during the time (about 20 minutes) that the mowing operation was observed (Figure 6.12). The objects were discharged from the side and rear of the mower 78% of the time (Figure 6.13). This observation supports the assumption made in Chapters 4 and 5 that objects are more likely to be thrown to the rear and side of the mower.

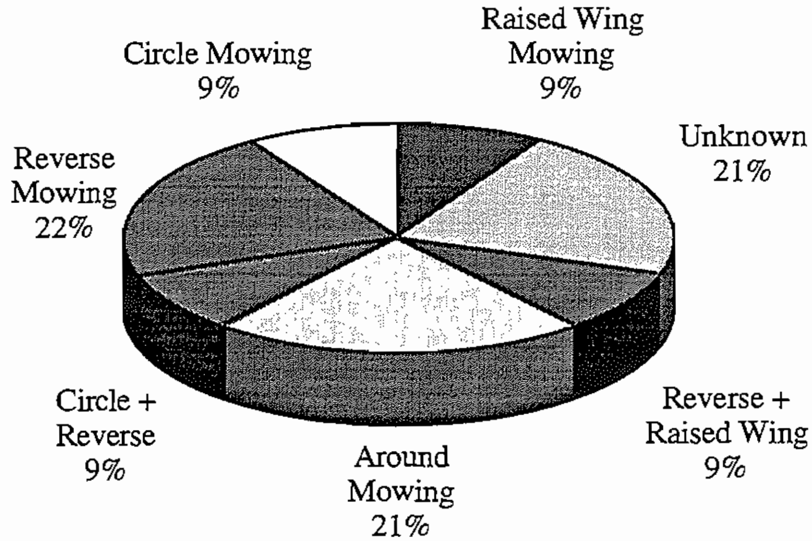

Figure 6.9: Observed methods used to mow around obstacles

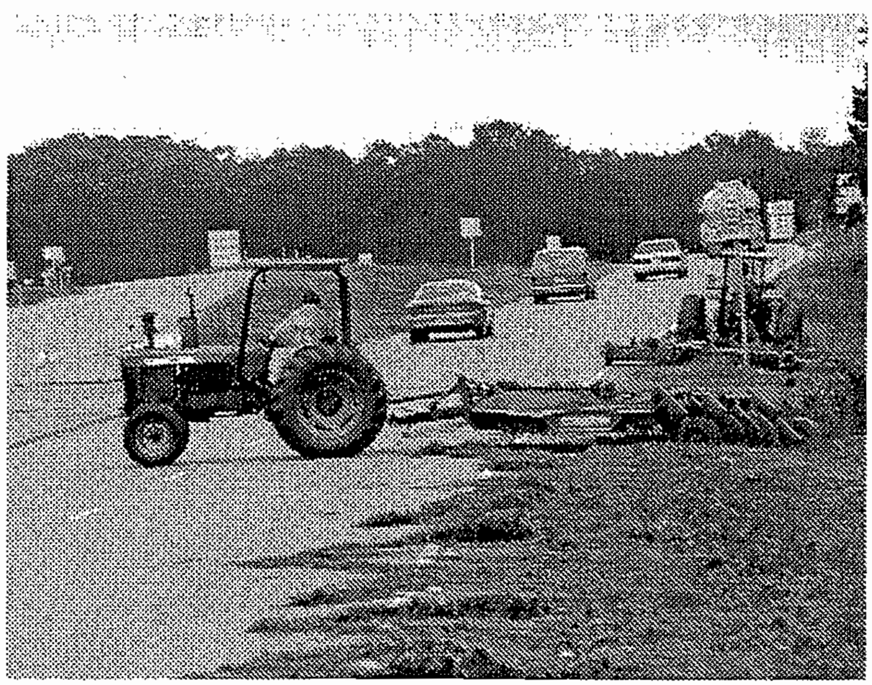

Figure 6.10: Mower on roadway mowing around roadside obstacle

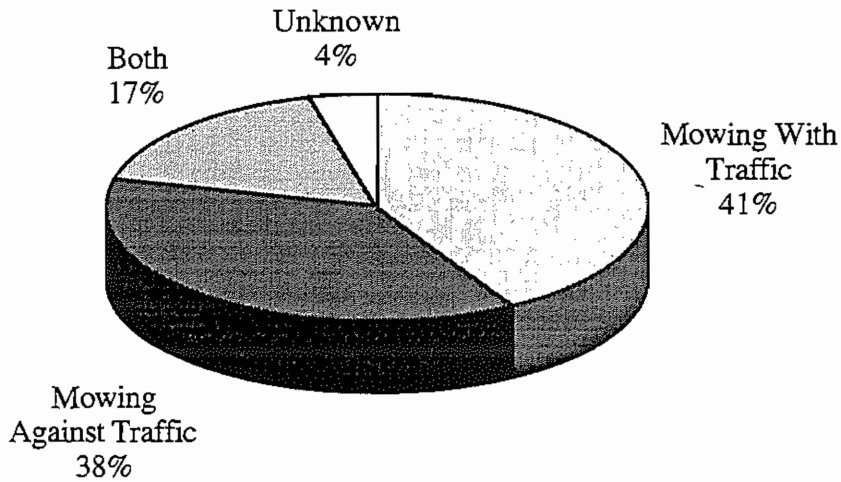

Figure 6.11: Observed mowing direction

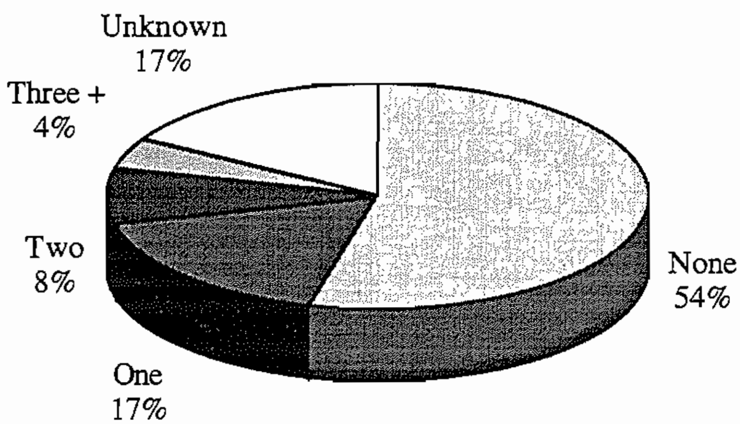

Figure 6.12: Number of mower thrown objects observed during observation period

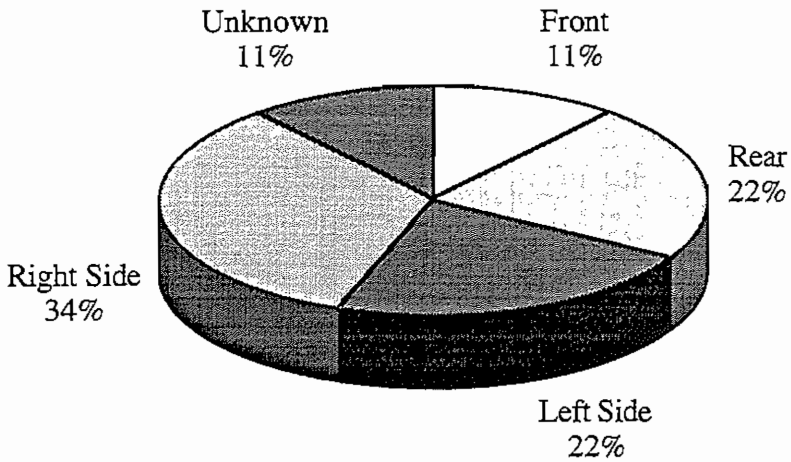

Figure 6.13: Location where objects were discharged from mower

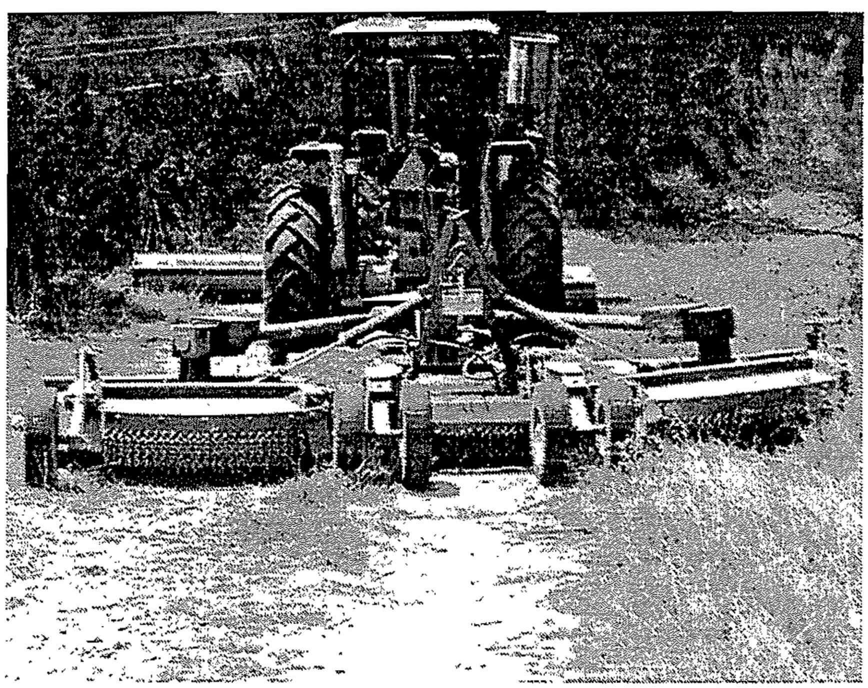

Figure 6.14: Safety chains on the rear of a foldable wing rotary mower

Safety chains were seen on all the mowers observed. These chains are required by TxDOT as part of the mowing contract. Safety chains on the front and rear of the mower were observed in 92% of the cases (Figure 6.14); and 8% of the mowers did not have rear safety chains, but were equipped with chains on the front and sides.

Operators have reportedly received traffic citations for traveling in the wrong direction on the roadway. No traffic citations were issued during the observed mowing period.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions and recommendations for improved mower safety. The conclusions and recommendations are based on the work presented in the previous chapters.

Conclusions

Equipment

The foldable wing rotary mower is currently the best mower to use for highway mowing because of its lower initial cost, higher productivity, and lower maintenance costs.

Mowing Direction

A summary of the advantages and disadvantages of (1) mowing against traffic and (2) mowing with no direction restrictions is presented in Table 7.1. There is no conclusive theory to support the adoption of either mowing procedure entirely. A combination of both procedures would produce the most effective and safest method of highway mowing.

Traffic Law Issues

Texas traffic laws do not apply to highway mowers since they are considered highway maintenance equipment and not vehicles while engaged in mowing operations. Therefore, mowing against traffic is not considered to be in violation of traffic laws applicable to direction of travel.

Table 7.1: Advantages and Disadvantages of Mowing Directions

Direction	Advantage	Disadvantage
Against Traffic	Reduced number of MTO accidents	Most effective when all travel lanes are moving in the same direction
	Reduced severity of MTO accidents	May increase cutting time in some areas
	Increased operator eye contact with oncoming traffic	Difficult to move onto roadway to mow around obstacles
No Restriction - with or against traffic or both	Easier to move onto roadway when mowing around obstacles	May increase the number of MTO accidents
	Preferred by operators and contractors	Increases the severity of MTO accidents
	Does not increase cutting time	Reduced operator eye contact with traffic

Recommendations for Implementation

The following changes should be made to the Vegetation Management Guidelines for Levels of Vegetation (Appendix G):

> Mowing shall be done against the flow of traffic in the lane or group of lanes nearest the mower for **Developed Urban Areas.** When performing full-width mowing or multiple strip mowing, the strip nearest the roadway shall be mowed last.
>
> Mowing should be done against the flow of traffic in the lane or group of lanes nearest the mower when possible for **Partially Developed Urban or Rural Areas.** Exceptions will be made by the district engineer. When performing full-width mowing or multiple strip mowing, the strip nearest the roadway shall be mowed last.
>
> The direction of mowing shall be left to the discretion of the mower operator and contractor for **Rural Areas.** When conditions allow, mowing should be performed against traffic flow in the nearest lane.

Recommendations for Future Research

1. Additional study should be conducted to investigate whether line trimmers could be used to mow around obstacles in order to allow mowers to minimize their access to the roadway.

2. Future research should be conducted to determining if a safety standard for highway mowing similar to the one given in Appendix D should be adopted and placed in the mowing contract. This could improve the safety of all those involved in mowing operations.

3. Future efforts should address improving communications with mower manufacturers. For example, when mowing specifications such as cutting height are modified, mower manufacturers could insure that the equipment is capable of providing safe operation.

4. Future efforts should address improving communications with mowing contractors to insure they are aware of current mowing specifications and proposed changes to mowing specifications.

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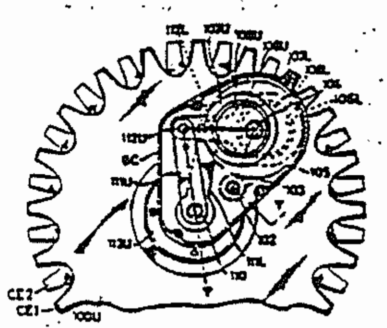
Appendix A
Patents

4,998,401
MOWING MACHINE

Akio Terai, Machida; Junichi Yoshino, Tokyo; Shinroku Satsumi, Machida, and Mitsuru Taniguchi, Tokyo, all of Japan, assignors to Komatsu Zenoah Co., Tokyo, Japan

Continuation of Ser. No. 86,496, Aug. 17, 1987, Pat. No. 4,881,363. This application Mar. 15, 1989, Ser. No. 324,011
Claims priority, application Japan, Aug. 26, 1986, 61-198226; Jul. 6, 1987, 62-102664; Jul. 6, 1987, 62-102665
The portion of the term of this patent subsequent to Nov. 21, 2006, has been disclaimed.
Int. Cl.5 A01D *34/76, 34/68*
U.S. Cl. 56—255 10 Claims



1. A mowing machine, comprising:
a motive power source;
first and second pivotal cutting wheels slidably superposed with each other and each provided with a number of grass cutting edges; and
means for oscillating said cutting wheels in opposite directions each through a predetermined angle, respectively, wherein said oscillating means comprises:
(a) a crank shaft rotatably driven by said motive power source;
(b) a first shaft coupled to said first cutting wheel;
(c) a substantially cylindrical second shaft into which said first shaft is rotatably and coaxially inserted and coupled to said second cutting wheel; and
(d) a crank lever mechanism provided between said crank shaft and said first and second shafts for converting a rotational motion of said crank shaft into two oppositely directed oscillating motions of said first and second shafts to oscillate the first and second wheels relative to each other, respectively, with respect to an axis of said shafts through the predetermined angle.

5,027,591

MOWING APPARATUS

Masaharu Nakamura, and Minoru Wada, both of Tokyo, Japan, assignors to Komatsu Zenoah Company, Tokyo, Japan

Filed Feb. 21, 1990, Ser. No. 482,754

Claims priority, application Japan, Feb. 23, 1989, 1-41558; Feb. 23, 1989, 1-41559; Jun. 2, 1989, 1-64005

Int. Cl.[5] A01D *34/68*

U.S. Cl. 56—240 7 Claims

1. A mowing apparatus comprising:

a motive power source for supplying rotational motion;

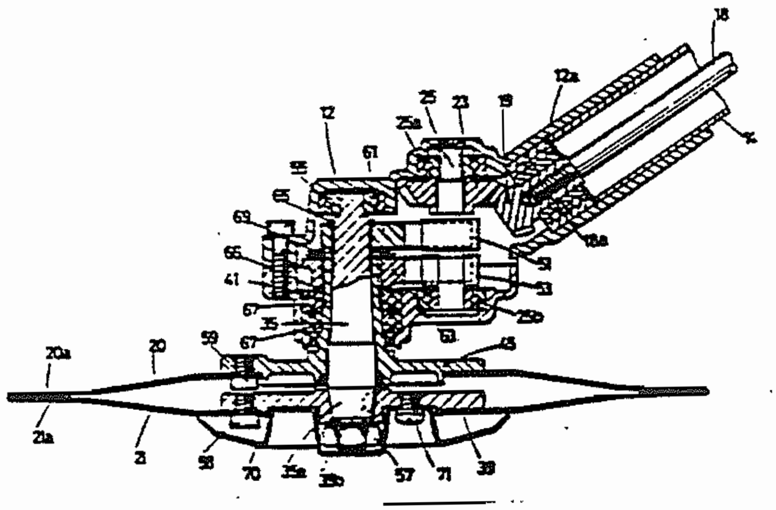
a pair of first and second cutting wheels slidably superposed with each other and each of the wheels being provided with a number of grass cutting edges; and

means for reciprocatively rotating each cutting wheel in opposite directions through a predetermined angle, respectively, the rotating means comprising a first shaft coupled to the first wheel, a cylindrical-shaped second shaft into which the first shaft is rotatably and coaxially inserted and coupled to the second wheel, and converting means provided between the power source and the first and second shafts for converting the rotational motion from the motive power source into two oppositely and reciprocatively rotational motions of the first and second shafts within the predetermined angle,

wherein the converting means comprises:

a cam shaft rotatably driven by the motive power source, the cam shaft being provided in parallel with the first and second shafts;

first and second eccentric cam plates which are eccentrically fixed to the cam shaft in vertical direction thereof so as to be radially symmetrical with each other with respect to a central axis of the cam shaft; and



first and second arms each having opposite ends, a concave portion being formed at one end thereof, and the other ends of the first and second arms being coupled to the first and second shafts, respectively, each concave portion of the first and second arms being adapted to receive each of the first and second cam plates, respectively, in such a manner that the first and second arms can be pivotably oscillated in mutually opposite directions to each other in accordance with the rotation of the first and second cam plates, whereby the first and second cutting wheels being reciprocatively rotated relative to each other toward opposite directions about an axis of the shafts through the predetermined angle.

5,010,717

OSCILLATING-TYPE MOWING APPARATUS

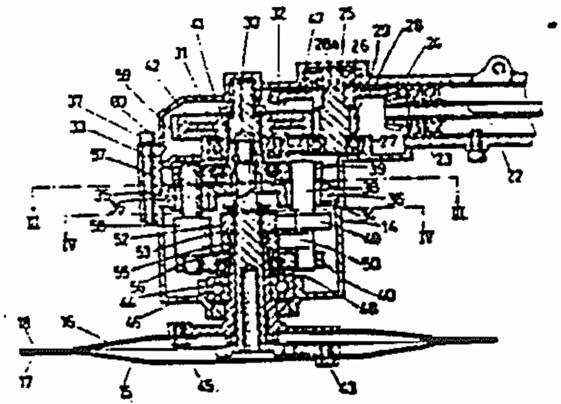
Masaharu Nakamura, and Kazuo Kajimura, both of Tokyo, Japan, assignors to Komatsu Zenoah Company, Tokyo, Japan

Filed Mar. 26, 1990, Ser. No. 498,631

Claims priority, application Japan, Mar. 27, 1989, 1-71854; Jun. 2, 1989, 1-64005[U]

Int. Cl.[5] A01D *34/30, 34/84*

U.S. Cl. 56—17.6 8 Claims



1. A mowing apparatus, comprising;
a motive power source for supplying rotating motion;
a pair of first and second cutting disks slidably supported with respect to each other, each of said disks including a plurality of peripheral cutting teeth;
means for reciprocatively oscillating said first and second cutting disks in opposite directions relative to each other within a predetermined oscillating range by the rotating motion of said motive power source; and
means for rotating said first and second cutting disks in one direction while said first and second cutting disks are oscillated reciprocatively by said reciprocatively oscillating means, said rotating means also being driven by the rotating motion of said motive power source through said reciprocatively oscillating means.

5,054,276

CUTTING BLADE FOR A MOWING APPARATUS

Akio Terai, Machida, and Minoru Wada, Tokyo, both of Japan, assignors to Komatsu Zenoah Company, Tokyo, Japan

Filed Apr. 11, 1989, Ser. No. 336,154

Claims priority, application Japan, Apr. 12, 1988, 63-48319[U]

Int. Cl.[5] A01D *34/76*

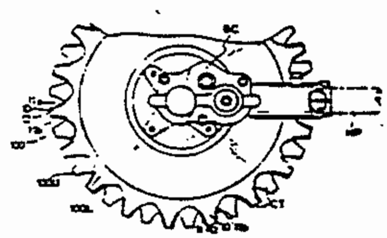
U.S. Cl. 56—242 4 Claims

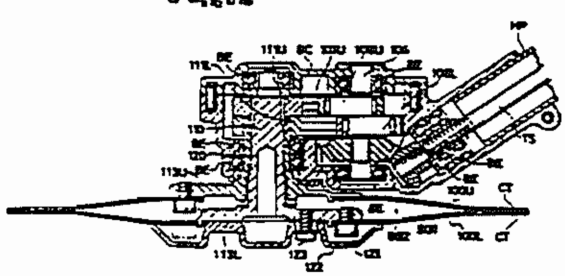
1. A cutting blade for a mowing apparatus comprising:

a pair of first and second pivotal cutting wheels slidably superposed with each other and each including a plurality of cutting teeth along its circumference, each tooth having a major surface, two sides edges and an outer peripheral edge, wherein the side edges of each tooth of the cutting wheels form a profile respectively, defined by an inclined surface forming an acute angle relative to the major surface of the tooth so as to form a cutting edge, and wherein the outer peripheral edge is defined by a plane substantially perpendicular to the major surface of the tooth; and

means for reciprocatingly rotating the cutting wheels in opposite directions relative to each other through a predetermined angle;

wherein the cutting teeth of each of the cutting wheels are bent slightly toward the opposite cutting wheel so that only tip portions of said cutting teeth of each cutting wheel elastically contact each other when the cutting wheels are correspondingly superposed and the tip portions of the cutting wheels are in engagement with each other when the cutting wheels are mutually pivoted and wherein the cutting teeth of each cutting wheel are inter-





meshed so that contacting portions of the cutting teeth of the first and second cutting wheels are displaceable along the profile of each cutting edge according to pivotal motion of the cutting wheels.

5,271,212
LAWNMOWER BLADE WITH YIELDABLE OPPOSITE OUTER CUTTING SECTIONS

Ray S. Anderson, 306 Maple St., Bell Buckle, Tenn. 37020

Filed Dec. 23, 1992, Ser. No. 996,315
Int. Cl.[5] A01D 34/68
U.S. Cl. 56—12.7 17 Claims

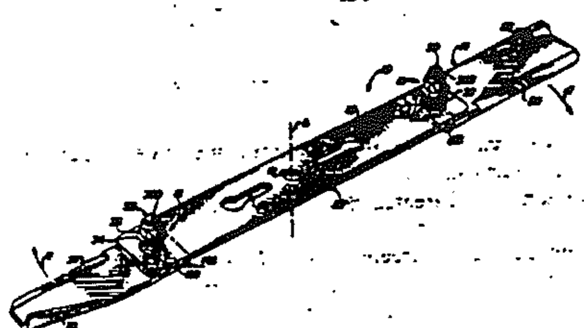
1. A lawnmower blade, comprising:

(a) a center blade section having a pair of opposite end portions and means for mounting said blade to a lower end of a mower drive shaft;

(b) a pair of opposite outer blade sections each having a cutting edge; and

(c) a pair of yieldable articulating joints each attaching one end portion of each of said outer blade sections to one of said opposite end portions of said center blade section such that each of said outer blade sections can both pivot upwardly and rotate backwardly relative to a forward direction of blade rotation and to a respective one of said opposite end portions of said center blade section so as to yield upon striking an object and thereby prevent damage to the mower drive shaft and said cutting edges on said yielding outer blade sections;

(d) each of said yieldable articulating joints including



(i) means for pivotally connecting one of said opposite end portions of said center blade section with said one end portion of one of said outer blade sections such that said one end portion of said one outer blade section is disposed below said one opposite end portion of said center blade section, and

(ii) means mounted to said connecting means for biasing said one end portion of said one outer blade section and said one opposite end portion of said center blade section toward one another, said biasing means being yieldable to permit said one end portion of said one outer blade section to pivot away from said one opposite ends of said outer blade section upon said outer blade section striking an object.

5,233,819

Patent Not Issued For This Number

5,233,820

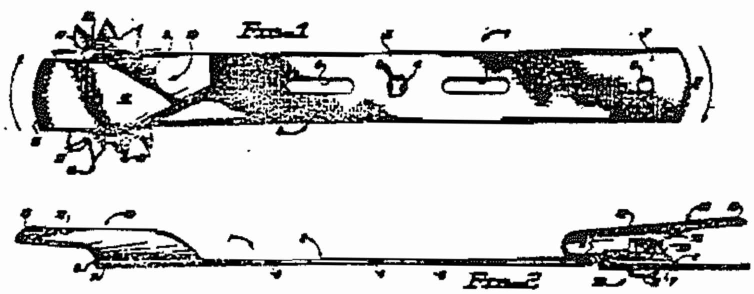
LAWNMOWER BLADE

Raymond W. Willsie, Rte. 1 Box 39 A-6, Ashdown, Ark. 71821

Filed Dec. 18, 1992, Ser. No. 992,549

Int. Cl.[5] A01D *34/64, 34/73*

U.S. Cl. 56—255 **20 Claims**



1. A lawnmower blade for mounting on a powered rotary lawnmower, comprising:

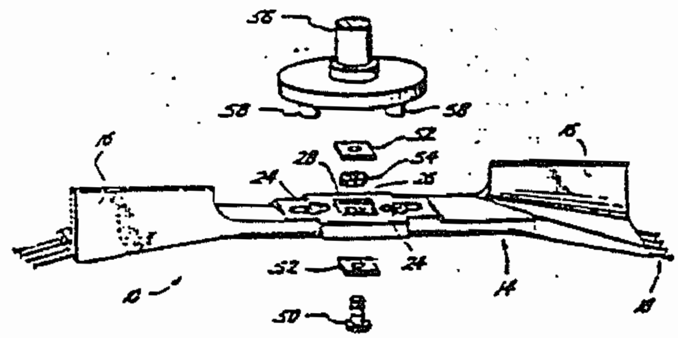
(a) an elongated blade bar mounted for rotary operation on the lawnmower;
(b) a circular cutter blade pivotally and rotatably secured to each end of said blade bar and a plurality of teeth provided on the periphery of said cutter blade for cutting grass and weeds; and
(c) a generally U-shaped grass blower secured to each end of said blade bar and shaped to extend above and at least partially over said cutter blade, respectively, for removing cut grass and weeds.

4,936,884

GRASS CUTTING DEVICE

David L. Campbell, Houston, Tex., assignor to Wesley R. Oder and Stephen M. Bingham, both of Houston, Tex., part interest to each

Filed Dec. 20, 1988, Ser. No. 287,337
Int. Cl.[5] A01D 55/18
U.S. Cl. 56—12.7 21 Claims



1. A grass or weed cutting device adapted for attachment to a lawnmower, comprising:

an elongated, rectangular, curved, rigid support member having two distal ends and structure disposed at a central location between the distal ends for attaching the member to the lawnmower;

airfoil means attached to the member between a distal end and the central location and curved upwardly towards an upstanding orientation relative to the member, and with the device attached to the lawnmower said airfoil means being oriented towards the lawnmower and away from the grass for providing suction on the grass; and

a plurality of elongated, transversely flexible tines attached to each distal end of the member, each tine extending outwardly from the member in general longitudinal alignment with the member, each tine having a distal tip disposed below the respective distal end of the member with the device attached to the lawnmower.

Appendix B
Texas Traffic Laws, Article VI

driving.

(b) Every person convicted of reckless driving shall be punished upon such conviction by a fine of not more than Two Hundred Dollars ($200), or by imprisonment in the county jail for a period of not more than thirty (30) days, or by both such fine and imprisonment.

ARTICLE VI. DRIVING ON RIGHT SIDE OF ROADWAY; OVERTAKING AND PASSING, ETC.

Sec. 52. Drive on right side of roadway—exceptions. (a) Upon all roadways of sufficient width a vehicle shall be driven upon the right half of the roadway, except as follows:

1. When overtaking and passing another vehicle proceeding in the same direction under the rules governing such movement;
2. When an obstruction exists making it necessary to drive to the left of the center of the highway; provided, any person so doing shall yield the right-of-way to all vehicles traveling in the proper direction upon the unobstructed portion of the highway within such distance as to constitute an immediate hazard;
3. Upon a roadway divided into three marked lanes for traffic under the rules applicable thereon; or
4. Upon a roadway restricted to one-way traffic.

(b) Upon all roadways any vehicle proceeding at less than the normal speed of traffic at the time and place and under the conditions then existing shall be driven in the right-hand lane then available for traffic, or as close as practicable to the right-hand curb or edge of the roadway, except when overtaking and passing another vehicle proceeding in the same direction or when preparing for a left turn at an intersection or into a private road or driveway.

(c) Upon any roadway having four or more lanes for moving traffic and providing for two-way movement of traffic, no vehicle shall be driven to the left of the center line of the roadway, except when authorized by official traffic-control devices designating certain lanes to the left side of the center of the roadway for use by traffic not otherwise permitted to use such lanes, or except as permitted under Subsection (a)2 hereof. However, this subsection shall not be construed as prohibiting the crossing of the center line in making a left turn into or out of an alley, private road, or driveway.

Sec. 53. Passing vehicles proceeding in opposite direction. Drivers of vehicles proceeding in opposite directions shall pass each other to the right, and upon roadways having width for not more than one line of traffic in each direction each driver shall give to the other at least one-half (½) of the main-traveled portion of the roadway as nearly as possible.

Sec. 54. Overtaking a vehicle on the left. The following rules shall govern the overtaking and passing of vehicles proceeding in the same direction, subject to those limitations, exceptions and special rules hereinafter stated:

(a) The driver of a vehicle overtaking another vehicle proceeding in the same direction shall pass to the left thereof at a safe distance and shall not again drive to the right side of the roadway until safely clear of the overtaken vehicle.

(b) Except when overtaking and passing on the right is permitted, the driver of an overtaken vehicle shall give way to the right in favor of the overtaking vehicle on audible signal and shall not increase the speed of his vehicle until completely passed by the overtaking vehicle.

Sec. 54A. Operation of vehicle on improved shoulder. (a) A driver may operate a vehicle on an improved shoulder to the right of the main traveled portion of the roadway as long as necessary and when the operation may be done in safety only under the following circumstances:

(1) to stop, stand, or park;

(2) to accelerate prior to entering the main traveled lane of traffic;

(3) to decelerate prior to making a right turn;

(4) to overtake and pass another vehicle that is slowing or stopped on the main traveled portion of the highway disabled or preparing to make a left turn;

(5) to allow other vehicles to pass that are traveling at a greater speed;

(6) when permitted or required by an official traffic control device; or

(7) at any time to avoid a collision.

(b) A driver may operate a vehicle on the improved shoulder to the left of the main traveled portion of a divided or controlled-access highway when the operation may be done in safety only under the following conditions:

(1) to slow or stop when the vehicle is disabled and traffic or other circumstances prohibit the safe movement of the vehicle to the shoulder to the right of the main traveled portion of the roadway;

(2) when permitted or required by an official traffic control device; or

(3) to avoid a collision.

(c) The provisions of this section limiting the operation of vehicles upon improved shoulders shall not apply to:

(1) authorized emergency vehicles responding to calls;

(2) police patrols;

(3) vehicles and equipment actually engaged in work upon a highway but shall apply to such persons and vehicles when traveling to or from such work; or

(4) bicycles.

Sec. 55. When overtaking on the right is permitted. (a) The driver of a vehicle may overtake and pass upon the right of another vehicle only under the following conditions:

1. When the vehicle overtaken is making or about to make a left turn;

2. Upon a street or highway with unobstructed pavement not occupied by parked vehicles of sufficient width for two or more lines of moving vehicles in each direction;

3. Upon a one-way street, or upon any roadway on which traffic is restricted to one direction of movement, where the roadway is free from obstructions and of sufficient width for two (2) or more lines of moving vehicles.

(b) The driver of a vehicle may overtake and pass another vehicle upon the right only under conditions permitting such movement in safety. In no event shall such movement be made by driving off the main traveled portion of the roadway except as provided in Section 54A.

Sec. 56. Limitations on overtaking on the left. No vehicle shall be driven to the left side of the center of the roadway in overtaking and passing another vehicle proceeding in the same direction unless authorized by the provisions of this Act and unless such left side is clearly visible and is free of oncoming traffic for a sufficient distance ahead to permit such overtaking and pass-

Appendix C
Industry Safety Standards

SAE J232 Dec. 1984
Industrial Rotary Mowers Section 7.6
Thrown Object Test

7.5.2 TEST CONDITIONS—The mower should be positioned so the cutting edge of a stationary blade is 305 mm (12 in) ± 13 mm (0.5 in) above sand base. When supports are necessary to position the mower such that the cutting edge of the blade is 305 mm (12 in) above the sand base, the supports shall be of round steel bars or tubing no larger than 40 mm (1.0 in) in diameter and no more than six shall be used per frame unit. The supports shall be placed as necessary under wheels, side skids, or other structural components which normally rest on the ground if the mower were at the minimum cutting height. If additional supports are needed, they should be located at least 150 mm (6.0 in) outside the blade enclosure. The mower may also be supported from above.

7.5.3 TEST PROCEDURE—The test shall consist of vertical downward introduction of test rods inserted into each of eight equally spaced holes for each blade assembly in accordance with Fig. 7B. The test rods shall be introduced through the tube and funnel arrangement as specified by Fig. 7A or through a similar arrangement with air or mechanical assist. A sufficient number of test rods shall be dropped into each of the eight positions so that a blade contacts at least twelve test rods per position.

7.5.4 TEST ACCEPTANCE—The mower shall remain in compliance with all applicable requirements of this recommended practice. The test rods shall not break through the blade housing or blade enclosure but may escape through deflector-type shields such as chain shielding as long as no failure is caused to shielding.

7.6 Thrown Object Test—(To be conducted after the structural integrity test). (Does not apply to arm-type mowers) (See reporting form, Appendix A.)

7.6.1 TEST EQUIPMENT—Use test projectiles per paragraph 3.10 and test fixture per Figs. 2, 3, or 4 as applicable. For undermounted units, a 915 mm (36 in) diameter vertical cylinder of target material shall be placed in the operator zone such that the back of the cylinder shall be 76 mm (3 in) behind the back of the operator's seat or 76 mm (3 in) behind the rear position of an actual operator in the event that there is no back support on the seat. The target cylinder shall extend from the operator's normal foot position to a height of 1 m (39 in) above the operator's seat.

Note: Provisions must be made to protect the operator during the test.

7.6.2 TEST CONDITIONS (See paragraph 7.1.)

7.6.3 TEST PROCEDURE—The test shall consist of vertical downward introduction of 75 test projectiles head first and 75 test projectiles point first inserted into each of eight equally spaced holes for each blade assembly in accordance with Fig. 7B. The test projectiles shall be introduced through the tube and funnel arrangement as specified by Fig. 7A or through a similar arrangement with air or mechanical assist. The introduction shall be repeated three times for each hole (450 per hole) for a total of 3600 per blade assembly. The drop velocity should remain relatively constant and be adjusted to ensure that between 5 and 15% of the test objects drop through the blade without making blade contact (in order to ensure that the entire length of the test object is exposed to the blade). After each 150 test projectiles are introduced, the projectiles in a 610 mm (24 in) diameter circle under the introduction hole shall be counted to verify that between 5 and 15% of the test projectiles pass through the blade without making blade contact. See Fig. 7C for height "x" calculation.

On some mowers, it may not be possible to prevent more than 15% of the test projectiles from passing through the blade path without contact. In this case, the 150 quantity must be increased to assure that at least 127 projectiles do make blade contact each test. This can be determined either by sound or counting the pass-throughs.

7.6.4 SCORING—After every 150 nails have been introduced, record the number of nails contacted by the blade and record the marks on the wall above the blade line in the following groups:

(a) Hits in the operator zone
(b) Punctures in the operator zone
(c) Hits outside the operator zone
(d) Punctures outside the operator zone

Total the number of marks in each of these four categories to obtain their totals for the particular blade spindle. (Punctures are a result of a hole in both surfaces of the target material so they will also be included when counting hits. Therefore, do not add hits to punctures for scoring purposes as this would count each puncture twice as a hit.) Divide each sum by the total number of blade-nail contacts for that spindle.

7.6.5 TEST ACCEPTANCE—For each blade spindle, none of the composite individual spindle scores shall exceed the following acceptance criteria:

(a) 2% hits in the operator zone
(b) 0.5% punctures in the operator zone
(c) 15% hits outside the operator zone
(d) 5% punctures outside the operator zone

Failure of any of the four acceptance criteria shall constitute failure of the machine. In the event the machine fails the test, it may be retested. The scores are then computed on the sum of the two tests. If the score still exceeds the acceptance criteria, the machine has failed the test.

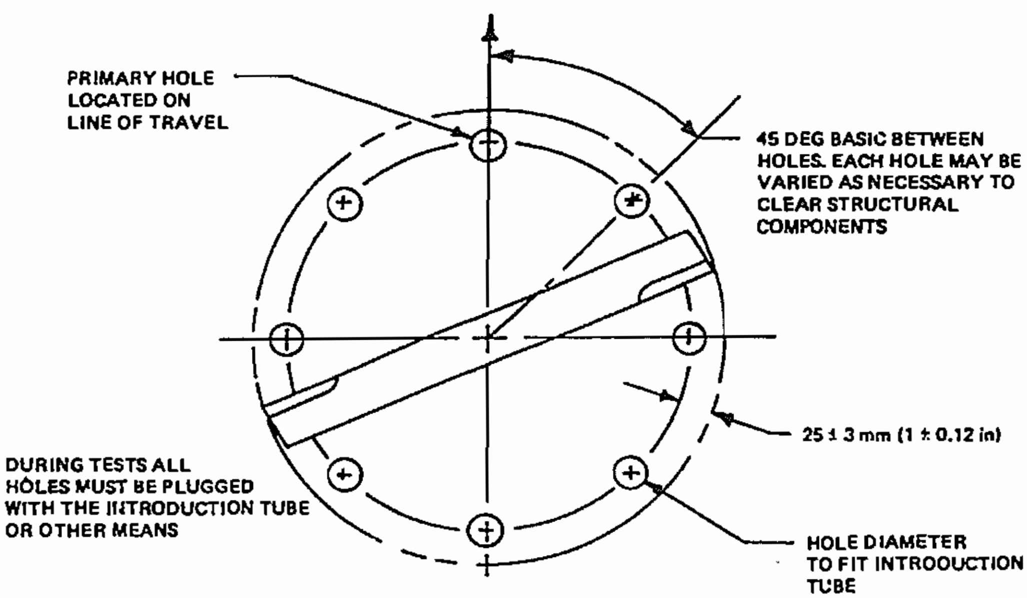
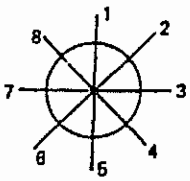


FIG. 7B—TYPICAL INTRODUCTION TUBE LOCATION

APPENDIX A



INDUSTRIAL ROTARY MOWER THROWN OBJECT TESTING

HIT: RUPTURE OF THE FIRST LAYER OF THE THROWN OBJECT TARGET MATERIAL BY A TEST PROJECTILE.

PUNCTURE: RUPTURE OF ALL LAYERS OF THE THROWN OBJECT TARGET MATERIAL BY A TEST PROJECTILE.

MACHINE MODEL: ______________________

SHIELDING TYPE (If used): ______________________

SERIAL NO.: ______________________

SHIELDING PT. NO.: ______________________

BLADE SPINDLE (If Multiple): ______________________

CONDUCTED BY: ______________________

BLADE PT. NO.: ____________ TYPE: ____________

DATE: ______________________

%Based on test object hits or punctures divided by number of objects hit by blade

Hole Position	Run No.	No. of Test Objects Dropped (150 Min)	No. of Test Objects Hit by Blade (127 Min)	Outside Operator Zone: Object Target Hits No.	Outside Operator Zone: Object Target Hits % of Hits	Outside Operator Zone: Object Target Punctures No.	Outside Operator Zone: Object Target Punctures % of Punct.	In Operator Zone: Object Target Hits No.	In Operator Zone: Object Target Hits % of Hits	In Operator Zone: Object Target Punctures No.	In Operator Zone: Object Target Punctures % of Punct.
1.	1.										
	2.										
	3.										
Total #1											
2.	1.										
	2.										
	3.										
Total #2											
8.	1.										
	2.										
	3.										
Total #8											
Total of all 8 holes											
					(15% Max)		(5% Max)		(2% Max)		(0.5% Max)

Subpart D—Safety for Agricultural Equipment

§ 1928.57 Guarding of farm field equipment, farmstead equipment, and cotton gins.

(a) *General*—(1) *Purpose.* The purpose of this section is to provide for the protection of employees from the hazards associated with moving machinery parts of farm field equipment, farmstead equipment, and cotton gins used in any agricultural operation.

(2) *Scope.* Paragraph (a) of this section contains general requirements which apply to all covered equipment. In addition, paragraph (b) of this section applies to farm field equipment, paragraph (c) of this section applies to farmstead equipment, and paragraph (d) of this section applies to cotton gins.

(3) *Application.* This section applies to all farm field equipment, farmstead equipment, and cotton gins, except that paragraphs (b)(2), (b)(3), and (b)(4)(ii)(A), and (c)(2), (c)(3), and (c)(4)(ii)(A) do not apply to equipment manufactured before October 25, 1976.

(4) *Effective date.* This section takes effect on October 25, 1976, except that paragraph (d) of this section is effective on June 30, 1977.

(5) *Definitions*—*Cotton gins* are systems of machines which condition seed cotton, separate lint from seed, convey materials, and package lint cotton.

Farm field equipment means tractors or implements, including self-propelled implements, or any combination thereof used in agricultural operations.

Farmstead equipment means agricultural equipment normally used in a stationary manner. This includes, but is not limited to, materials handling equipment and accessories for such equipment whether or not the equipment is an integral part of a building.

Ground driven components are components which are powered by the turning motion of a wheel as the equipment travels over the ground.

A *guard* or *shield* is a barrier designed to protect against employee contact with a hazard created by a moving machinery part.

Power take-off shafts are the shafts and knuckles between the tractor, or other power source, and the first gear set, pulley, sprocket, or other components on power take-off shaft driven equipment.

(6) *Operating instructions.* At the time of initial assignment and at least annually thereafter, the employer shall instruct every employee in the safe operation and servicing of all covered equipment with which he is or will be involved, including at least the following safe operating practices:

(i) Keep all guards in place when the machine is in operation;

(ii) Permit no riders on farm field equipment other than persons required for instruction or assistance in machine operation;

(iii) Stop engine, disconnect the power source, and wait for all machine movement to stop before servicing, adjusting, cleaning, or unclogging the equipment, except where the machine must be running to be properly serviced or maintained, in which case the employer shall instruct employees as to all steps and procedures which are necessary to safely service or maintain the equipment;

(iv) Make sure everyone is clear of machinery before starting the engine, engaging power, or operating the machine;

(v) Lock out electrical power before performing maintenance or service on farmstead equipment.

(7) *Methods of guarding.* Except as otherwise provided in this subpart, each employer shall protect employees from coming into contact with hazards created by moving machinery parts as follows:

(i) Through the installation and use of a guard or shield or guarding by location;

(ii) Whenever a guard or shield or guarding by location is infeasible, by using a guardrail or fence.

(8) *Strength and design of guards.* (i) Where guards are used to provide the protection required by this section, they shall be designed and located to protect against inadvertent contact with the hazard being guarded.

(ii) Unless otherwise specified, each guard and its supports shall be capable of withstanding the force that a 250 pound individual, leaning on or falling against the guard, would exert upon that guard.

(iii) Guards shall be free from burrs, sharp edges, and sharp corners, and shall be securely fastened to the equipment or building.

(9) *Guarding by location.* A component is guarded by location during operation, maintenance, or servicing when, because of its location, no employee can inadvertently come in contact with the hazard during such operation, maintenance, or servicing. Where the employer can show that any exposure to hazards results from employee conduct which constitutes an isolated and unforeseeable event, the component shall also be considered guarded by location.

(10) *Guarding by railings.* Guardrails or fences shall be capable of protecting against employees inadvertently entering the hazardous area.

(11) *Servicing and maintenance.* Whenever a moving machinery part presents a hazard during servicing or maintenance, the engine shall be stopped, the power source disconnected, and all machine movement stopped before servicing or maintenance is performed, except where the employer can establish that:

(i) The equipment must be running to be properly serviced or maintained;

(ii) The equipment cannot be serviced or maintained while a guard or guards otherwise required by this standard are in place; and

(iii) The servicing or maintenance can be safely performed.

(b) *Farm field equipment*—(1) *Power take-off guarding.* (i) All power take-off shafts, including rear, mid- or side-mounted shafts, shall be guarded either by a master shield, as provided in paragraph (b)(1)(ii) of this section, or by other protective guarding.

(ii) All tractors shall be equipped with an agricultural tractor master shield on the rear power take-off except where removal of the tractor master shield is permitted by paragraph (b)(1)(iii) of this section. The master shield shall have sufficient strength to prevent permanent deformation of the shield when a 250 pound operator mounts or dismounts the tractor using the shield as a step.

(iii) Power take-off driven equipment shall be guarded to protect against employee contact with positively driven rotating members of the power drive system. Where power take-off driven equipment is of a design requiring removal of the tractor master shield, the equipment shall also include protection from that portion of the tractor power take-off shaft which protrudes from the tractor.

(iv) Signs shall be placed at prominent locations on tractors and power take-off driven equipment specifying that power drive system safety shields must be kept in place.

(2) *Other power transmission components.* (i) The mesh or nip-points of all power driven gears, belts, chains, sheaves, pulleys, sprockets, and idlers shall be guarded.

(ii) All revolving shafts, including projections such as bolts, keys, or set screws, shall be guarded, except smooth shaft ends protruding less than one-half the outside diameter of the shaft and its locking means.

(iii) Ground driven components shall be guarded in accordance with paragraphs (b)(2)(i) and (b)(2)(ii) of this section if any employee may be exposed to them while the drives are in motion.

(3) *Functional components.* Functional components, such as snapping or husking rolls, straw spreaders and choppers, cutterbars, flail rotors, rotary beaters, mixing augers, feed rolls, conveying augers, rotary tillers, and similar units, which must be exposed for proper function, shall be guarded to the fullest extent which will not substantially interfere with normal functioning of the component.

(4) *Access to moving parts.* (i) Guards, shields, and access doors shall be in place when the equipment is in operation.

(ii) Where removal of a guard or access door will expose an employee to any component which continues to rotate after the power is disengaged, the employer shall provide, in the immediate area, the following:

(A) A readily visible or audible warning of rotation; and

(B) A safety sign warning the employee to:

(*1*) Look and listen for evidence of rotation; and

(*2*) Not remove the guard or access door until all components have stopped.

Appendix D

Safety Standard for Highway Mowing

SAFETY STANDARD FOR HIGHWAY MOWING

1 ***Purpose***

These specifications are intended to provide a guideline for purchasers, contractors, and operators of industrial rotary mowers to reduce the number of thrown objects during use.

2 ***Scope***

These specifications apply to towed rotary mowers with more than one blade assembly, a total cutting width of 84 inches or greater, mounted on a propelling tractor or machine intended as industrial mowing equipment and designed for cutting grass and other growth in public use areas (e.g. roadways and highways).

Specifications **do not** apply to:

- Turf care equipment primarily designed for personal use, consumption, or enjoyment of a consumer in or around a household or residence
- Equipment designed primarily for agricultural purposes but may be used for industrial use
- Self-powered or self-propelled mowers or mowing machines

3 ***Definitions***

3.1 Propelling machine: a tractor or self-propelled machine

3.2 Rotary mower: a power mower in which one or more functional components cut by impact and rotate about a vertical axis.

3.3 Safety sign: a durable label used to convey safety information that meets the requirements for safety signs as specified in ASAE S441.

3.4 Shield (or Guard): a barrier which minimizes inadvertent personal contact with hazards created by moving machinery parts.

3.5 Towed: implements that are pulled from the drawbar of a propelling machine and are usually equipped with wheels for transport.

4 ***General Requirements***

All mowers included in the scope of this specifications must also meet the following industry and federal safety standards:

SAE J232 SAE Recommended Practice: Industrial Rotary Mowers

OSHA 1928.57 Guarding of farm field equipment, farmstead equipment, and cotton gins*

* The term "farm field equipment" shall be taken to include industrial rotary mowers included under the scope of this specification

In addition, mowers may not be altered in such a manner that they no longer comply with any section of this and the above standards.

5 *Guarding and Shielding*

5.1 COMPLIANCE - If any guard or shield which is offered as an option or standard equipment is required for the mower to comply with any standard or test in this specification, that guard or shield shall always be in place while operating the mower. This fact shall also be made known to the operator and shall be displayed on a prominent safety sign located on the mower.

5.2 MAINTENANCE - If any guard or shield on the mower which is no longer in a condition suitable to comply with section 5.1, that guard or shield shall be replaced or repaired in order to comply with section 5.1.

5.2.1 If a guard or shield is constructed with material which may be subject to rapid wear or deterioration, the guard or shield shall undergo frequent inspection for repair or replacement.

6 *Recommended Practices*

6.1 TRAINING AND INSTRUCTION

6.1.1 In accordance with the Occupational Safety and Health Administration (OSHA) standard, Subpart D, section 1928.57, paragraph (6): Operating instructions:

> " At the time of initial assignment and **at least annually** thereafter, the employer shall instruct every employee in the safe operation and servicimg of all covered equipment with which he is or will be involved, including at least the following safe operating practices:
> (i) Keep all guards in place when the machine is in operation ;
> (ii) Permit no riders ... other than persons required for instruction or assistance in machine operation;
> (iii) Stop engine, disconnect the power source, and wait for all machine movement to stop before servicing, adjusting, cleaning, or unclogging the equipment, except where the machine must be running to be properly serviced or maintained, in which case the employer shall instruct employees as to all steps and procedures which are necessary to safely service or maintain the equipment;
> (iv) Make sure everyone is clear of machinery before starting the engine, engaging power, or operating the machine;
> (v) Lock out electrical power before performing maintenance or service."

6.1.2 The employee shall instruct every employee **at least annually** on the proper mowing procedures and recommended practices set forth in this document and in "Roadside Vegetation Management" a volume of the Infrastructure Maintenance Manual of the TxDOT including:

Chapter 1: Vegetation Management Guidelines
Chapter 2: Mowing Standards
Chapter 4: Native Grasses, Wildflowers, and Legumes

The employer shall also make the employee aware of any changes to mowing practices given by the Texas Department of Transportation.

6.1.3 The employer shall make available to every employee the safety brochure and/or safety video and/or prescribed training program on mowing safety designated by the Texas Department of Transportation.

6.2 MOWING DIRECTION

6.2.1 Divided highways or roadways with a center turning lane shall be mowed against the flow of traffic in the lane or group of lanes nearest the mower.

6.2.3 Roadways with two travel lanes flowing opposite each other shall be mowed in the safest, most efficient manner possible as dictated by the terrain and traffic conditions. Mowing should proceed against traffic flow in the nearest lane whenever possible.

6.2.4 Full width mowing or areas that require more than one pass to complete required mowing shall be mowed in a manner such that the strip nearest the travel lane be mowed last and against the flow of traffic in the nearest lane.

6.2.5 Center medians should be mowed in the safest, most efficient manner possible as dictated by the terrain and traffic conditions. For those center medians which require only a single strip mowing along the shoulder as defined in "Roadside Vegetation Management", that strip shall be mowed against the flow of traffic in the lane or group of lanes nearest the mower.

6.3 CUTTING HEIGHT

6.3.1 The cutting height of the mower shall be set to the height described in "Highway Mowing Standards" determined by the Texas Department of Transportation.

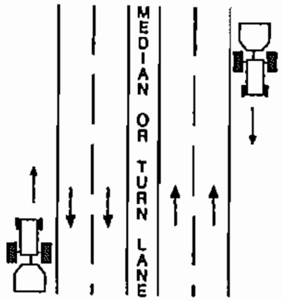
6.3.2 The cutting height of the mower shall be checked and adjusted for correctness every time that machine is to be used.

6.3.3 The blade encasement of the mower shall be adjusted according to manufacturer's instructions such that the rear of the mower is between 1/2 inch to 1 inch higher than the front of the mower. The cutting height shall be measured on a level surface from the ground to the lowest part of the blade.

Appendix E
Sample Safety Training Brochure

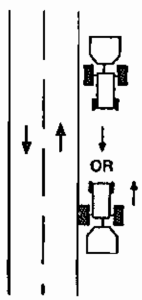
Roadway Type

- Divided Highway or Roadway with center turn lane



Mow against th ffic direction to reduce the speed of a thrown object and a car.

- Two Lane Highway



Mow in the safest, most efficient way possible. Mow against traffic flow in nearest lane when possible.

For areas where mowing more than one strip is required, mow the strip nearest the road last whenever possible.

Safety Precautions

- Never operate unless all shields and guards are properly installed.
- Never dismount tractor while the PTO is turning.
- Do not attempt to raise wings on slopes or banks. This may cause mower and tractor to tip over.
- Pick up all rocks and other debris before cutting. Never assume an area is clear.
- Do not raise wing with blades rotating if bystanders are withing 300 feet of mower.
- Set height of the back of the mower one inch higher than the front. This tends to force objects forward and down into the ground.

CTR

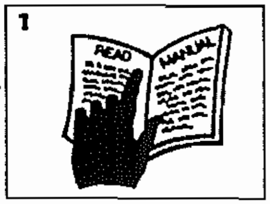
Center for Transportation Research
3208 Red River, Suite 200
Austin, Texas 78705

Safe Mowing Practices for Rotary Bat-Wing Mowers

Center for Transportation Research
The University of Texas at Austin

General Safety Instructions

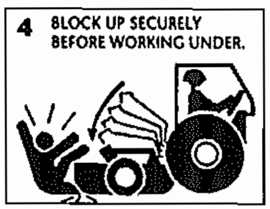
Study Operator's Manuals thoroughly to prevent misuse, abuse, and accidents.



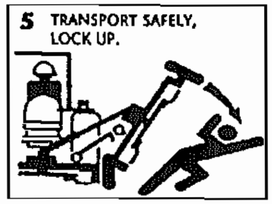
DO NOT ALLOW CHILDREN or others to ride on tractor or implement. Falling off can injure or kill.

Always operate with roll-over-protection (ROPS) and fastened seat belts to prevent injury or death.

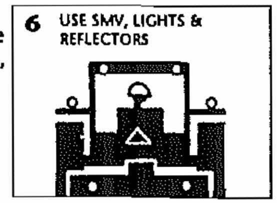
Block up or support cutter securely before working under lifted components. Area must be clear before lowering.



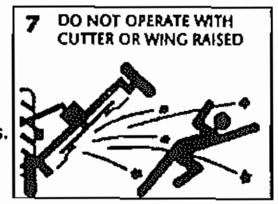
Before transporting, place lift lever in full-lift position. Follow local traffic codes. Slow down at night, for turns, and on hillsides.



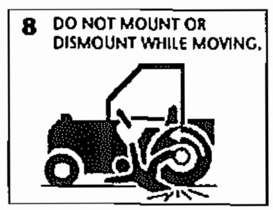
Make certain that Slow Moving Vehicle signs, warning lights, and reflectors are clearly visible.



NEVER operate with cutter or section raised off ground. Injury or death may result from objects thrown under guards.



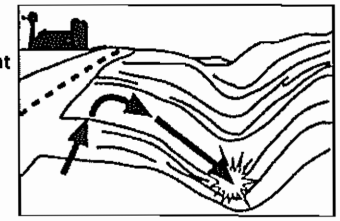
Before dismounting, secure implement in transport position or lower to ground. Put in park/set brake/stop engine/remove key.



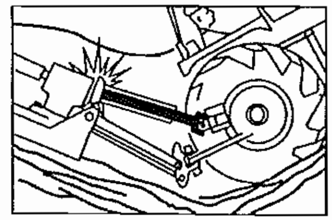
Rough Terrain

When approaching a ditch...

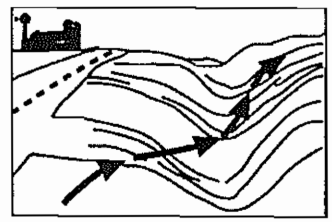
DO NOT approach ditch straight ahead...



Drive shaft bottoms out...



Approach ditch at an angle.



Incorrect approach can cause the driveline to come loose from the tractor. The result could cause injury or death to the operator, as well as expensive damage to the machine.

Appendix F
Improved Accident Data Collection Form

Instructions

(1) For the purpose of a TxDOT mowing safety study, this form should be completed both by the mower operator and the driver of the other vehicle. **This document is not an insurance form.**

(2) Please answer all question that you can, and leave the rest blank.

(3) Read each question first, and then draw a diagram of the accident in the space provided below.

Diagram of Accident

1. Time of Accident____________ 2. Date of Accident___________

3. County in which the accident occurred______________________________

4. Equipment type:
   ___push mower
   ___riding lawn mower
   ___tractor-pulled mower
   ___other____________________________
   ___unknown

5. Equipment manufacturer	Mower	Tractor
Make (ex: John Deere)		
Model number		

6. Equipment class:
   ___rotary
   ___flail
   ___sickle
   ___disc
   ___other________________
   ___unknown

7. Road class:
   ___interstate highway
   ___farm to market
   ___underpass
   ___feeder
   ___off ramp
   ___parking lot
   ___state highway
   ___ranch road
   ___overpass
   ___on ramp
   ___street
   ___other____________________

8. Road surface:

___concrete ___asphalt
___gravel ___dirt
___brick ___other________________________

9. Road characteristics:

___one-way, number of lanes__________
___two-way, number of lanes per direction_________
___inside emergency lanes
___outside emergency lanes
___highway intersection
___stoplight intersection
___turn
___sharp curve
___fork
___other____

10. Speed limit of road:

___0-20 mph
___21-40 mph
___41-60 mph
___61-65 mph
___unknown

11. Mower position:

___side of road ___median
___ditch ___slope
___other ___unknown

12. Motion of mower:

___forward ___reverse
___stationary ___unknown

13. Mower direction:

___against traffic of closest lane ___with traffic of closest lanes
___perpendicular to traffic ___other____________________
___unknown

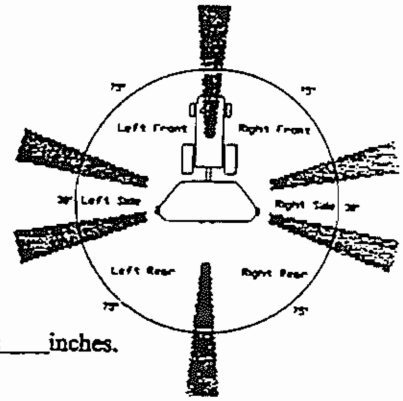
14. Number of lanes between mower and vehicle:

___0 ___1
___2 ___3
___other_______ ___unknown

15. Vehicle direction:

___direction opposite of mower ___direction same as mower
___perpendicular to mower ___other____________________
___unknown

16. Direction object left mower:
___front right
___front left
___rear right
___rear left
___right side
___left side
___other___________
___unknown



17. Cutting height of mower at the time of the accident was____inches.

18. Installed safety devices:
___chains
___floating side skirts
___rubber skirt
___internal duct and baffles
___rear and front stand-off deflectors
___unknown
___other_______________
___cable reinforced chains
___dragging canvas
___modified exhaust port
___automatic leveling mechanism

19. Signs and warnings:
___advanced warning signs
___arrow board
___flags
___none seen
___reduced speed signs
___flashing lights
___cones
___other_________________

20. Location of vehicle damage (circle any that apply):

Body: front, rear, hood, top, right side, left side, tire, other_______

Window: windshield, right-side, left-side, rear, other____________

21. Amount of vehicle damage (final dollar amounts only, no estimates): $______

Appendix G
Roadside Vegetation Management Manual

Section 3
Guidelines for Levels of Vegetation Management

Level One

Average Daily Traffic:	VARIED (This level is determined solely by surrounding property use)
Surrounding Property Use:	DEVELOPED URBAN ONLY (residential, commercial, or services development — including rights-of-way within small cities, towns, and villages)
Indicated on the map by:	RED

Conduct vegetation management on roadways designated as *level one* according to the following guidelines:

Mowing and Trimming:

- Use frequent mowing for developed areas. Consider strip mowing for safety instead of full width mowing in wide right-of-way areas.
- Set cutting height no lower than seven inches (18 cm).
- Mechanically trim behind curbs where appropriate.

Herbicide:

Chemically treat pavement edges, paved medians, signs, riprap, delineators, guardrails, etc. (as per the *Herbicide Operations Manual*).

Wildflowers:

Seed large interchanges with wildflowers each year if practical.

NOTE: Narrow medians, narrow outer separations, and areas adjacent to manicured private property are inappropriate for wildflower propagation.

Ornamental Plantings:

- Remove all dead ornamental plants as soon as possible and replace with appropriate plants as soon as practical.
- Expand ornamental plantings on a gradual basis to ensure proper plant establishment with available maintenance personnel.

(continued)

Level One *(continued)*

Irrigation Systems:

Keep all irrigation systems in good operating condition.

Erosion Control:

Implement erosion control measures as necessary (slope stabilization, seeding, mulching, etc.).

Level Two

Average Daily Traffic:	10,000 AND ABOVE
Surrounding Property Use:	PARTIALLY DEVELOPED URBAN OR RURAL
Indicated on the map by:	BLUE

Conduct vegetation management on roadways designated as *level two* according to the following guidelines:

Mowing and Trimming:

- Perform strip mowing only where necessary, during wildflower season. Perform subsequent strip mowings as necessary (a minimum of two strips is recommended). Perform one full-width mowing in late fall.

  NOTE: In high rainfall areas and areas of year-round moderate temperature, rapid vegetative growth may require additional strip and spot mowing for safety and to facilitate drainage.
- Set cutting height no lower than seven inches (18 cm) to leave some residual cover for strong regeneration of native grasses.
- Mechanically trim where appropriate.

Herbicide:

- Use chemical overspray or ropewick applicators to control tall grasses such as Johnsongrass and/or other pest plants at least 10 days prior to mowing.
- Chemically treat pavement edges, paved medians, signs, riprap, delineators, guardrails, etc. (as per the *Herbicide Operations Manual*).

Ornamental Plantings:

Remove all dead ornamental plants as soon as possible and replace with appropriate plant material as soon as practical.

Erosion Control:

Implement erosion control measures as necessary (slope stabilization, seeding, mulching, etc.).

Wildflowers:

Seed areas with wildflowers where practical and delay mowing until mature seeds are set.

Level Three

Average Daily Traffic:	3,000 – 10,000
Surrounding Property Use:	RURAL
Indicated on the map by:	YELLOW

Conduct vegetation management on roadways designated as *level three* according to the following guidelines:

Mowing and Trimming:

- Normally, perform strip mowing as needed for safety during wildflower season and throughout the April 1 through August 15 wildlife nesting and rearing season (a minimum of two strips is recommended). Perform spot mowing as necessary. Perform one full-width mowing in late fall.

  NOTE: In high rainfall areas and areas of year-round moderate temperatures, rapid vegetative growth may require additional strip and spot mowings for safety and to facilitate drainage.
- Set cutting height no lower than seven inches (18 cm) to:
  - ensure strong regeneration of native grasses
  - provide erect residual cover for the following year's early nesters
  - provide roosting and escape cover for wildlife
  - facilitate drainage and brush control.
- Establish non-mow areas where appropriate (slopes, wide rights-of-way, large interchanges, etc.) to allow for maximum reseeding and vigor of native grasses, forbs, legumes, and wildflowers and to provide for almost continuous nesting use from spring until late summer.
- Mechanically trim where appropriate.

Herbicide:

- Use chemical overspray or ropewick applicators to control tall grasses such as Johnsongrass and/or other pest plants at least 10 days prior to mowing.
- Chemically treat pavement edges, paved medians, signs, riprap, delineators, guardrails, etc. (as per the *Herbicide Operations Manual*).

(continued)

Level Three *(continued)*

Ornamental Plantings:

Remove all dead ornamental plants as soon as practical and replace with appropriate plants when funds are available, using locally adapted native tree, shrub, and brush species indigenous to the ecological region.

Erosion Control:

Implement erosion control measures as necessary (slope stabilization, seeding, mulching, etc.).

Wildlife Habitat and Native Plant Conservation:

Minimize and delay mowing activities to promote:

- continued propagation of native seed sources across the state
- ground cover for erosion control
- nesting and escape cover for many forms of wildlife.

Public Awareness and Support

Place "ROADSIDES FOR WILDLIFE" signs at selected locations to foster public appreciation of rural roadsides managed as wildlife nesting cover. Signs will signify to passers-by that this practice not only saves money but aids a variety of natural birds and mammals.

Wildflowers:

Seed areas with wildflowers where practical and delay mowing until mature seeds are set.

Level Four

Average Daily Traffic:	0 – 3,000
Surrounding Property Use:	RURAL
Indicated on the map by:	GREEN

Conduct vegetation management on roadways designated as *level four* according to the following guidelines:

Mowing and Trimming:

- Perform spot and strip mowing as needed for safety (a minimum of two strips is recommended). Perform only one full-width mowing in late fall as necessary for the management of native grasses and wildflowers.

  NOTE: In high rainfall areas and areas of year-round moderate temperatures, rapid vegetative growth may require additional strip and spot mowings for safety and to facilitate drainage.

- Set cutting height no lower than seven inches (18 cm) to:
  - ensure strong regeneration of native grasses
  - provide erect residual cover for the following year's early nesters
  - provide roosting and escape cover for wildlife
  - facilitate drainage and brush control.
- Establish non-mow areas where appropriate (slopes, wide rights-of-way, large interchanges, etc.).
- Mechanically trim where appropriate.

Herbicide:

- Use chemical overspray or ropewick applicators to control tall grasses such as Johnsongrass and/or other pest plants at least 10 days prior to mowing.
- Chemically treat pavement edges, paved medians, signs, riprap, delineators, guardrails, etc. (as per the *Herbicide Operations Manual*).

Erosion Control:

Implement erosion control measures as necessary (slope stabilization, seeding, mulching, etc.), favoring the use of native grass mixtures.

(continued)

Level Four *(continued)*

Wildlife Habitat and Native Plant Conservation:

Minimize and delay mowing activities to promote:

- continued propagation of native seed sources across the state
- ground cover for erosion control
- nesting and escape cover for many forms of wildlife.

Public Awareness and Support:

Place "ROADSIDES FOR WILDLIFE" signs at selected locations to foster public appreciation of rural roadsides managed as wildlife nesting cover. Signs will signify to passers-by that this practice not only saves money but aids a variety of natural birds and mammals.

Notes:

Appendix H
Calculations

Calculations

Probability Distributions

Using the SIMAN statistical software package and the results of the performed experiments in Reference 17 gives:

Distribution of Thrown Rocks:

Weibull Distribution with parameters alpha = 0.239, beta = 4.33

Mean = 34.8 ft., Standard Deviation = 59.4 ft.

Distribution of Thrown Blocks:

Exponential Distribution with parameter lambda = 0.0176 and shifted -0.001 ft.

Mean = 56.9 ft., Standard Deviation = 57.1 ft.

Distribution of the Combination of Blocks and Rocks

Exponential Distribution with parameter lambda = 0.0218 and shifted -0.001 ft.

Mean = 45.8 ft., Standard Deviation = 59 ft.

Velocity Calculations

Using the linear momentum equation from Reference 11:

$$m_{o1}v_{o1} + m_{b1}v_{b1} = m_{o2}v_{o2} + m_{b2}v_{b2} \qquad (1)$$

where:

m_{o1}, m_{o2} : initial and final mass of thrown object = 0.5 lb

m_{b1}, m_{b2} : initial and final mass of the blade assembly = 25 lb

v_{o1}, v_{o2} : initial and final velocity of thrown object

v_{b1}, v_{b2} : initial and final velocity of the blade assembly

and the coefficient of restitution equation:

$$e = \frac{v_{b2} - v_{o2}}{v_{o1} - v_{b1}} \qquad (2)$$

where e is the coefficient of restitution,

the exit velocity of a thrown object can be found.

Experimental data from Reference 16 gives the range of e from 0.45 to 0.90 for the impact of an object and blade assembly. The value used was **e = 0.82**, approximately the value for an impact of steel and rock.

Mower brochures from John Deere and Alamo Group list the blade tip velocity, v_{b1} **= 280 kph.**

The initial velocity of the thrown object, $\mathbf{v_{o1}}$ **= 0 kph.**

Solving equations (1) and (2) simultaneously gives the object's exit velocity, $\mathbf{v_{o2}}$ **= 500 kph.**

<u>Relative Velocity and Impact Velocity</u>

Assume:

- Vehicles are traveling at 97 mph
- Object is thrown at 45° to the roadway
- Object arrives at both vehicles with the same velocity
- Air resistance is neglected

Using the thrown object velocity above v_{o2} = 500 kph and the four configurations shown in Chapter 5, Figure 5.2:

<u>Case I:</u>

Far Lane: Relative velocity at impact

x-dir: 0 - (-138.6 cos(45)) = 98 m/s
y-dir: 26.8 - (-138.6 sin (45)) = 124.8 m/s
Impact speed: 158.7 m/s

Near Lane: Relative velocity at impact

x-dir: 0 - (-138.6 cos(45)) = 98 m/s
y-dir: 26.8 - (-138.6 sin (45)) = 124.8 m/s
Impact speed: 158.7 m/s

Case II:

Far Lane: Relative velocity at impact

x-dir: 0 - (-138.6 cos(45)) = 98 m/s
y-dir: -26.8 - (-138.6 sin (45)) = 71.2 m/s
Impact speed: 121 m/s

Near Lane: Relative velocity at impact

x-dir: 0 - (-138.6 cos(45)) = 98 m/s
y-dir: 26.8 - (-138.6 sin (45)) = 124.8 m/s
Impact speed: 158.7 m/s

Case III:

Far Lane: Relative velocity at impact

x-dir: 0 - (-138.6 cos(45)) = 98 m/s
y-dir: 26.8 - (-138.6 sin (45)) = 124.8 m/s
Impact speed: 158.7 m/s

Near Lane: Relative velocity at impact

x-dir: 0 - (-138.6 cos(45)) = 98 m/s
y-dir: -26.8 - (-138.6 sin (45)) = 71.2 m/s
Impact speed: 121 m/s

Case IV:

Far Lane: Relative velocity at impact

x-dir: 0 - (-138.6 cos(45)) = 98 m/s
y-dir: -26.8 - (-138.6 sin (45)) = 71.2 m/s
Impact speed: 121 m/s

Near Lane: Relative velocity at impact

x-dir: 0 - (-138.6 cos(45)) = 98 m/s
y-dir: -26.8 - (-138.6 sin (45)) = 71.2 m/s
Impact speed: 121 m/s

Appendix I

Data Collection Documents for Investigation of Mowing Activity

Name of Contractor:

Name of Team Member:

Area Code of the Contractor:

Date/Time Interviewed:

Questions for Mowing Contractors

1. What safety features do you use on your equipment to prevent thrown objectives?

2. If the TxDOT provided updates on safety equipment and advances in mowing equipment, would you read this material?

3. What problems does mowing against traffic create for you?

4. Do you provide safety training? If so, what type?

5. Does your safety training for the mower operators include increasing their awareness of mower-thrown-objects? How?

6. How do you feel about providing safety training if TxDOT gave you materials?

7. Would you be willing to contribute to TxDOT for the development of a mower certification program?

8. How do you handle claims reported by the motorists regarding MTO damages or injuries? What are the methods that you take to handle such claims?

9. How many claims do you get per year?

10. What types of objects were thrown?

11. Does putting the tractor/mower in reverse increase the risk of your operator being struck by mower thrown objects?

12. How do you feel about filling out accident forms for TxDOT, if required?

13. Are your mower operators paid on the basis of time or land mowed?

14. What types of mowers do you currently use to mow your contracted land?

15. Do you currently employ people whose task is specifically to search through the land to be mowed for foreign objects such as glass, rocks, trash?

16. How are your mowing guideline developed?

17. Do you have any other ideas or suggestions for the TxDOT concerning mowing?

Name of Team Member:

Name of Mower Operator Interviewed:

Time and Date of Interview:

Method of Interview:

Questions for Mowing Operators

1. How often do you mow against the traffic?

2. Does mowing only against the flow of traffic increase the time it takes to complete a mowing job?

3. Does mowing only against the flow of traffic increase the number of times you have to cross the road?

4. Can you mow in any direction if it is not convenient to mow against the flow of traffic?

5. If you need permission to mow with the flow of traffic, is the person you need to ask easy to access?

6. If an object is thrown by your mower, are you aware of it?
(Circle One): always usually sometimes rarely never

7. In which cases are more objects thrown?
(Circle One): moving forward turning moving in reverse unknown

8. How far have objects been thrown by your mower? (Circle Any): into the nearest lane two lanes away more than two lanes unknown

9. Has any motorists complained to you about damages to their vehicles resulting from MTOs?

10. Do you mow over visible foreign objects that are not grass?

11. How often do you perform maintenance on your equipment?

12. Are you aware of any safety chains on the mower? If so, are you aware of the purpose of these chain?

13. Are you aware of any other safety device on your mower to prevent MTOs?

14. Do you prefer using a certain brand of mower? If so, what kind?

15. How often do you mow a certain area?

16. Would you be willing to spend time to participate in a mower training program or a mower certification program provided by the TxDOT?

17. If an improved mowing procedure, one that is significantly different from what you normally do, is offered to you by the TxDOT, would you change your mowing procedure?

18. What do you prefer? Mowing with the traffic, mowing against the traffic, mowing perpendicular to the traffic, or mowing in circles.

19. How would you mow around signs or obstacles?

20. How much control does the site supervisor have on procedural decisions?

21. From where on the mower are the most objects being thrown, and what direction?

22. Are you aware of the traffic laws concerning mowing along state roadways?

23. Have you ever been warned by law enforcement personnel regarding to mowing violations?

24. Do you have any ideas or suggestions for the TxDOT concerning mowing?

Observation Checklist

Date: Time:

Location: Contractor:

Number of Mowers Type of Mower:

---

1. Mower direction with respect to the flow of traffic:

   Against the flow With the flow

2. Mower procedure when mowing roadside obstacles:

   Reverse mowing Wing raised mowing Circle mowing

3. Reverse mowing when not mowing:

   Blades engaged Blades disengaged

4. Terrain condition:

   Flat Rocky Hilly Urban Rural Trench

5. How does the mower operator handle road transitions (such as a split in the road)?

6. Around what objects are the mower wings raised?

Signs Road Obstacles Bridges Trenches

Rocks Trees Gates

Blades engaged Blades disengaged

7. MTO observed?

NO YES How many?

The type of terrain present:

Flat Rocky Hilly Urban Rural Trench

Direction of mower during occurrence of MTO:

Forward Reverse Stationary

8. Origin of MTO from mower:

Front Rear Left side Right side

9. TxDOT inspector present?

NO YES

Within sight Out of sight

10. Height of grass after mow: (for 5 measurements, 100 yards apart)

1.

2.

3.

4

5.

Average _________

11. Mowing Types:

Strip Mowing   Spot Mowing   Full Width Mowing

12. Diagram of Mowing Pattern:

13. Traffic citation issued?

NO   YES

Name traffic code violation

14. Were there safety chains on the mower?

NO YES

Where?

Front Sides Rear

15. Were there warning signs present on roadway?

NO YES

Were they clearly visible?

NO YES

16. OTHER COMMENTS:

CTR
Center for Transportation Research
3208 Red River, Suite 200
Austin, Texas 78705