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Studded Tire

AN OVERVIEW OF STUDDED AND STUDLESS TIRE TRACTION AND SAFETY

by

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16. ABSTRACT

Studded tires have generated much controversy over the years; a number of states have banned them, while others, including Washington, have restricted their use and passed legislation to require lighter-weight studs. This report reviews recent studies that have addressed the performance and safety of the current generation of studded tires as well as the new "studless" winter tires on late-model vehicles. The well-documented correlation between studded tires and pavement wear was not the focus of this work.

The issues surrounding studded tire performance and safety are complex. From the standpoint of traction alone, studded tires, when new, often provide some benefit over other tire types on ice-covered roads when the temperature is near freezing. However, the advent of the new studless tires has diminished the marginal benefit, and recent studies suggest that the infrequent, narrow range of conditions necessary for benefit from studded tires may not outweigh their detrimental effect on traction in dry or wet conditions on certain pavement types. In addition, a host of primary and secondary safety factors are related to studded tire use, many of which are very difficult to quantify, including facets of driver behavior and safety perception.

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EXECUTIVE SUMMARY

This study presents an extensive review of publications documenting recent research on the performance and safety of studded tires. Although a substantial volume of research has investigated the negative impact of studded tires on pavement, this report does not concentrate on pavement wear issues. Rather, the focus of this work was to review the latest findings regarding the performance of late-model vehicles equipped with the current generation of studded tires, as well as those equipped with the new "studless" winter tires such as the "Blizzak" made by Bridgestone/Firestone.

The use of studded tires has been controversial over the years. A number of states have banned them, while others, including Washington, have placed restrictions on their use and passed recent legislation requiring lighter-weight studs to reduce pavement wear. The issues surrounding the use of studded tires are very complex, involving not just the obvious competing advantages and disadvantages of improved icy-road traction performance versus the costly impact of pavement damage. There are many factors to consider, including the parameters that are used to define traction performance, the conditions under which studded tires are compared with other tires, the "safety" of studded tires as measured by traffic incident data, and driver behavior while using studded tires based on drivers' perception of safety. There are also a host of secondary effects, including the introduction of suspended particulate matter (dust) from roadway wear, reduced vehicle control on roadways rutted by stud wear, the potential for improved traction characteristics on roadways "roughened" by studded tire use, the cost of studded tires in comparison with new studless winter tires, the increase in fuel consumption for studded versus studless tires, and the possible trade-off in the use of traditional snow-clearing methods.

This report presents a brief history of studded tires and their usage, a discussion of the newer studded and "studless" winter tires, and a discussion of the traction performance characteristics of studded versus non-studded tires under varying conditions. The broader issue of safety is also addressed through presentation of the many complex issues surrounding studded tire use that have been raised by recent research worldwide.

CONCLUSIONS

1. Studded tires produce their best traction on snow or ice near the freezing mark and lose proportionately more of their tractive ability at lower temperatures than do studless or all-season tires.
2. The traction of studded tires is slightly superior to studless tires only under an ever-narrowing set of circumstances. With less aggressive (lightweight) studs being mandated, and with the advent of the new "studless" tire, such as the Blizzak, since the early 1990s, the traction benefit for studded tires is primarily evident on clear ice near the freezing mark, a condition whose occurrence is limited. For the majority of test results reviewed for snow, and for ice at lower temperatures, studded tires performed as well as or worse than the Blizzak tire. For those conditions in which studded tires provided better traction than studless tires, the increment usually was small.
3. The precise environmental conditions under which studded tires provide a traction benefit are relatively rare. The maximum frictional gain (in comparison to non-studded (not studless) tires) is found for new studded tires on smooth ice, where

they have been shown to provide up to 100 percent gain in certain tests. However, the relative frictional gain of studded tires diminishes or becomes negative on roughened ice, as the temperature drops, as the studs wear, or if the comparison is made with studless tires.

4. Traction performance can be characterized in many ways, including braking, acceleration, cornering, controllability, and grade climbing. Though all factors are important, the single best indicator of tire performance is braking distance and deceleration.

5. Studded tires reduce the difference in friction factor between optimum-slip and locked-wheel braking in comparison to non-studded tires. This may reduce the risk of drivers misjudging the necessary braking distance and may improve the braking potential for anti-lock brakes.

6. In one set of stopping distance tests in Alaska, studded, studless, and all-season tires performed nearly equally on snow, when averaged across several vehicles. On ice, stopping distances for studded tires were 15 percent shorter than for Blizzaks, which in turn were 8 percent shorter than for all-season tires.

7. In another set of tests in Alaska, studless Blizzak tires offered the best traction performance, especially for braking on both packed snow and ice in comparison to studded tires (which were second) and all-season tires (which were last).

8. The use of two studded tires on the front of a vehicle produced stopping traction results on snow and ice that were about halfway between the result of four studded tires and four all-season tires. However, other controllability penalties, such as yaw instability, should be considered.

9. On bare pavement, studded tires tend to have poorer traction performance than other tire types. This is especially true for concrete; for asphalt, there is little difference in stopping distance between studded and non-studded tires.

10. Tractive performance of studded tires is sensitive to stud wear. Studded tires may lose more of their tractive ability over time (from stud wear) than studless tires. When stud protrusion diminishes to 0.024 in. (0.6 mm), the frictional effect from the studs becomes negligible. Tire tread wear (on studded tires) has relatively little frictional effect if stud protrusion is maintained at 0.039 in. to 0.043 in. (1.0-1.1 mm).

11. A Norwegian study concluded that the use of studded tires tends to reduce the accident rate by a small amount – from 1 to 10 percent.

12. A number of driver behavior issues have been postulated that tend to affect the judgment of studded tire effectiveness. There is not consensus on these points: 1) drivers with studded tires care more about safety, hence they drive more safely, 2) they drive faster (because of a false sense of security or confidence), and 3) drivers with non-studded tires avoid driving when weather is severe.

13. Pavement rutting caused by accelerated wear from studded tires can cause the dangerous conditions of tramlining, hydroplaning on accumulated water in the ruts, excessive road spray, and premature damage to pavement markings.

14. The roughening of ice and pavement from studded tires provides a safety benefit for all vehicles (with and without studs) by helping to prevent formation of smooth, glare ice.

15. The cost of studless tires is significantly higher than studded tires—by approximately 50 percent.

16. Studded tires increase fuel consumption by a small amount (~1.2 percent) over non-studded tires on bare roadways. But the other effects of unevenness, snow, and ice are far more significant than this factor and can increase fuel consumption by 15 percent.

17. Suspended particulate matter from pavement dust created by studded tires and noise from studded tires are health concerns in heavily traveled urban areas.

1. INTRODUCTION

Studded tires were introduced in the United States in the early 1960s. They quickly became popular in the northern climes because they provided the motorist with a built-in traction aid without the installation headaches required by temporary aids such as tire chains. Studded tires are convenient, relatively quiet and comfortable (in comparison to tire chains), and they have been well accepted by the general public as a means of enhancing mobility. However, studded tires have long been the source of considerable controversy.

Legislation in many states has banned or limited the use of studded tires and has mandated less aggressive studs in an effort to reduce costly pavement damage (see appendices A and B). Numerous recent studies have documented the pavement wear caused by studded tires, so these issues will not be presented here in detail. Rather, this study focuses on the performance on various road surface conditions of studded tires as compared with that of other common winter tires, including all season radials and the new "studless" winter tires. It encompasses a review of recent literature, particularly from the past 10 years, that documents studies relevant to the new generation of lighter weight studs, studless winter tires, and vehicles with front-wheel drive, four-wheel drive, and anti-lock brakes. In addition to performance data, a review of studies that examined the complexities of evaluating the safety of studded tires is also presented.

STUDY APPROACH

The objectives of this study were accomplished by comprehensively reviewing literature reporting on studded tire performance research that was performed in the

United States, Canada, Europe, and Japan. Though some of the foundations for this study were developed from the 1960s through the 1980s, the focus was on more recent data, mostly from the 1990s. This research also sought data on the effects of recent developments on vehicle traction, including the more widespread use of front- and four-wheel-drive vehicles, and studless winter tires.

2. BACKGROUND

HISTORY AND COMPOSITION OF TIRE STUDS

After their introduction in 1963, studded tires became popular with drivers across the U.S. In many states, studded tire use approached 30 percent of passenger vehicles by 1972, and in Alaska, Montana, and Vermont approximately 60 percent of passenger vehicles used studded tires (Malik 2000). Currently, approximately 10 percent of passenger vehicles in western Washington use two or more studded tires and approximately 32 percent of passenger vehicles in eastern Washington use two or more studded tires. In Spokane, approximately 56 percent of passenger vehicles use two or more studded tires (Angerinos et al. 1999).

The tire stud consists of two basic parts that have varied in size, weight, and composition over the years. The outside part of the stud is known as the stud jacket or sleeve; a flange at the base of the stud jacket holds it in place. The stud core, pin, or insert is situated within the jacket and protrudes from the tire to make contact with the pavement (Figure 1). After insertion of a tire stud (jacket and pin) into the tire, a "break-in" period occurs during which time the tire rubber completely surrounds the stud jacket, filling any space between the jacket and the rubber. In this way, the rubber secures the jacket in place (Angerinos et al. 1999).

Conventional studs in the 1960s were approximately 0.307 in. (7.8 mm) long, with a protrusion of about 0.087 in. (2.2 mm). Since the 1970s, as stud weight and protrusion length were shown to be significant factors in pavement wear rates, both the weight and protrusion have been reduced. The advent of the Controlled Protrusion (CP) stud allowed for nearly a 40 percent reduction in pin protrusion to 0.039 to 0.059 in. (1.0 to 1.5 mm) by using a tapered pin that is able to move back into the stud jacket as the tire rubber is worn (Figure 2). The weight of the conventional stud from the 1960s averaged approximately 0.081 oz. (2.3 grams), while the typical CP stud, which is the only stud in use in the U.S. today, weighs 0.059 to 0.067 oz. (1.7 to 1.9 grams) (Angerinos 1999).

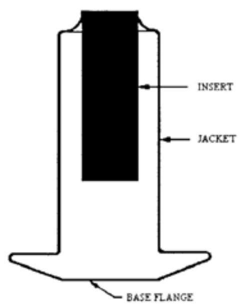
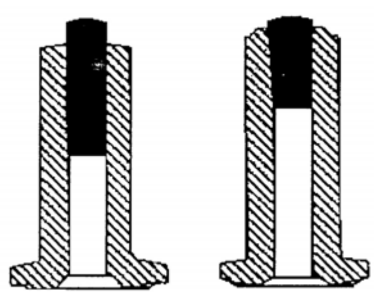


Figure 1. Typical First-Generation Stud Profile (Angerinos et al. 1999)



First-Generation Stud   CP Stud

Figure 2. Comparison of First-Generation Stud with Controlled Protrusion (CP) Stud (Angerinos et al. 1999)

In the Scandinavian countries, additional efforts have been made to reduce stud protrusion and weight. Studs there now range in length from 0.047 to 0.059 in. (1.2 to 1.5 mm) and weigh approximately 0.039 oz. (1.1 grams). Testing in Scandinavia has shown reduced wear effects for studs with a lightweight plastic jacket (0.025 oz./0.7 gram), as well as those with a lightweight metal jacket (0.033 oz./0.95 gram) (Brunette 1995).

STUDDED TIRE USAGE

It is difficult both to obtain accurate estimates of the usage of studded tires in cold weather climates and to determine whether the use of studded tires is increasing or decreasing. The earliest data (NCHRP 1975) showed widely varying usage numbers across the northern United States and Canada, ranging from 10 percent in Oregon to 61 percent in Alaska. Washington usage was 35 percent in that survey. According to a 1995 survey of the 25 northern states and four Canadian provinces, most perceived that studded tire use had declined and that winter tire use had dropped to less than 10 percent for passenger cars (Angerinos 1999). A WSDOT survey conducted during the winter of 1996-1997 showed that on average, 10 percent of passenger vehicles used studded tires in the western portion of Washington, and 32 percent used them in the eastern portion of the state (based on two studded tires per vehicle) (Angerinos 1999). The survey sampled parking lots and garages in 14 locations. The lowest stud usage was observed in Puyallup (6 percent), while the highest was found in Spokane (56 percent).

The most detailed examination of usage rates was found in Oregon. Historical studded tire usage rates in Oregon show that usage was fairly constant or declined somewhat from 9.3 percent in 1974 to 3.5 percent in 1989 (Table 1) (Malik 2000). These rates were determined by moving traffic counts, in which vehicles equipped with studded tires were distinguished audibly from those that were not. Hence, the usage rates were determined on a per-vehicle basis. Then, in 1990,usage rates appeared to climb. Some of this may have been attributable to an increase in the number of vehicles that had studded tires on both axles instead of one. Early surveys could not distinguish this difference. A 1990 visual parking lot survey showed an increase in usage to 11.5 percent. This technique provided a means for developing an effective studded tires usage rate by accounting for the number of axles that used studded tires, not just the number of vehicles.

Table 1. Historic Studded Tire Use Estimates (Percentage of Vehicles) for Oregon (Malik 2000)

Zone	1973-74	1983-4	1983-4	Dec. 1989	Mar. 1990	Mar. 1990 Parking Lot
1	1.5%	3.9%	1.5%	1.6%	1.8%	0.0%
2	4.3	2.8	3.4	3.4	2.7	5.3
3	11.0	5.8	5.5	1.5	2.7	10.0
4	15.0	11.6	14.2	8.0	14.2	24.0
Statewide	**9.2%**	**6.7%**	**6.6%**	**3.4%**	**6.1%**	**11.5%**

Zone 1: Entire state coastal zone, 10-15 miles inland from coast
Zone 2: Western valley bordered by Cascase range to east, Zone 1 to west, midway between Portland and Salem to north, California state line to south.
Zone 3: Northwest quadrant of state, including Portland, bordered by Zone 1 to west, Mt. Hood to east, Washington state line to north
Zone 4: Everything else

Extensive telephone and parking lot surveys conducted in 1995 and 1996 on behalf of the Oregon Department of Transportation indicated that studded tire use varied widely depending on the month and region being surveyed (Malik 2000). This survey was conducted primarily to determine the effect of studded tires on pavement wear. Results showed that approximately half of vehicles in Oregon that were equipped with studded tires used them on both axles, a considerable increase from the 1970s when the majority of vehicles installed studded tires only on the driving axle. Hence, it was necessary to account for the effective studded tire usage on a per-axle basis. For the winter driving season of November through April, the average effective studded tire usage rate statewide in Oregon ranged from about 16 percent to 23.5 percent, depending on who conducted the survey and how it as performed.

No data have been found to assess the usage rates of studless winter tires such as the Bridgestone/Firestone Blizzak.

3. WINTER TIRE PERFORMANCE

Studded tire performance and safety, though intuitively related, are two different topics and, as such, will be dealt with independently. The performance of studded tires relative to non-studded tires, which is more quantitative, was the focus of this work.

Determination of studded versus non-studded tire performance can be measured in a number of different ways. Some of the metrics include

- straight line braking
- acceleration
- cornering
- controllability
- grade climbing.

A multitude of variables will affect results, including the following:

- initial speed (for braking tests)
- tire type (studded, non-studded, studless)
- number of studded tires (two or four)
- vehicle type (automobile, truck, SUV)
- vehicle drive configuration (front-wheel drive, rear-wheel drive, four-wheel drive)
- vehicle weight distribution
- brake system type (ABS or non-ABS)
- roadway pavement type and condition

- roadway surface condition (dry, wet, loose snow, packed snow, smooth ice, stud-roughened ice)
- temperature (above freezing, near freezing, well below freezing).

The traction performance of tires is primarily a function of the frictional characteristics between the tire and the driving surface. Studded tires were obviously intended to increase friction between tire and a driving surface, for betterment of control during braking, acceleration, and cornering. Though this occurs under certain slippery conditions involving ice, tests over the years have shown that stopping distances are often increased on dry or wet pavement surfaces. It has further been shown that under certain cold temperature conditions on icy roadways, studded tires do not necessarily shorten stopping distances.

To develop a comprehensive test matrix that would consider the effect of each of these variables would be a monumental task, and to our knowledge, has not been done. Instead, most of these factors have been tested individually and in various combinations by a variety of researchers over many years. The results of some of those studies are presented below.

FRICTIONAL CHARACTERISTICS

One measure of tire performance is through tire frictional characteristics, often represented by the coefficient of friction between the tire and roadway surface. This dimensionless value, though relatively theoretical, is useful for predicting many facets of vehicle performance, including braking, acceleration, and cornering. The static coefficient of friction is the ratio of the horizontal force that can be sustained by the tire to the vertical force (usually weight) on the tire. Because coefficient of friction represents a measure of only the specific interaction between the tire and roadway, it is difficult to measure in a practical sense; other vehicle and environmental factors enter into the actual measurement of vehicle/roadway frictional performance. Hence, the term friction factor, or drag factor, is sometimes used to represent the cumulative effect of all these variables and can be interpreted as the "effective" coefficient of friction. Some references use the terms coefficient of friction and friction factor interchangeably; that will be the case here also. Friction factor can be defined as the force that can be generated by a tire (vehicle) in braking, accelerating, or cornering divided by the vertical load (weight) on the tire. Friction factors for a tire undergoing braking, acceleration, and cornering may be different, but relative values for tires within each performance category should be comparable.

TEMPERATURE EFFECTS AND ROAD CONDITIONS

Studs are most effective on ice at or near 32 degrees F (0 degrees C) and lose their efficacy as temperatures drop and the ice becomes too hard for the studs to grip or when temperatures rise and ice melts to slush or wet pavement. However, it has been estimated that ice at or near freezing exists only 1 percent of the time in the State of Washington (WSDOT website). Average winter road conditions in the states of Alaska, Connecticut, and Minnesota are shown in Table 2 (Lu 1994). These data for Alaska and Minnesota, both of which have harsh winters, show that the roads are icy only 12 to 13 percent of the time. Another study in Alaska stated that because of the temperature limitations on the effectiveness of studded tires (between 0 and 32 degrees F (–18 and 0 degrees C)), their capabilities can only be used for 6 percent of the winter (Alaska Studded Tire Study 1973).

Table 2. Average Winter Road Surface Conditions (Lu 1994)

State	Dry/Wet Pavement (%)	Snow/Packed Snow (%)	Icy Pavement (%)
Alaska	65	22.6	12.4
Connecticut	96.5	3	0.5
Minnesota	75	12	13

An older study reported that about 13 percent of all vehicle travel in Minnesota was on ice or hard-packed snow (NCHRP 1975), though no distinction was drawn between ice and hard-packed snow, nor for icy roads near the freezing point. Hence, the total proportion of vehicle miles traveled on ice near the freezing point, where studded tires have some recognized effectiveness, was likely to be considerably less than 13 percent. The same source named a similar study in Ontario that examined average winter conditions for two years in the early 1970s. That study showed that icy conditions prevailed for an average of 2.15 percent of the vehicle miles traveled. Again, no distinction was drawn between ice near the freezing point and ice at lower temperatures, so the traction benefits from studded tires would likely accrue for even fewer miles than the reported 2.15 percent.

The temperature sensitivity of traction performance complicates the evaluation of studded versus non-studded or studless tires. Because studded tires, in comparison with studless tires, tend to show advantages on ice near freezing and are at a disadvantage at temperatures well below freezing, it is difficult to predict which tire will perform better unless temperature is part of the equation.

PENNSYLVANIA TRANSPORTATION INSTITUTE STUDY

A study performed by the Pennsylvania Transportation Institute reported a comparison of friction factors for vehicles fitted with various traction aids on icy, snowy, or wet surfaces (Hayhoe and Kopac 1981). Researchers performed tests and gathered published data to substantiate analytical estimates of friction factors for various tire and vehicle configurations. Their values measured braking, driving traction, and "controllability" of the test vehicles equipped with standard highway tires, snow tires, studded tires, four-wheel drive, and anti-lock brakes. Locked wheel braking tests measured tire/roadway friction at 20 mph (32 kph). Traction tests involved measuring the traction force while spinning the drive wheels of a vehicle that was either stationary or traveling. Controllability values represented lateral tire frictional forces. The results of the testing and analysis are summarized in Table 3.

Results showed that studded tires had slightly better locked-wheel braking performance (higher friction factor) on ice than highway or snow tires but were identical in performance to snow tires on snowy or wet surfaces. Results were similar for the traction and controllability tests. Not surprisingly, four-wheel drive was vastly superior for traction and controllability but offered no improvement in braking. Anti-lock brakes showed benefit for controllability tests but not for locked-wheel braking or traction maneuvers.

Table 3. Vehicle Friction Factors for Various Vehicle and Traction Aid Configurations, Maneuvers, and Conditions[1] (Hayhoe 1981)

	Locked-Wheel Braking			Traction			Controllability		
	Ice	Snow	Wet	Ice	Snow	Wet	Ice	Snow	Wet
Highway Tires	0.08	0.15	0.4	0.024	0.03	0.19	0.08	0.15	0.4
Snow Tires (on rear only)	0.08	0.175	0.4	0.024	0.055	0.19	0.08	0.175	0.4
Steel Tire Chains (on rear only)	0.19	0.27	0.4	0.13	0.17	0.19	0.19	0.27	0.4
Studded Snow Tires (on rear only)	0.09	0.175	0.4	0.032	0.055	0.19	0.09	0.175	0.4
Four-wheel Drive	0.08	0.15	0.4	0.064	0.12	0.37	0.16	0.3	0.8
Anti-lock Brakes (4-wheel systems)	0.08	0.15	0.4	0.024	0.03	0.19	0.16	0.3	0.8
Anti-lock Brakes (2-wheel systems)	0.08	0.15	0.4	0.024	0.03	0.19	0.12	0.23	0.6

[1]For rear wheel drive vehicle, except where noted; ice temperature 25° F

SWEDISH ROAD AND TRAFFIC INSTITUTE STUDY

Another comparison of the frictional characteristics of studded and non-studded tires was performed by the Swedish Road and Traffic Institute (VTI) in 1988 (Nordstrom and Samuelsson 1991). This research compared the frictional differences between studded tires and non-studded winter tires (intended to be studded). It also considered the effect of stud protrusion (which includes the effect of stud wear), tire wear, ice condition (smooth versus stud-roughened), and ice temperature. New, studded tires, fitted with 105 to 123 studs each, and with stud protrusion of 0.043 to 0.070 in. (1.1-1.8 mm) were tested. Tests included optimum-slip braking, locked-wheel braking, and maximum cornering. A partial summary of test results can be found in Table 4.

Table 4. Friction Coefficients for Studded and Non-Studded Tires Under Various Conditions (based on Nordstrom and Samuelsson 1991)

	Friction Coefficient		Friction Gain due to Studs
Temperature: 32°F (0°C) Smooth Ice	**Non-Studded Tire**	**Studded Tire**	
Optimum Slip	0.09-0.11	0.14-0.21	0.05-0.10
Locked Wheel	0.10-0.12	0.12-0.19	0.02-0.07
Maximum Cornering	0.12-0.12	0.16-0.17	0.04-0.05
Temperature: 32°F (0°C) Stud-Roughened Ice			
Optimum Slip	0.36-0.38	0.36-0.44	0.00-0.07
Locked Wheel	0.2-0.23	0.24-0.33	0.02-0.13
Temperature: 30.2° to 6.8°F (-1 to -14°C) Smooth Ice			
Optimum Slip	0.09-0.25	0.14-0.26	0.00-0.09
Locked Wheel	0.10-0.14	0.12-0.19	0.02-0.07
Maximum Cornering	0.21-0.25	0.21-0.26	(-0.02-0.03)
Temperature: : 30.2° to 6.8°F (-1 to -14°C) Stud-Roughened Ice			
Optimum Slip	0.14-0.27	0.18-0.27	(-0.02-0.04)
Locked Wheel	0.10-0.13	0.15-0.20	0.05-0.08

In reviewing Table 4, note that optimum slip is defined as the degree of brake application necessary to achieve maximum deceleration (or maximum coefficient of friction). Locked-wheel braking is when all four wheels are arrested; the degree of deceleration achieved under such conditions is usually not as great as with optimum-slip braking. Typically, optimum slip occurs when there is between 10 and 15 percent wheel slippage (rather than 100 percent slippage, which occurs under locked-wheel braking). The purpose of ABS is to automatically optimize slip while braking, both for maximizing deceleration and for enhancing vehicle stability and control.

Key findings from the VTI study included the following:

For the comparison of new studded with non-studded tires, the greatest effective gain in friction coefficient (0.10) occurred for studded tires undergoing optimum-slip braking. This occurred on smooth ice at 32 degrees F (0 degrees C), where the friction coefficient for non-studded tires was 0.09 to 0.11, a benefit of nearly 100 percent.

On 32 degree F (0 degree C) ice roughened by studs, the friction coefficient for new, non-studded tires under optimum-slip braking was 0.36 to 0.38. The friction gain due to studs was modest at 0.00 to 0.07. For locked wheel braking under the same conditions, the friction gain was higher for studded tires (0.02-0.13), but the baseline friction coefficient was lower for non-studded tires (0.20-0.23).

Under certain conditions, there was no frictional gain from studded tires, particularly when temperatures were below the freezing mark. For example, on ice roughened by studs at temperatures between 14 and 18 degrees F (–10 and –8 degrees C), the frictional change from new, non-studded to studded tires was –0.02 to 0.04.

The frictional effect of studs becomes negligible when stud protrusion drops to about 0.024 in. (0.6 mm). On smooth ice under optimal-slip braking, the effect of worn tires is not nearly so pronounced. In contrast, studded tires worn to 0.197 in. (5 mm) tread depth with stud protrusion of 0.039 to 0.043 in. (1.0-1.1 mm) yield friction values similar to that of a new studded tire under the same conditions. Hence, stud protrusion has much more influence than tire wear under these circumstances.

Friction generally increased with increasing ice roughness. On 32 degree F (0 degree C) "wet" ice, the friction factor for both studded and non-studded tires at least doubled on roadways with roughened ice as compared with smooth ice. This suggests a benefit to traction for vehicles not equipped with studded tires when they travel on icy roads previously traversed by vehicles with studded tires. However, this benefit greatly diminished when ice temperatures dropped below freezing.

Studded tires are most beneficial when used on wet, clear ice near 32 degrees F (0 degrees C), or on colder ice with surface contamination from snow or ice powder.

Studded tires reduce the difference in friction factor between optimum-slip and locked-wheel braking more than do non-studded tires. This could reduce the risk of misjudgment of necessary braking distance and may improve the braking potential for anti-lock brakes.

1994 ALASKA STUDIES

Of the researchers of studded tire performance over the past 10 to 15 years, perhaps the most prolific was Jian John Lu, of the Transportation Research Center at the University of Fairbanks, Alaska. Mr. Lu's work was performed in the mid 1990s. The highlights of his work, which include test data as well as a review of data from other sources, will be presented here along with findings from other sources. The work performed by Mr. Lu is particularly relevant to the present study undertaken by the State of Washington because it represents a recent examination of the performance issues of the latest generation of studded and studless radial tires on contemporary vehicles with such characteristics as front-wheel drive and anti-lock brakes.

Tests were conducted by the University of Alaska at Fairbanks in the spring of 1994 (Lu 1994). The tests compared the effects of the Bridgestone/Firestone "Blizzak" tire, one of a series of modern "studless" snow tires developed for increased winter traction, with conventional studded tires and all-season tires. Studless winter tires, developed in the early 1990s, represent a new class of tire dedicated to winter travel. These tires incorporate an aggressive, deep tread design in a soft rubber compound with multiple sipes and, in the case of the Bridgestone Blizzak, micro-bubbles that provide tiny gripping edges on ice*. The Blizzak is one of the more popular alternatives to studded tires, and many studies have sought to compare the performance of the Blizzak with that of studded tires on ice and packed snow surfaces.

* Other studless winter tires (Q-rated/Snowflake symbol)

Bridgestone Blizzak MZ-01
Bridgestone Blizzak MZ-02
Bridgestone Blizzak WS-15 (original)
Bridgestone Blizzak WS-50
Bridgestone Blizzak W965 (Light Truck)
Bridgestone Winter Dueler DM-Z2 (Light Truck)
Dunlop Graspic DS-1
Dunlop Graspic HS1 / HS2
Dunlop Grandtrek SJ4 (Light Truck)
Goodyear Ultra Grip Ice
Michelin Arctic-Alpin
Michelin 4X4 Alpin (Light Truck)
Pirelli Winter Ice Asimmetrico
Pirelli Winter 210 Performance Ice
Yokohama Guardex 600
Yokohama Guardex RV F340

Tests were conducted at the Fairbanks International Airport under conditions of packed snow, ice, and bare pavement using 1) a front-wheel-drive Chevrolet Lumina equipped with anti-lock brakes (ABS), 2) a two-wheel-drive, full-size Chevrolet pickup truck equipped with ABS, and 3) a rear-wheel-drive Chevrolet Caprice with ABS. Stopping distances and starting traction were recorded and averaged; results are shown in tables 5 and 6.

Table 5. Stopping Distances (feet (m)) on Packed Snow, Icy, and Bare Pavement Surfaces in Fairbanks, Alaska (based on Lu 1994)

	Front Wheel Drive Car	2 Wheel Drive Pickup	Rear Wheel Drive Car	Average
Packed Snow Surface				
Blizzak Tire	62.2 (18.9)	79.3 (24.2)	50.7 (15.4)	64.1 (19.5)
Studded Tire	64.3 (19.6)	68.6 (20.9)	59.4 (18.1)	64.1 (19.5)
All-Season Tire	64.0 (19.5)	69.0 (21.0)	57.4 (17.5)	63.5 (19.3)
Icy Surface				
Blizzak Tire	104.0 (31.4)	122.0 (37.2)	128.5 (39.2)	118.2 (36.0)
Studded Tire	84.0 (25.6)	116.5 (35.5)	117.7 (35.9)	106.1 (32.3)
All-Season Tire	105.5 (32.1)	152.7 (46.5)	127.0 (38.7)	128.4 (39.1)
Bare Pavement Surface				
Blizzak Tire	N/A	16.3 (4.9)	N/A	16.3 (4.9)
Studded Tire	N/A	17.0 (5.2)	N/A	17.0 (5.2)
All-Season Tire	N/A	16.6 (5.0)	N/A	16.6 (5.0)

Note: all vehicles equipped with ABS

Stopping distance results averaged across the three vehicles showed that on packed snow there was little to distinguish one tire from another. On ice, the studded tires were superior, showing 15 percent shorter stopping distances than the Blizzaks, while the stopping distances of the all-season radials were 8 percent longer than the Blizzaks. For bare pavement, the stopping distances of the three tires (tested only on the pickup) were very similar. The longest stopping distance was for the studded tires, but only by 2 percent over the all-season radials and 5 percent over the Blizzaks. These differences may not be significant.

Table 6. Starting Traction Tests (Time to Reach 25 mph (40.3 km/h)) (sec) on Packed Snow, Icy, and Bare Pavement Surfaces in Fairbanks, Alaska (Lu 1994)

	Front Wheel Drive Car	2 Wheel Drive Pickup	Rear Wheel Drive Car	Average
Packed Snow Surface				
Blizzak Tire	8.88 sec	9.5 sec	10.41 sec	9.6 sec
Studded Tire	9.27	8.53	9.57	9.12
All-Season Tire	10.06	10.42	10.99	10.49
Icy Surface				
Blizzak Tire	12.7	13	17.53	14.41
Studded Tire	9.94	12.63	13.01	11.86
All-Season Tire	12.94	19.08	18.03	16.68
Bare Pavement Surface				
Blizzak Tire	N/A	3.52	N/A	3.52
Studded Tire	N/A	3.74	N/A	3.74
All-Season Tire	N/A	3.73	N/A	3.73

Note: all vehicles equipped with ABS

For the starting traction tests, traction was defined by the time (in seconds) it took for the vehicle to accelerate from a standstill to 25 mph (40.3 km/h). All the tests were relatively vehicle and driver dependent. Results, shown in Table 6, showed that for packed snow, the studded tires and Blizzaks were very similar, at 9.12 and 9.6 seconds, respectively, which is marginally significant. The all-season tires were slightly behind, at 10.49 seconds. On ice, front- and rear-drive cars equipped with studded tires held a clear advantage over the Blizzaks and all-season tires. But on the pickup, the studded tires provided traction very similar to that of the Blizzaks, and both showed superior traction to the all-season tires by about 40 percent. On the average for all vehicles, the Blizzak traction times to reach 25 mph (40.3 km/h) were about 18 percent longer than those for studded tires, but about 13 percent less than for the all-season tires. On bare pavement, only the pickup was used. The studded and all-season tires had nearly identical results, while the Blizzak was approximately 7 percent faster. It is not clear whether this difference is significant, however.

Tests were also conducted by the University of Alaska at Fairbanks to investigate cornering and hill climbing ability. For the cornering tests, the vehicles were operated on curves with radii of 25 ft (7.7 m) and 50 ft (15.4 m) while lateral acceleration was recorded. Lateral acceleration was measured with instrumentation, and maximum cornering speeds were calculated from the data. Maximum lateral acceleration on snow was found to be 0.25 to 0.40, and on ice was 0.1 to 0.2.

Results summarized in Table 7 show that studded tires generally had the lowest cornering speeds, and the Blizzak generally had the highest. Variations were not large, however, and not likely significant.

Table 7. Maximum Speeds During Cornering (mph (kp/h))
(based on Lu 1994)

25-ft (7.7 m) Curve	Packed Snow	Ice on Pavement
Blizzak Tires	12.1 (19.5)	10.1 (16.2)
Studded Tires	10.9 (17.5)	9.8 (15.8)
All-Season Tires	11.8 (19.0)	10.3 (16.6)

50-ft (15.4 m) Curve	Packed Snow	Ice on Pavement
Blizzak Tires	17.2 (27.7)	14.2 (22.8)
Studded Tires	15.9 (25.6)	13.6 (21.9)
All-Season Tires	17.2 (27.7)	13.7 (22.0

Gradability was analytically determined by measuring the longitudinal acceleration during traction tests in both Anchorage and Fairbanks. Maximum starting grades are summarized in Table 8 for tests on packed snow, ice on pavement, and lake ice. Tests determined that both the studded snow tires and the Blizzaks had similar grade climbing capability in packed snow, but the studded tires had a slight advantage in icy conditions. Both the studded snow tires and the Blizzaks were superior to the all-season tires for grade climbing.

Table 8. Maximum Starting Grades (percent) (Lu 1994)

	Packed Snow	Ice on Pavement
Fairbanks Results		
Blizzak Tires	16%	11%
Studded Tires	16	12
All-Season Tires	15	10
Anchorage Results		
Blizzak Tires	18	10
Studded Tires	16	11
All-Season Tires	15	N/A

1995 ALASKA STUDIES

As a continuation of the 1994 research project in Alaska, additional testing was performed there in 1995 (Lu 1995) to validate previous results and to consider other factors, including

1) the effects of used (worn) winter tires on traction performance

2) the performance of lightweight studded tires

3) the performance of a front-drive car and a rear-drive pickup with studded tires on only the two front wheels
4) the effect of tire wear and pavement surface temperature on traction performance
5) vehicle controllability (lateral traction) performance tests
6) the effect of vehicle type on traction performance.

For all tasks, the vehicles tested included a Chevrolet Lumina without ABS, a full-sized, two-wheel-drive Chevrolet pickup truck with ABS on only the rear wheels, and a rear-wheel-drive Chevrolet Caprice with four-wheel ABS. Unlike the tests conducted in 1994, which were mostly conducted on airport taxiways, tests for this study were primarily conducted on roads and parking lots around Fairbanks, Alaska, to more closely simulate real roadway conditions.

The first task involved traction performance tests on snowy and icy surfaces with the same tires that had been tested in 1994 (which were new at that time). The purpose of the first task was to explore the effect of tire wear on braking and starting traction. The tires had accrued more than 1000 miles (1610 kilometers) of wear since they were originally tested in 1994. For the braking traction tests, stopping distance and maximum deceleration were measured after brakes were applied (in an effort to lock the brakes) on vehicles traveling 25 mph (40.3 km/h). The air temperature during testing was reported to be below 10 degrees F (-12 degrees C).

When results for the first task were averaged for all three vehicles, the shortest stopping distance for the snowy surface was from the Blizzaks, which were 9 to 13 percent better than the studded tires and 18 to 24 percent better than the all-season tires.

On the icy surface, the Blizzaks and studded tires were more closely matched, but both were approximately 25 percent better than the all-season tires. Maximum deceleration for the three tire types, averaged across each vehicle, corresponded predictably to the braking traction results and hence are not presented here. Table 9 and Figure 3 show the results of these tests.

Table 9. Averaged 25 mph (40.3 km/h) Stopping Distances ft (m)) from Task 1 (based on Lu 1995)

Snowy Surface	**Lumina**	**Pickup**	**Caprice**	**Average**
Blizzaks	82.3 (25.1)	72.5 (22.1)	50.2 (15.3)	68.2 (20.8)
Studded	87.6 (26.7)	82.7 (25.2)	63.9 (19.5)	78.1 (23.8)
All Season	114.5 (34.9)	88.9 (27.1)	69.9 (21.3)	91.2 (27.8)
Icy Surface				
Blizzaks	90.2 (27.5)	83.7 (25.5)	71.2 (21.7)	81.7 (24.9)
Studded	90.9 (27.7)	89.2 (27.2)	76.8 (23.4)	85.6 (26.1)
All Season	128.3 (39.1)	96.8 (29.5)	104.6 (31.9)	109.9 (33.5)

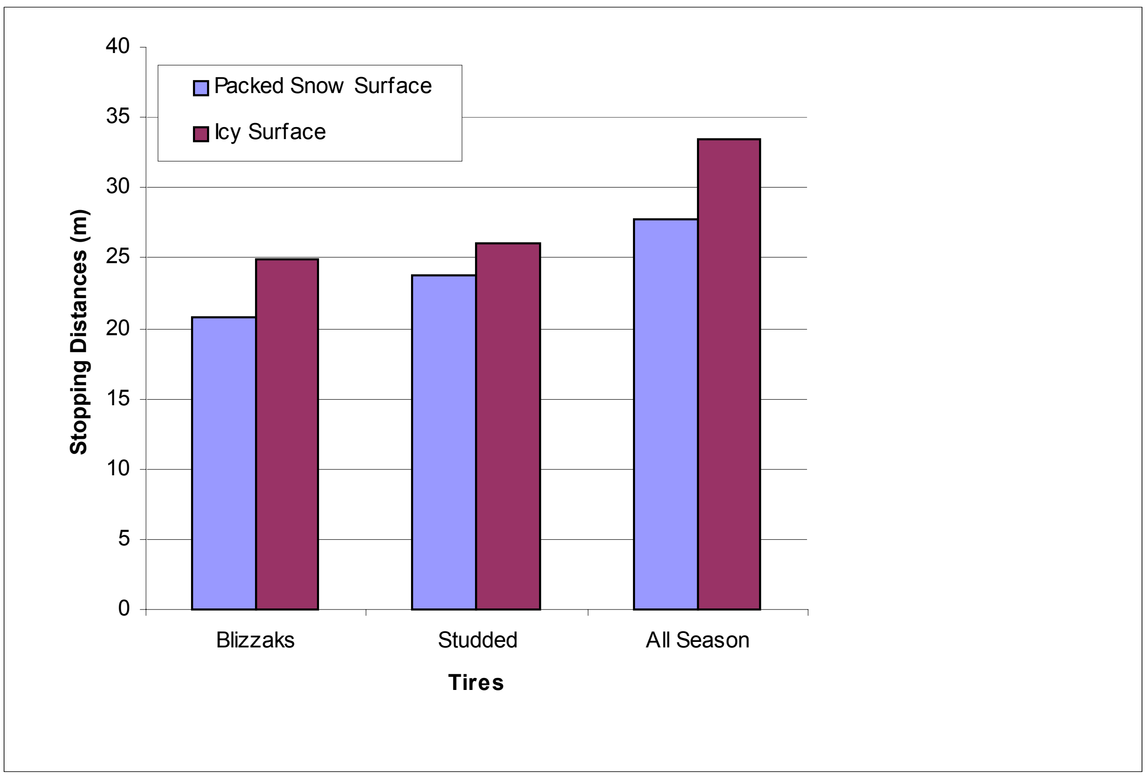


Figure 3. Stopping Distances (m) of Test Tires with All Vehicle Types Combined (Lu 1995)

Starting traction performance tests were conducted similarly to those in 1994; each vehicle was accelerated at maximum rate from a standstill and timed until it reached 20 mph (32.2 km/h). Results (Table 10 and Figure 4) showed that nearly the same starting traction performance was obtained for the studded tires and the Blizzaks, regardless of whether they were tested on snowy or icy surfaces. Both these tire types performed considerably better than all season tires (11 percent better on snow and 25 percent better on ice).

Table 10. Averaged Starting Traction (Time to reach 20 mph (32.2 km/h)) (sec) from Task 1 (based on Lu 1995)

Snowy Surface	**Lumina**	**Pickup**	**Caprice**	**Average**
Blizzaks	7.67 sec	8.65 sec	7.51 sec	7.94 sec
Studded	7.54	8.17	8.35	8.02
All Season	9.58	8.07	9.9	9.18
Icy Surface				
Blizzaks	7.84	8.14	7.95	7.98
Studded	8.18	7.86	8.53	8.19
All Season	11.15	9.68	11.3	10.71

The conclusions from these tests were that the Blizzaks offered the best overall traction performance on both packed snow and icy surfaces, slightly ahead of studded tires, but both the Blizzaks and the studded tires performed considerably better than the all-season tires. The studded tires appeared to lose proportionally more of their traction capability than did the other tires.

The second task of the 1995 Alaska study (Lu 1995) compared the stopping traction performance of new “lightweight” studded tires (with aluminum studs) that have been developed in response to concerns about pavement damage from conventional steel studs. Braking tests were conducted in the same manner as previously—on both a packed snow surface and an icy surface, with the driver attempting locked-wheel stops from 25 mph (40.3 km/h). Two vehicles were used: the full-sized Chevrolet pickup and the Chevrolet Caprice. Air temperature during these tests was about 0 degrees F (-18 degrees C). The tires with lightweight studs were new; the standard studded tires and Blizzak tires were the same (used) tires that had been tested previously in this program and in the 1994 program.

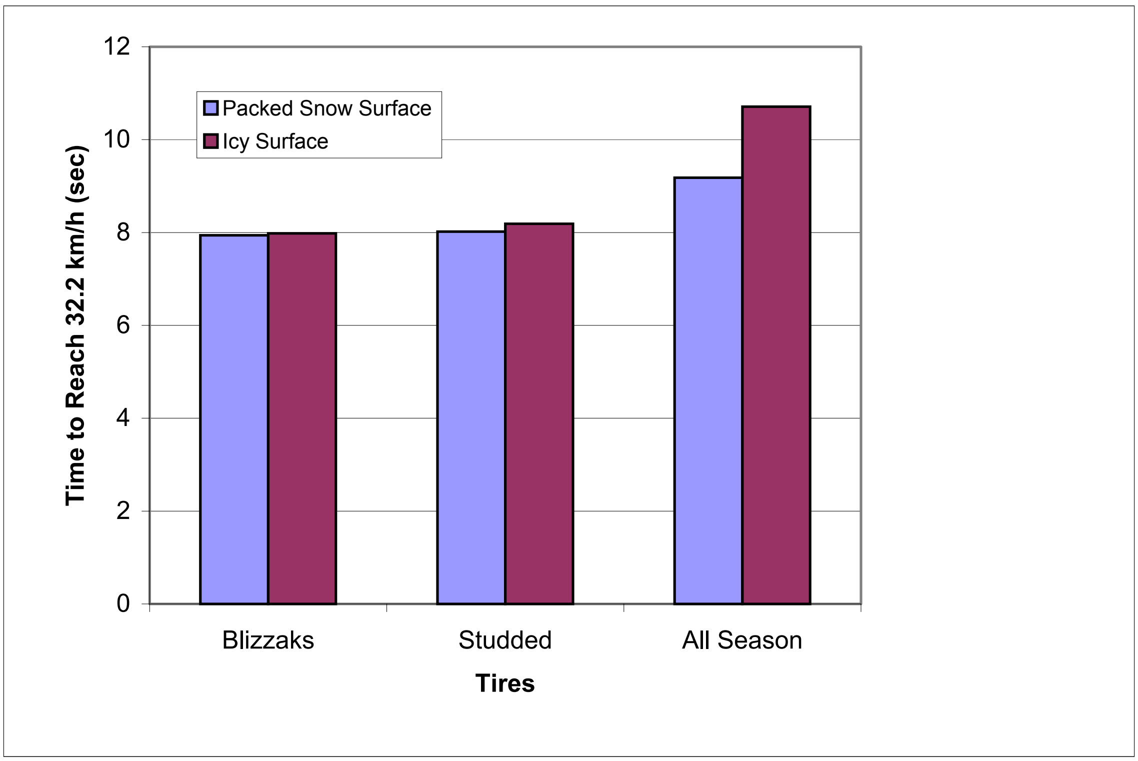


Figure 4. Starting Traction of Test Tires (Time to reach 20 mph (32.2 km/h)) with All Vehicle Types Combined (sec) (Lu 1995)

Stopping traction test results (Table 11 and Figure 5) showed that on a packed snow surface, the Blizzaks had the shortest stopping distance of the three tires tested. About 10 percent behind the Blizzaks were the lightweight-studded tires, and about 16 percent behind the Blizzaks were the standard-studded tires. On an icy surface, the lightweight-studded tires showed the best stopping traction, with braking distances approximately 11 percent shorter than the Blizzaks and about 17 percent shorter than the standard-studded tires.

Table 11. Averaged 25 mph (40.3 km/h) Stopping Distances (ft (m)) from Task 2 (based on Lu 1995)

Snowy Surface	**Pickup**	**Caprice**	**Average**
Blizzaks	72.5 (22.1)	40.3 (12.3)	55.4 (16.9)
Standard Studded	80.7 (24.6)	51.2 (15.6)	65.9 (20.1)
Lightweight Studded	70.2 (21.4)	52.5 (16.0)	61.3 (18.7)
Icy Surface			
Blizzaks	82.3 (25.1)	76.1 (23.2)	79.4 (24.2)
Standard Studded	83.0 (25.3)	86.3 (26.3)	84.6 (25.8)
Lightweight Studded	71.2 (21.7)	69.9 (21.3)	70.5 (21.5)

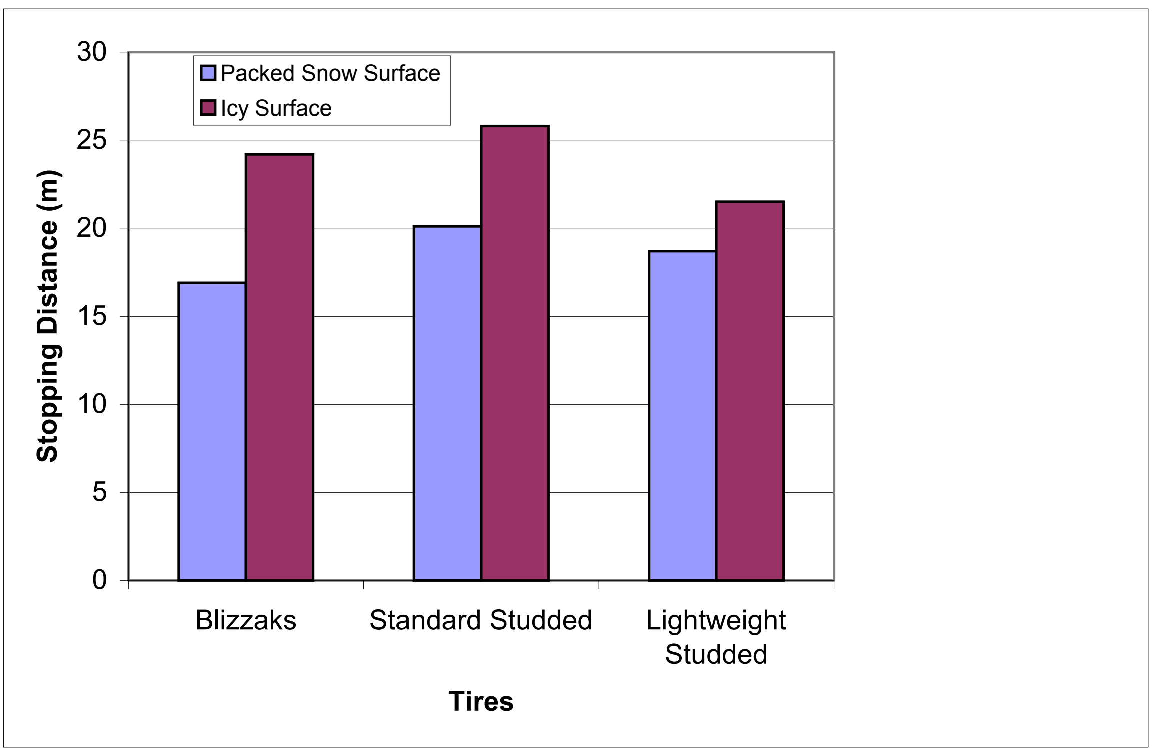


Figure 5. Stopping Distances (m) of Test Tires with All Vehicle Types Combined (Lu 1995)

Stopping traction results measured with an accelerometer yielded results consistent with the stopping distance measurements: on snow, the Blizzaks had the greatest deceleration, followed by the lightweight-studded and standard-studded tires. On ice, the lightweight-studded tires had the greatest deceleration followed by the Blizzaks and standard-studded tires (the latter two of which were nearly equal).

Starting traction performance produced similar results: the lightweight-studded tires on snow and ice required the shortest time to reach 25 mph (40.3 km/h), followed by the Blizzaks. But the greatest acceleration on snow came from the Blizzaks, followed by the lightweight-studded tires. On ice, the greatest acceleration came from the standard studded tires, but the value was nearly identical to that of the Blizzaks.

In conclusion, the lightweight studded tires generally produced the best stopping and starting traction performance when compared with the Blizzaks and standard-studded tires. However, the Blizzaks and standard-studded tires were somewhat worn, while the lightweight-studded tires were new, which may have affected the results.

In a third task, the 1995 Alaska research also examined the braking traction performance of two studded tires only, mounted to the front wheels, instead of all four tires, as had been the case for all previous testing. These tests were apparently conducted because the option of running two instead of four studded tires has been considered for reducing pavement wear. Two vehicles were tested, a front-wheel drive Chevrolet Lumina with ABS and a full-sized (rear-wheel drive) Chevrolet pickup truck. Comparisons were made for each vehicle equipped three different ways: standard studded tires on all four wheels, on just the front wheels (with all-season tires on the rear) and with all-season tires on all four wheels. Tests were only for braking traction (not starting traction) and were conducted similarly to those performed previously except that a 35 mph (56.4 km/h) initial speed was used.

When test results from both snowy and icy surfaces were averaged (Table 12 and Figure 6), the vehicle with two front studded tires performed about 8 percent better than the vehicle with four all-season tires, and about 7 percent worse than the vehicle with all four studded tires. This result confirms a fairly predictable outcome: when two studded tires are placed on the front wheels, the benefit to braking traction is roughly half of the benefit if studded tires are used on all four wheels. Presumably, the use of two versus four studded tires would provide a commensurate decrease in pavement wear. However, further thought and testing must be applied to determine whether such a practice also may compromise other facets of vehicle performance. Obviously, for rear-wheel drive vehicles such as the pickup truck, starting traction performance would not be enhanced if studded tires were placed only on the front (non-driving axle). If the studded tires were placed only on the rear of the rear-wheel drive pickup, it is likely that the braking traction performance would not have been enhanced as much as with the studded tires in front (because of the forward weight distribution). A more serious concern, however, would be the directional stability, particularly under braking and/or cornering, when tires of different friction factor were used in the front and rear. It is possible that various vehicles, under certain conditions, could become unstable in yaw if mismatched tire types were mounted front to rear. This could cause the vehicle to become directionally unstable and to rotate about a vertical axis, or “spin out,” while decelerating or cornering.

Table 12. Averaged Stopping Distance (ft (m)) from Task 3 (based on Lu 1995)

Tire Type	Snow Surface Average	Icy Surface Average	Total Average
Four Wheel Studded	92.5 (28.2)	127.3 (28.8)	93.5 (28.5)
Standard Studded	99.7 (30.4)	101.7 (31.0)	100.7 (30.7)
Lightweight Studded	113.5 (34.6)	104.6 (31.9)	109.2 (33.3)

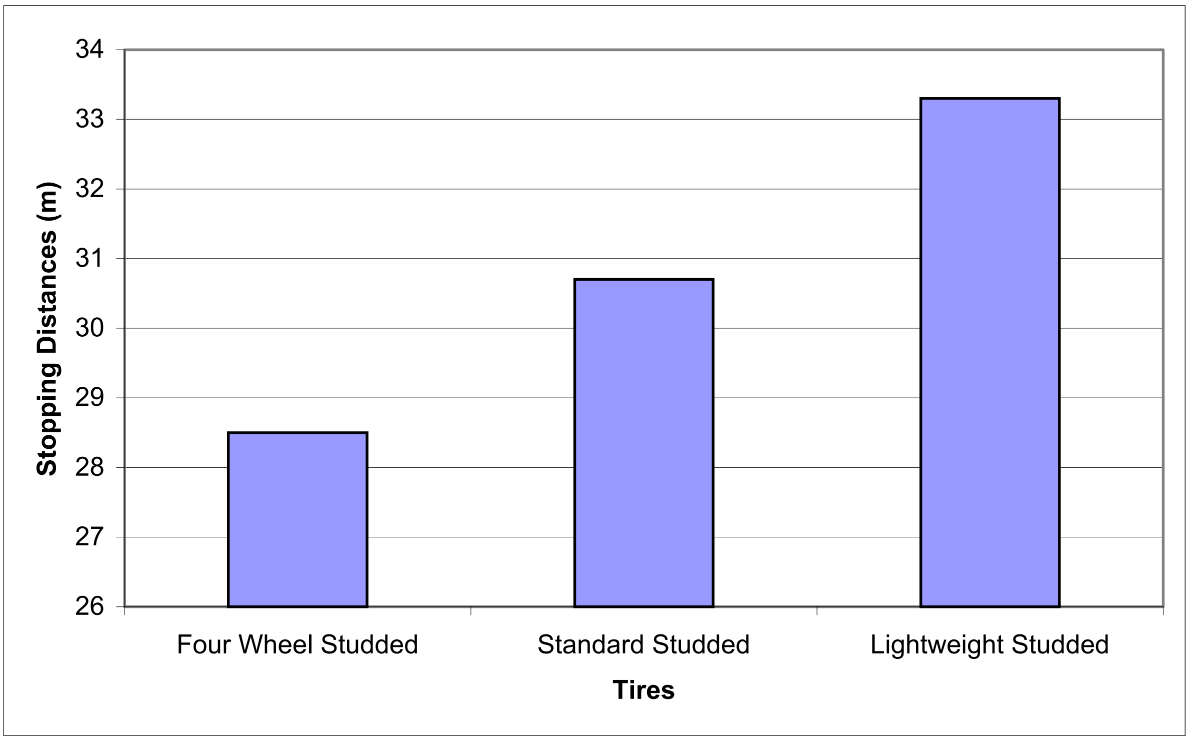


Figure 6. 35 mph (56.4 km/h) Stopping Distances (m) from Task 3 with All Vehicle Types and Surface Conditions Combined (Lu 1995)

The fourth task of the Alaska study (Lu, 1995) included an examination of the effects of tire wear and surface temperature on stopping and starting traction. For the tire wear tests, the same lightweight-studded tires tested while new in the second task were driven 1000 miles (1610 km) on the road. Stopping distances from 25 mph (40.3 km/h) and starting traction times to the same speed were measured on a packed snow surface at about 32 degrees F (0 degrees C) both before and after the tires had been "worn" on the road. Only the Chevrolet Caprice was used for this comparison.

Results (Table 13) showed that after accruing tire wear through use, the lightweight-studded tires required about 12 percent longer distances to stop from 25 mph (40.3 km/h) and about 2 percent longer to attain this speed than when they were new. This confirmed that tire and stud wear diminish the traction performance capability of the tires.

Table 13. Stopping and Starting Traction Performance Comparison between New and Used (1000 mile/1610 km wear) Lightweight Studded Tires[1], Task 4 (based on Lu 1995)

Studded Tire Type	Stopping Traction	Starting Traction
	Stopping Distance (ft/m) from 25 mph (40.3 km/hr)	Time (sec) to Reach 25 mph (40.3 km/h)
New Lightweight	48.2 (14.7)	6.73 sec
Old Lightweight	55.1 (16.8)	6.9 sec
Difference	12%	2%

[1]Caprice on packed snow surface, 32°F, (0°C)

Upon comparison with the second task, wherein new lightweight-studded tires were tested on the Caprice, the effect of temperature was noted. Tests from the second task were run at temperatures of 0 degrees F (–18 degrees C), whereas the tests for the fourth task were run at the freezing mark. Stopping distances were 6 percent longer at the colder temperature (for the "new" tires on a packed snow surface).

A more formal test of the effect of temperature was performed as part of the fourth task. For these tests, stopping distance data at 25 mph (40.3 km/h) were collected for the full-sized Chevrolet pickup on packed snow and icy surfaces at temperatures of -20 degrees F (-29 degrees C) and 32 degrees F (0 degrees C). Three tire types were tested: standard studded tires, Blizzaks, and all-season tires.

Results generally showed that stopping distances were shorter at temperatures near freezing than at –20 degrees F (-29 degrees C). The only exception was the all-season tire on ice, which stopped 6 percent shorter at the colder temperature. With all vehicles and surface conditions combined and the results averaged (Table 14 and Figure 7), the studded tires showed the most significant difference—with 5 percent shorter average stopping distances at temperatures near freezing. This differential was more than twice that of the all-season tires and five times that of the Blizzaks. One possible explanation for this is that at the higher temperatures, the snow and ice are warmer and hence softer. Especially for ice near freezing, the traction of the studded tires is particularly enhanced because of the more aggressive engagement in the ice by studs. Thus, the potential benefit from studs becomes less apparent as temperature drops.

Table 14. Averaged 25 mph (40.3 km/h) Stopping Distances (ft (m)) at Different Temperatures, Task 5 (based on Lu 1995)

Snowy Surface	**Temp: -20°F (-29°C)**	**Temp: 32°F (0°C)**	**Difference**
Blizzaks	72.5 (22.1)	72.5 (22.1)	0%
Standard Studded	82.7 (25.2)	80.7 (24.6)	2%
All Season	88.9 (27.1)	77.7 (23.7)	12%
Icy Surface			
Blizzaks	83.7 (25.5)	82.3 (25.1)	2%
Standard Studded	89.2 (27.2)	83.0 (25.3)	7%
All Season	96.8 (29.5)	103.3 (31.5)	-6%
Snowy-Icy Combined			
Blizzaks	78.1 (23.8)	77.4 (23.6)	1%
Standard Studded	85.9 (26.2)	82.0 (25.0)	5%
All Season	92.8 (28.3)	90.5 (27.6)	2%

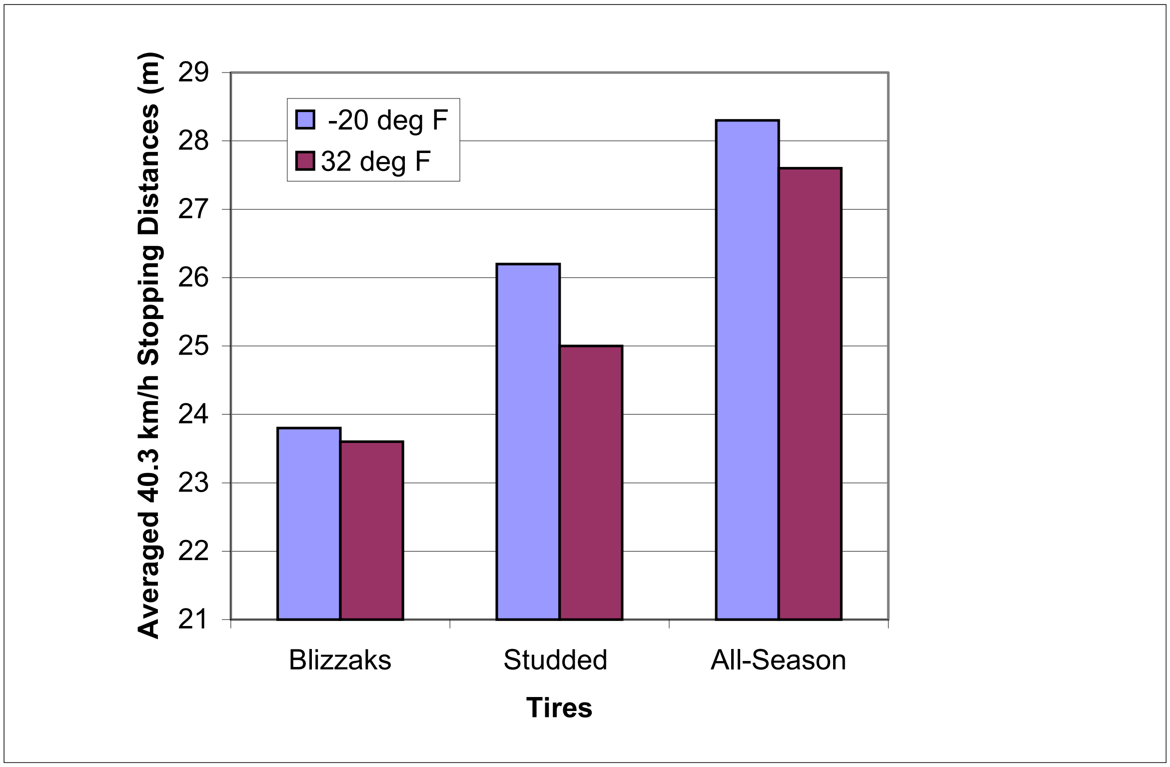


Figure 7. Temperature Effects on 25 mph (40.3 km/h) Stopping Distances (m) of Chevy Truck (Lu 1995)

The fifth task of the 1995 Alaska study examined vehicle lateral controllability during stopping maneuvers. In these tests, the test vehicles were fitted either with Blizzaks, all-season tires, four studded tires, or two studded (front) and two all-season tires. They were stopped from 35 mph (56.4 km/h) on both snow and ice at temperatures near freezing. A video camera recorded the vehicle trajectory, and later analysis of the video tape allowed measurement of the maximum lateral displacement and maximum angular directional change.

Results showed that for snow and ice combined, the vehicle equipped with four studded tires had the best lateral traction performance (the least lateral displacement and least angular rotation), the all-season tires were next, and the other two groups followed. Results were very close, however, and the differences were not particularly significant.

For the sixth task in the 1995 Alaska study, the effect of vehicle type and drive configuration on traction performance was examined. In these tests, stopping and starting traction were compared for the front-wheel drive Chevrolet Lumina; rear-wheel drive, half-ton Chevrolet pickup; and rear-wheel drive Chevrolet Caprice. Stopping distances were measured for initial speeds of 25 mph (40.3 km/h), as were times to reach 20 mph (32.2 km/h) from a standstill. Tests were conducted with standard studded tires, all-season tires, and Blizzaks on snow and ice at very low temperatures of –20 to –30 degrees F (-29 to –35 degrees C).

Results averaged across all conditions and tire types (Table 15 and Figure 8) showed that for the stopping traction tests, the Caprice stopped in the shortest distance, ahead of the truck by 15 percent and the Lumina by 26 percent. Drive configuration is not likely to have played a part in this disparity because the vehicles were being braked. A number of vehicle factors probably contributed to this difference, particularly vehicle weight distribution, tire size and contact area, and suspension dynamics. For starting traction tests, the truck had the best performance, ahead of the Lumina by 3 percent and the Caprice by 6 percent. The spread in results was not significant and was likely the result of experimental technique and the variation in vehicle parameters discussed above.

Table 15. Averaged 25 mph (40.3 km/h) Stopping Distances (ft (m)) from Task 6 (based on Lu 1995)

Snowy Surface	**Blizzaks**	**Studded**	**All Season**	**Average**
Lumina	82.3 (25.1)	87.6 (26.7)	114.5 (34.9)	94.8 (28.9)
Chevrolet Pickup	72.5 (22.1)	82.7 (25.2)	88.9 (27.1)	81.4 (24.8)
Caprice	50.2 (15.3)	63.9 (19.5)	69.9 (21.3)	61.3 (18.7)
Icy Surface				
Lumina	90.2 (27.5)	90.9 (27.7)	128.3 (39.1)	103.0 (31.4)
Chevrolet Pickup	83.7 (25.5)	89.2 (27.2)	96.8 (29.5)	89.9 (27.4)
Caprice	71.2 (21.7)	76.8 (23.4)	104.6 (31.9)	84.3 (25.7)

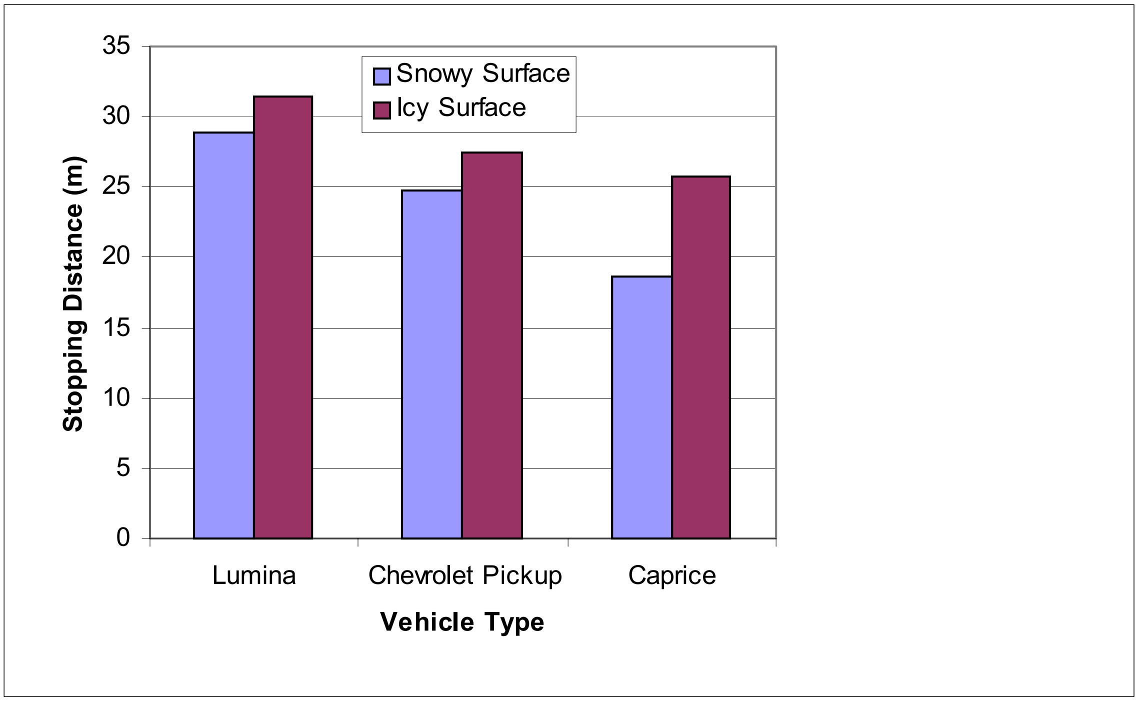


Figure 8. Stopping Distances (m) of Test Vehicles with All Tires Combined
(Lu 1995)

The following overall conclusions were drawn from the Alaska Studies (Lu 1995):

1. The non-studded Blizzak tires offered the best traction performance, especially for braking on both packed snow and ice, while all-season tires showed the worst performance. The same was true for starting traction, though performance differences for the studded tires and Blizzaks were not significantly different. Studded tires may lose more of their tractive ability over time than Blizzaks.
2. Tests showed that lightweight (aluminum) studs produced better stopping and starting traction results on snow and ice than standard studded tires and Blizzaks, though this conclusion may have been confounded by the fact that the lightweight studded tires were new, while the other tires tested had been worn somewhat.

3. The use of only two studded tires (on only the front wheels) produced stopping traction results on snow and ice that were about halfway in between the results of four studded tires and four all-season tires. However, other controllability penalties, such as yaw instability, should be considered.
4. Wear on lightweight-studded tires diminishes their stopping and starting traction performance capability. This effect was most prominent for braking maneuvers, where worn tires with lightweight studs had stopping distances on snow that were 12 percent longer than when new.
5. Stopping and starting traction performance on snow and ice generally diminishes at temperatures below about 20 degrees F (-7 degrees C). Studded tires produce their best traction on snow or ice near the freezing mark and lose proportionately more of their tractive ability at lower temperatures than do studless or all-season tires.
6. Lateral traction performance differences between the various tire groups did not show significant variation.
7. Tests of stopping and starting traction performance for different vehicle types and configurations on snow and ice showed that significant differences occur for braking distances, but not for starting traction. The Caprice stopped 15 percent shorter than the pickup truck and 26 percent shorter than the Lumina. These differences were primarily ascribed to vehicle differences such as weight distribution, tire size and contact area, and suspension dynamics, and were not likely related to the drive configuration (front-wheel drive, rear-wheel drive).

OTHER PERFORMANCE DATA FROM ALASKA

In another study performed in Alaska (Lu et al. 1995), tests were conducted to determine the performance of studded tires in comparison with all-season tires and Blizzak tires on packed snow, ice, and bare pavement. The first test, conducted by the University of Alaska at Fairbanks, involved the use of the same three types of vehicles used in the 1995 tests (Lu 1995), but for this series of tests, the Lumina had four-wheel ABS. Stopping distances were recorded from initial vehicle speeds of 25 mph (40.3 km/h) at a location in Fairbanks on packed snow, ice, and bare pavement. Most tests were conducted at near-freezing temperatures.

Results (Table 16 and Figure 9) showed that all three tire types produced the same results on packed snow. On ice, stopping distances were generally two or three times longer than on packed snow, and were shortest for studded tires followed by the Blizzaks (8 percent longer) and all-season tires (15 percent longer). On bare pavement, stopping distances for the Blizzaks and all-season tires were 5 percent and 2 percent shorter, respectively, than the studded tires, but the differences were deemed insignificant.

Table 16. Stopping Distances (ft (m)) for 25 mph (40.3 km/h) on Packed Snow, Ice, and Bare Pavement, Fairbanks
(based on Lu et al. 1995)

Packed Snow Surface	Lumina	Pickup	Caprice	Average
Blizzaks	62.3 (19.0)	79.4 (24.2)	50.8 (15.5)	64.3 (19.6)
Studded	64.3 (19.6)	68.6 (20.9)	59.4 (18.1)	64.3 (19.6)
All Season	63.9 (19.5)	68.9 (21.0)	57.4 (17.5)	63.6 (19.4)
Icy Surface				
Blizzaks	104.0 (31.7)	122.0 (37.2)	128.6 (39.2)	118.4 (36.1)
Studded	83.9 (25.6)	116.5 (35.5)	117.8 (35.9)	106.3 (32.4)
All Season	105.6 (32.2)	152.9 (46.6)	126.9 (38.7)	128.6 (39.2)
Bare Pavement				
Blizzaks	N/A	16.4 (5.0)	N/A	16.4 (5.0)
Studded	N/A	17.0 (5.2)	N/A	17.0 (5.2)
All Season	N/A	16.7 (5.1)	N/A	16.7 (5.1)

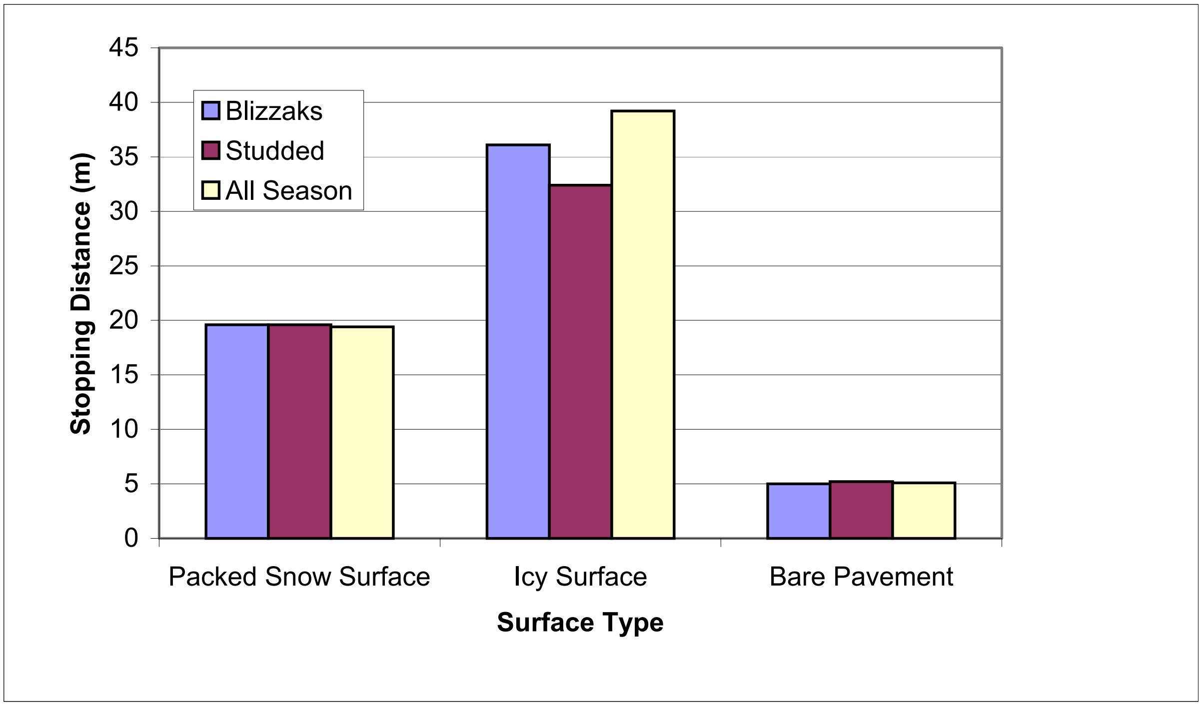


Figure 9. Stopping Distances (m) for Various Tires on Slippery and Bare Pavement, Fairbanks (Lu et al. 1995)

In a similar test, conducted by the University of Alaska at Anchorage (Lu et al. 1995), stopping distances were determined for packed snow, ice, and bare pavement. The vehicles were the same, except that a Ford Crown Victoria (rear-wheel drive with ABS) was exchanged for the Caprice.

Results showed that on packed snow, the Blizzaks and studded tires were nearly equivalent and both were significantly better than the all-season tires (Table 17 and Figure 10). On the icy surface, the all-season tires were not tested, but the studded tires stopped 11 percent shorter than the Blizzaks. On bare pavement, the studded tires had stopping distances 40 percent and 42 percent longer than the Blizzaks and all-season tires, respectively.

Table 17. Stopping Distances (ft (m)) for 25 mph (40.3 km/h) on Packed Snow, Ice, and Bare Pavement, Anchorage
(based on Lu et al. 1995)

Packed Snow Surface	Lumina	Pickup	Crown Victoria	Average
Blizzaks	50.5 (15.4)	39.8 (10.6)	37.1 (11.3)	40.7 (12.4)
Studded	52.8 (16.1)	36.1 (11.0)	36.7 (11.2)	41.9 (12.8)
All Season	55.4 (16.9)	53.1 (16.2)	47.6 (14.5)	51.8 (15.8)
Icy Surface				
Blizzaks	97.1 (29.6)	66.6 (20.3)	100.1 (30.5)	87.9 (26.8)
Studded	64.3 (19.6)	83.7 (25.5)	86.6 (26.4)	78.1 (23.8)
All Season	N/A	N/A	N/A	N/A
Bare Pavement				
Blizzaks	N/A	N/A	11.1 (3.4)	11.1 (3.4)
Studded	N/A	N/A	17.4 (5.3)	17.4 (5.3)
All Season	N/A	N/A	10.8 (3.3)	10.8 (3.3)

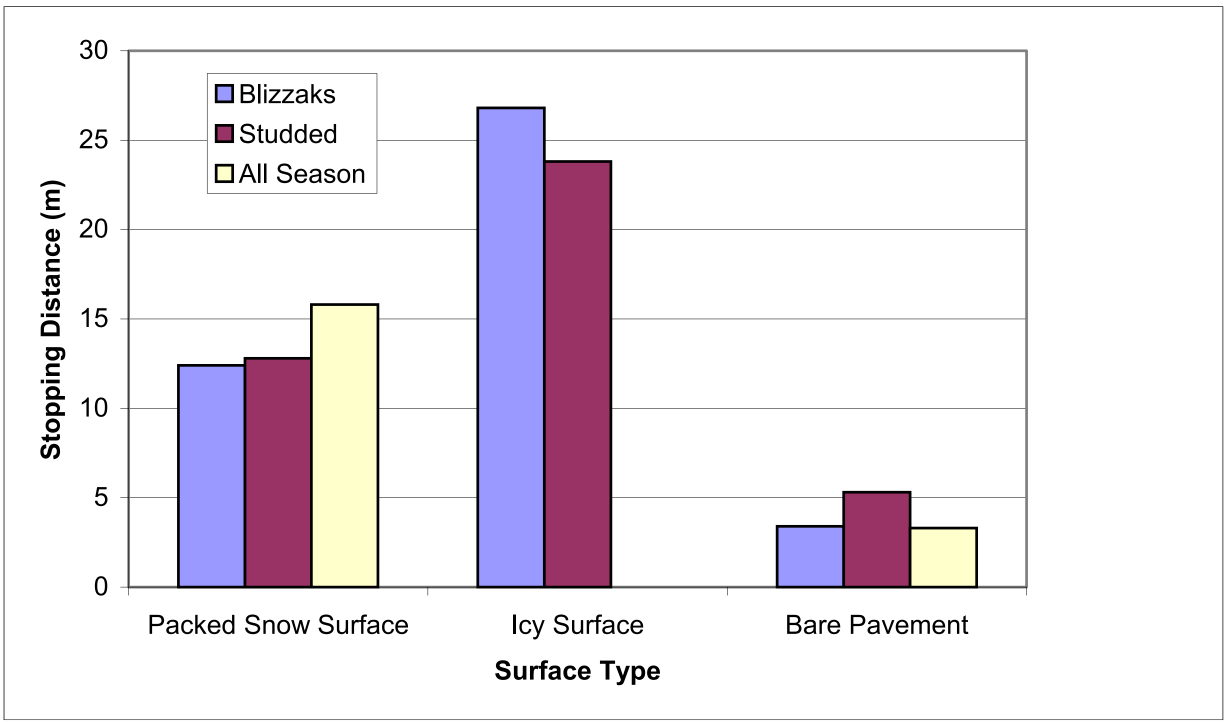


Figure 10. Stopping Distances (m) for Various Tires on Slippery and Bare Pavement, Anchorage (Lu et al. 1995)

Tests of starting traction times conducted in Fairbanks and Anchorage (Lu et al. 1995) showed that on bare pavement, studded tires fared the worst (or tied for worst) when compared with the other tires. In Fairbanks, the test involved use of the Chevrolet pickup accelerating to 25 mph (40.3 km/hr). The Blizzaks gave the best starts, with times 7 percent faster than the studded and all-season tires, which had the same starting traction performance. In Anchorage, the Crown Victoria was used for the same test. In this case, the Blizzaks and all-season tires had essentially the same starting traction, and showed about 10 percent lower elapsed time to reach the target speed.

In research performed much earlier in the State of Alaska (Alaska Studded Tire Study 1973), the merits of studded tires were debated from the standpoint of performance and safety. This study reported on performance tests conducted by the Canadian Safety Council in 1971 that examined stopping distances, traction, and maneuverability on ice, snow, wet and dry asphalt, and wet and dry concrete. Though some of the results may not apply to tire and automotive technology that has since advanced 30 years, some observations are still meaningful.

The 1973 Alaska study documented that during stopping distance tests, studded tires lose their effectiveness with declining temperature, and their performance becomes essentially indistinguishable from ordinary highway tires below 0 degrees F (-18 degrees C) (Figure 11). The effect of sand on ice also becomes minimal. This is consistent with other sources that suggest the colder and harder the ice, the less effective studs become.

The 1973 Alaska report also stated that there was almost no difference in stopping distances on wet or dry asphalt between vehicles equipped with highway tires, two studded tires on the rear, or four studded tires. For concrete, though, studded tires required longer stopping distances than highway tires. On dry pavement, a vehicle equipped with two studded tires required 11 percent longer distances to stop and 16

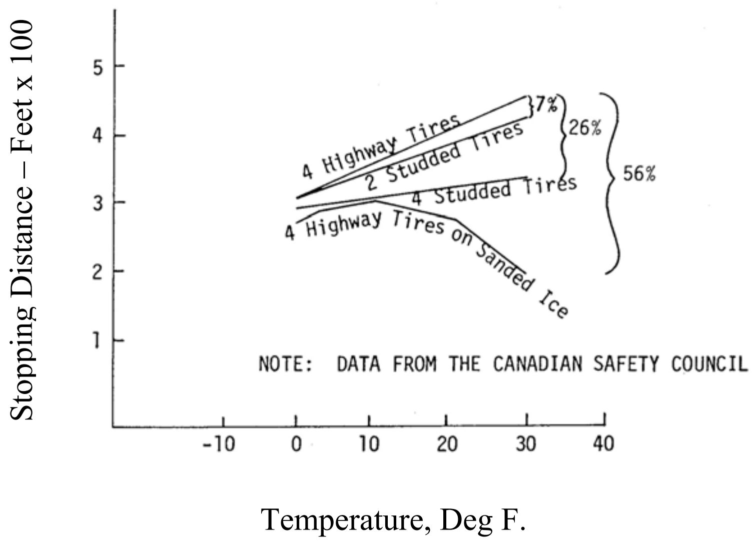


Figure 11. The Effect of Temperature (F) on Traction for Studded and Non-studded Tires (Alaska Studded Tire Study, Phase III, 1973)

percent longer when the concrete was wet. For four studded tires, this difference increased to 16 percent for dry conditions and 32 percent for wet conditions. Though such statistics may not be entirely valid for today's CP studs, radial tires, and ABS, they still indicate a trend that is likely to be valid: studded tires on wet or dry concrete provide less traction than non-studded tires. This is likely because the studs cannot penetrate the harder roadway surface, which actually lowers the effective coefficient of friction, in much the same way as studded tires lose effectiveness on ice at lower temperatures.

4. WINTER TIRE SAFETY

Aside from pure traction issues, a number of varied and complex safety issues surround the use of studded and non-studded tires. Some of the effects of studded tires are beneficial, and some are not; some seem obvious while others are subtle. Although not the primary focus of this report, a number of these issues are presented here briefly, including

- the effect of studded tires on accident risk
- driving hazards caused by pavement wear
- incidental traction improvements on roadways "roughened" by studded tire use
- the effect of studded tires on driver behavior.

THE EFFECTS OF STUDDED TIRE USE ON TRAFFIC ACCIDENT RISK

An extensive analysis of accident rates for vehicles equipped with studded tires was undertaken in Norway in 1998 (Elvik 1998). This "meta-analysis" involved a statistical analysis of 11 previously published studies on this topic from researchers in the U.S., Canada, Scandinavia, Germany, and Japan. The 11 studies showed large variations in results: the effects of studded tires on accident rates on snow- or ice-covered roads ranged from a reduction of 72 percent to a reduction of 4 percent. All of the studies showed a benefit from studded tires, though the effect was not significant in all the studies. On bare roads, the effects of studded tires on accident rates varied even more widely: from a 68 percent decline to a 151 percent increase. For all road surfaces combined, the effects of studded tires on automobile accident rates ranged from a 10 percent increase to a 70 percent decline.

The Norwegian study statistically analyzed the results of these 11 studies and classified them by strength. It was concluded that the use of studded tires improves road safety by reducing the accident rate, but the effect is quite small, on the order of 1 to 10 percent. Early data (from the 1970s) often suggested much greater reduction in accident rates for users of studded tires (on the order of 40 to 70 percent), which is not likely to be accurate anymore. This disparity is caused by several factors. First, the difference in friction between studded tires and non-studded winter tires is likely to have become smaller over time. The gap has narrowed both because regulations around the world have limited the aggressiveness of the studs and because tire technology has improved the frictional characteristics of newer, studless winter tires. Hence, the true safety benefits of studded tires have been reduced relative to non-studded tires.

Other confounding factors may have skewed historical and more recent accident rate predictions. Accident rate declines for vehicles equipped with studded tires that were presented in the 1970s have been postulated to have been wrong because of "selective recruitment" of the drivers (Elvik 1998). When studded tires were newly available, they may have been purchased by "safer drivers" who were more concerned about safety and hence likely to have a lower accident rate, regardless of what tire they were using. Also, drivers using non-studded tires reportedly cancelled more trips and drove more cautiously than those with studded tires. Some of these driver behavioral factors will be discussed in a later section.

A separate Norwegian study sent a questionnaire to drivers who reported car damage during the winter of 1994/1995 to assess the effect of studded tires on winter accident rates. The study found no significant difference in accident involvement between drivers with studded and non-studded tires when controlling for other car and driver characteristics (Fosser 1995).

DRIVING HAZARDS CAUSED BY PAVEMENT WEAR

Several obvious and well-understood driving hazards result from pavement rutting caused by accelerated wear that is the result of studded tire use. First, rutting can cause "tramlining," which adversely affects the directional controllability of a car by "steering" the car toward the center of the rut, or by upsetting the lateral stability while the car changes lanes (from rut to rut). When water is present, rutting allows standing water to accumulate in wheel troughs, thereby raising the potential for hydroplaning, which can cause complete lack of control. Standing water in ruts can also cause excessive road spray to obscure the vision of nearby motorists. Increased wear from studded tire use can also cause premature loss of pavement paint striping and marking.

INCIDENTAL TRACTION IMPROVEMENTS

Some studies have suggested that the roughening of driving surfaces, either pavement or ice, by extensive use of studded tires may have an overall benefit to the traction (and hence safety) of the roadway. Non-studded tires tend to pack the snow into compact ice, while studded tires tend to wear down this surface fairly quickly (Fridstrom 2001).

A 1993 ban of studded tires in Japan resulted in "extremely slippery" roads, a higher numbers of accidents, smoother pavement, and a 20-fold increase in the amount of anti-freezing agents applied (Asano et al. 2001). In the mid-1980s in Hokkaido, studded tire usage rates were close to 100 percent. During the period from 1989 to 1993, as studded tires were phased out, slippery roads did not become a problem until 1992 when the studded tire use rate fell below 20 percent. Icy or snowy roads were postulated to have been moderately roughened through use of studded tires, which made it safer for all vehicles, including those with non-studded tires that used the same roads.

Another study concluded that a ban on studded tires resulted in a slight decrease in fatal and injury-only accidents but in an increase in skidding accidents (Minsk and Kajiya 1993).

According to a 1995 study, 95 percent of the vehicles in Finland are equipped with studded tires (Kallberg 1995). The study concluded that the overall accident risk in winter would increase by only 9 percent if only 50 percent of the vehicles were equipped with studded tires. If only 20 percent of the vehicles had studded tires, the risk would increase by 17 percent. The increase in risk was found not to be linearly dependent on the proportion of cars equipped with studded tires because even a small proportion of cars with studded tires is sufficient to roughen icy roads, thereby improving traction for all vehicles whether or not they are equipped with studs. Another Finnish study by the same author concluded that one of the positive aspects of studded tire use is that it provides better traction on pavements that are susceptible to wear by studded tires (Kallberg 1993).

A 1998 study in Sweden investigated diminished skid resistance on roadways caused by the advent of lighweight studs and wear-resistant pavement mixes (Hobeda 1998). Before these developments, studded tire use in the winter months tended to roughen pavement texture and thus improve skid resistance in the summer. Hence, an unintended consequence of less pavement wear was lower skid resistance. Another

Swedish study indicated that pavement roughening by studded tires improves wet friction traction on bare surfaces, thereby improving grip for vehicles both with and without studded tires (Oberg 1994).

DRIVER BEHAVIOR

Human behavior should not be overlooked in assessing the safety of studded tires, though there is not consensus about the effects. Some studies have shown that drivers using studded tires tend to be more confident and therefore tend to drive faster than those using non-studded tires (Fridstrom 2001, Kallberg et al. 1995), hence increasing risk. It has been shown that even a small increase in speed can negate any increase in traction performance of studded tires. Another study found the risk for drivers of vehicles with studded and non-studded tires to be equal (Fosser 1996). Yet another study concluded that drivers of vehicles with studded tires drive more safely than those with non-studded tires (Sigthorsson 1998).

One body of research on the use of studded tires in Norway concluded that a reduction in the use of studded tires would not lead to a significant increase in injury accidents. The researchers found that during severe winter conditions, drivers of vehicles with studded tires tended to drive faster than others, creating a greater likelihood of control loss (Fridstrom 2001). Perhaps oddly, their analysis also found that accident risk was reduced on days when there was no snow on the ground or in the air. They postulated that this was because of a "surprise factor," wherein drivers of vehicles fitted with studded tires on fair days who encountered unexpected slippery conditions might have a traction advantage, and that such drivers had not lost this advantage by adapting (upward) their speed relative to drivers of vehicles without studded tires.

A study from Finland also examined driver behavior. The researchers found that drivers using studless tires braked more softly, negotiated steep curves more carefully, drove at lower speeds, and expressed complete satisfaction with the studless tires. Drivers who had previously been using studded tires did not want to switch back to using studded tires (Roine, 1994).

OTHER FACTORS AFFECTING THE USE OF STUDDED TIRES

Other factors to be considered in the debate over the use of studded tires include such issues as

- the cost of studded tires in comparison with new studless winter tires
- the increase in fuel consumption for studded versus studless tires
- convenience and mobility, including the trade-off in the use of traditional snow-clearing methods
- the introduction of suspended particulate matter (dust) from roadway wear
- increased noise from studded tires.

Cost of Studded versus Studless Tires

An informal survey of tire costs in the Seattle area revealed that typical winter tires for a mid-sized car vary substantially in cost. For example, a typical 205/60-14 studded snow tire costs approximately $60 (equipped with studs). The same size Blizzak tire costs closer to $100. Each tire is designed to give three or four average winter seasons before losing effectiveness as a winter tire; the Blizzak is designed to operate at its best for 30,000 to 40,000 miles. After its useful life as a snow tire, the Blizzak can easily (and legally) be “used up” during non-winter months. The studded snow tire, in Washington, cannot be driven on the street in the summer months. However, its studs can be removed, and it can be used as a highway tire.

Fuel Consumption

Field measurements conducted in Finland showed that slippery, snowy, and uneven roadway surfaces can increase fuel consumption by 15 percent over bare, dry, and even surfaces (Anila 1994). The difference in fuel consumption between bare pavement and the most slippery icy road was 4 percent. A decrease in coefficient of friction of 0.1 (from 0.4 to 0.3) increased fuel consumption by 0.7 percent. Fuel consumption with studded tires was about 1.2 percent higher than that with studless winter tires. Hence, the fuel consumption of studded versus studless tires depends on which tire creates the best traction, which is a function of the roadway condition. Given data presented from the Alaska studies (Lu 1994, 1995), which showed that studless tires, for most circumstances, have better traction than studded tires, fuel consumption for studded tireswill likely be higher, on the average, than that of studless tires. However, relative effects on fuel consumption of snow, ice, and road surface unevenness far outweigh the effects of studs on tires.

Convenience and Mobility

There is an intangible value of the mobility gained from the opportunity to use vehicles on roadways regardless of the weather. The use of studded tires affords users (at least) the perception of convenient icy-weather traction without the inconvenience associated with either staying home or using temporary traction aids such as chains. The tangible and intangible costs and benefits of studded tires and other traction-enhancing options must be compared with alternative methods of gaining mobility, including winter highway snow and ice control. For some states, winter highway maintenance comprises a large part of the yearly budget.

In Hokkaido, Japan, where studded tire use was banned in 1990, the roadway maintenance costs increased sharply throughout the 1990s. By the winter of 1998-1999, the use of deicing agents had increased by 20 times and abrasives had increased 30 times the amount applied in 1991-1992 (Asano et al. 2001).

Suspended Particulate Matter

While pavement damage and subsequent increases in hydroplaning and road spray have been well documented, the increase in suspended particulate matter (SPM) or dust from stud use is a more complicated safety issue. Mechanical interaction between the stud and pavement releases particulate matter (airborne dust) that is considered a risk to human health. Several studies performed in Japan documented the significantly increased presence of this dust during periods of stud usage (Fukuzaki 1985 and Asano 2001). In fact, concerns about air pollution from airborne dust resulted in a national ban on studded tires in Japan in the early 1990s.

Noise

Further studies have documented the increase in noise from vehicles equipped with studded tires (Fridstrom 2001, NCHRP 1975). Noise levels for pavement-tire contact are also affected by the roughness of the pavement surface (which, in turn, can be roughened by the use of studs). In addition to increased ambient noise levels from these effects, pavement roughness can transmit vibration to the vehicle chassis, causing passenger discomfort and an increased rate of vehicle deterioration.

Tests from the early 1970s showed that the increase in noise from studded tires (as compared with non-studded tires) was most prominent at speeds of 20 mph (32 km/h); at higher speeds of 60 mph (96 km/h), the differences diminished somewhat (NCHRP 1975). For noise increases on roughened pavement compared with adjacent (smoother) pavement, the differences were most pronounced when measured inside the vehicle.

CONCLUSIONS

1. Studded tires produce their best traction on snow or ice near the freezing mark and lose proportionately more of their tractive ability at lower temperatures than do studless or all-season tires.
2. The traction of studded tires is slightly superior to studless tires only under an ever-narrowing set of circumstances. With less aggressive (lightweight) studs being mandated, and with the advent of the new "studless" tire, such as the Blizzak, since the early 1990s, the traction benefit for studded tires is primarily evident on clear ice near the freezing mark, a condition whose occurrence is limited. For the majority of test results reviewed for snow, and for ice at lower temperatures, studded tires performed as well as or worse than the Blizzak tire. For those conditions in which studded tires provided better traction than studless tires, the increment usually was small.
3. The precise environmental conditions under which studded tires provide a traction benefit are relatively rare. The maximum frictional gain (in comparison to non-studded (not studless) tires) is found for new studded tires on smooth ice, where they have been shown to provide up to 100 percent gain in certain tests. However, the relative frictional gain of studded tires diminishes or becomes negative on roughened ice, as the temperature drops, as the studs wear, or if the comparison is made with studless tires.
4. Traction performance can be characterized in many ways, including braking, acceleration, cornering, controllability, and grade climbing. Though all factors

are important, the single best indicator of tire performance is braking distance and deceleration.

5. Studded tires reduce the difference in friction factor between optimum-slip and locked-wheel braking, in comparison to non-studded tires. This may reduce the risk of drivers misjudging the necessary braking distance and may improve the braking potential for anti-lock brakes.
6. In one set of stopping distance tests in Alaska, studded, studless, and all-season tires performed nearly equally on snow, when averaged across several vehicles. On ice, stopping distances for studded tires were 15 percent shorter than for Blizzaks, which in turn were 8 percent shorter than for all-season tires.
7. In another set of tests in Alaska, studless Blizzak tires offered the best traction performance, especially for braking on both packed snow and ice, in comparison to studded tires (which were second) and all-season tires (which were last).
8. The use of two studded tires on the front of a vehicle produced stopping traction results on snow and ice that were about halfway between the result of four studded tires and four all-season tires. However, other controllability penalties, such as yaw instability, should be considered.
9. On bare pavement, studded tires tend to have poorer traction performance than other tire types. This is especially true for concrete; for asphalt, there is little difference in stopping distance between studded and non-studded tires.

10. Tractive performance of studded tires is sensitive to stud wear. Studded tires may lose more of their tractive ability over time (from stud wear) than studless tires. When stud protrusion diminishes to 0.024 in. (0.6 mm), the frictional effect from the studs becomes negligible. Tire tread wear (on studded tires) has relatively little frictional effect if stud protrusion is maintained at 0.039 to 0.043 in. (1.0-1.1 mm).
11. A Norwegian study concluded that the use of studded tires tends to reduce the accident rate by a small amount—from 1 to 10 percent.
12. A number of driver behavior issues have been postulated to affect the judgment of studded tire effectiveness. There is not consensus on these points: 1) drivers with studded tires care more about safety, hence they drive more safely, 2) they drive faster (because of a false sense of security or confidence), and 3) drivers with non-studded tires avoid driving when weather is severe.
13. Pavement rutting caused by accelerated wear from studded tires can cause the dangerous conditions of tramlining, hydroplaning on accumulated water in the ruts, excessive road spray, and premature damage to pavement markings.
14. The roughening of ice and pavement from studded tires provides a safety benefit for all vehicles (with and without studs) by helping to prevent formation of smooth, glare ice.
15. The cost of studless tires is significantly higher than studded tires—by approximately 50 percent.
16. Studded tires increase fuel consumption by a small amount (~1.2 percent) over non-studded tires on bare roadways. But the other effects of unevenness,

snow, and ice are far more significant than this factor and can increased fuel consumption by 15 percent.

17. Suspended particulate matter from pavement dust created by studded tires and noise from studded tires are health concerns in heavily traveled urban areas.

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APPENDICES

APPENDIX A
State of Washington Laws Regarding Studded Tires

WAC 204-24-030, Standards for Studded Tires:

Studded tires shall meet the following specifications:

(1) Studs shall be metal, tipped with tungsten carbide.

(2) Metal studs shall be inserted only in a new tire or a newly-recapped tire which has molded in the tread the "pin-holes" into which metal studs are to be inserted. Studs shall not be inserted in any new tire or newly-recapped tire after it has been driven on a vehicle.

(3) Metal studs may be installed only by the tire manufacturer, or by a tire dealer or tire jobber who shall install the metal studs in conformance with the manufacturer's specifications.

(4) When a tire is sold or offered for sale as a studded tire or when studs are installed in a new tire or a newly-recapped tire, there shall be a minimum of seventy metal studs evenly spaced around the tread of the tire.

(5) A tire shall contain a minimum of fifty-six metal studs at all times in order to qualify as a "studded tire" or as an approved traction device where traffic control signs marked "approved traction tires required" are posted.

(6) Metal studs shall not be installed in any tire of a vehicle which has a gross vehicle weight of ten thousand pounds or over.

(7) School buses and fire department equipment tires are exempt from subsection (6) of this section.

[Statutory Authority: RCW 46.12.330. 00-15-009, § 204-24-030, filed 7/10/00, effective 8/10/00. Statutory Authority: RCW 46.37.420. 92-05-016, § 204-24-030, filed 2/10/92, effective 3/12/92; 83-21-080 (Order 83-10-01), § 204-24-030, filed 10/19/83; Order 7607, § 204-24-030, filed 9/14/76; Order 6902, § 204-24-030, filed 2/17/70.]

RCW 46.04.272, Lightweight Stud:

"Lightweight stud" means a stud intended for installation and use in a vehicle tire. As used in this title, this means a stud that is recommended by the manufacturer of the tire for the type and size of the tire and that:

(1) Weighs no more than 1.5 grams if the stud conforms to Tire Stud Manufacturing Institute (TSMI) stud size 14 or less;

(2) Weighs no more than 2.3 grams if the stud conforms to TSMI stud size 15 or 16; or

(3) Weighs no more than 3.0 grams if the stud conforms to TSMI stud size 17 or larger.

A lightweight stud may contain any materials necessary to achieve the lighter weight.

[1999 c 219 § 1.]

Proposed State of Washington Laws

Proposal is currently still being debated at the committee level (Staff: Jennifer Ziegler 786-7316).

SENATE BILL REPORT

SB 5747

SENATE COMMITTEE ON TRANSPORTATION

Background: The Legislature and the Governor formed the Blue Ribbon Commission on Transportation in 1998 to assess the local, regional, and state transportation system; ensure that current and future money is spent wisely; make the system more accountable and predictable; and prepare a 20-year plan for funding and investing in the transportation system. The commission consisted of 46 members representing business, labor, agriculture, tribes, government, ports, shipping, trucking, transit, rail, environmental interests, and the general public.

The commission made eighteen recommendations to the Governor and the Legislature.

Recommendation Five outlined several ways to invest in maintenance, preservation, and improvement of the entire transportation system so that transportation benchmarks can be achieved. The commission concluded that one method for preserving the transportation system was to phase out studded tires or establish a surcharge to recognize the cost of studded tire damage to the roadways.

In 1999, the Legislature enacted a bill requiring wholesalers to only sell lightweight studs for tires. Starting July 1, 2001, retailers may only install lightweight studs on tires. The Washington State Department of Transportation projects that by July 2005, lightweight studs will be the only studs on the road.

Summary of Bill: Beginning July 1, 2001 (bill has not yet passed), a fee of $15 per tire is levied on the sale of each studded tire. The buyer of the tires must pay the fee to the seller of the tires and the seller must send the fees to the Department of Revenue. The fees must be deposited in the motor vehicle fund.

Appropriation: None.

Fiscal Note: Requested on February 1, 2001.

Effective Date: The bill contains an emergency clause and takes effect on July 1, 2001.

WASHINGTON STATE LEGISLATURE

History of HB 1670

HB 1670 Imposing a fee on studded tires.

Sponsors: Representatives Fisher; Mitchell; Ruderman; Poulsen

By Request: The Blue Ribbon Commission on Transportation

Companion Bill(s): SB 5747 -- 2001 REGULAR SESSION --

Jan 31 First reading, referred to Transportation. -- 2001 1ST SPECIAL SESSION

Apr 25 By resolution, reintroduced and retained in present status.-- 2002 REGULAR SESSION --

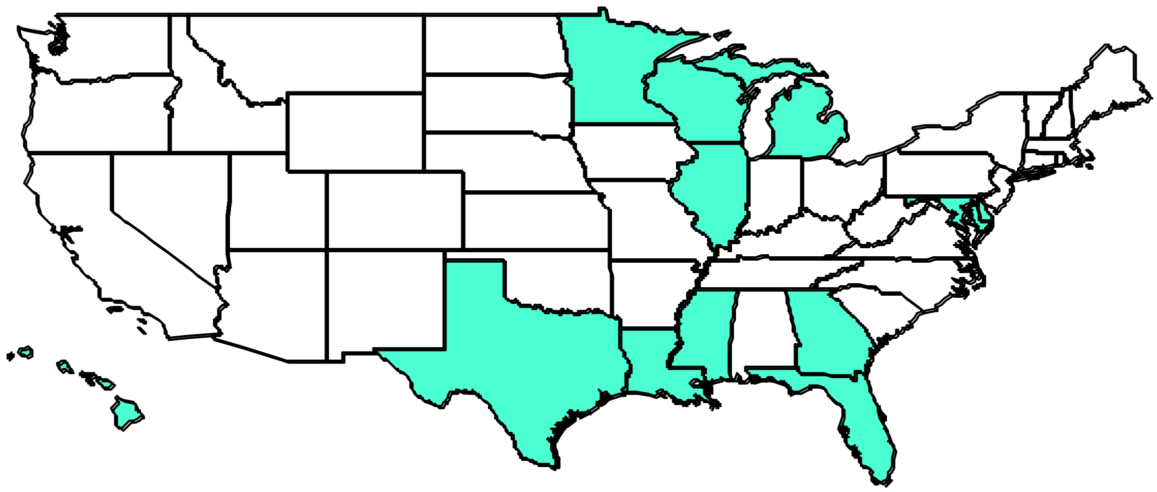
Jan 14 By resolution, reintroduced and retained in present status.

APPENDIX B
Other Studded Tire Regulations

STATE STUDDED TIRE REGULATIONS

Alabama	Rubber studs permitted. Metal illegal.
Alaska	Permitted: Sept. 15 — May 1 north of 60 degrees N; Sept. 30-April 15 south of 60 degrees N.
Arizona	Permitted: October 1-May 1
Arkansas	Permitted: November 15-April 15
California	Permitted: November 1-April 30
Colorado	Permitted: Year Round
Connecticut	Permitted: November 15-April 30 inclusive
Delaware	Permitted: October 15-April 15
District of Columbia	Permitted: October 15-April 15
Florida	Not Permitted. Studs which do not damage highway are permitted.
Georgia	Not permitted except for snow and ice driving conditions
Hawaii	Not permitted.
Idaho	Permitted: October 1-April 15
Illinois	Not permitted.
Indiana	Permitted: October 1-May 1
Iowa	Permitted: November 1-April 1
Kansas	Permitted: November 1-April 15
Kentucky	Permitted: No restrictions.
Louisiana	Not permitted.
Maine	Permitted: October 1-May 1
Maryland	Not permitted except in western counties: Nov. 1-March 31
Massachusetts	Permitted: November 2-April 30 unless otherwise authorized by registrar.
Michigan	Not permitted except under certain conditions. Check local officials.
Minnesota	Not permitted except for nonresidents who are subject to certain restrictions. Full time nonresident students and nonresidents employed within Minnesota are not permitted use of studded tires regardless of vehicle registry. Rural mail carriers may use studded tires under certain conditions.
Mississippi	Not permitted.
Missouri	Permitted: November 1-March 31
Montana	Permitted: October 1-May 31
Nebraska	Permitted: November 1-April 1
Nevada	Permitted: October 1-April 30
New Hampshire	Permitted: No restrictions
New Jersey	Permitted: November 15-April 1
New Mexico	No regulations.
New York	Permitted: October 16-April 30
North Carolina	Permitted: No restrictions
North Dakota	Permitted: October 15-April 15. Exception: school buses may use studded tires any time during the year.
Ohio	Permitted: November 1-April 15
Oklahoma	Permitted: November 1-April 1
Oregon	Permitted: November 1-April 1 unless specified differently by Department of Transportation because of weather conditions.
Pennsylvania	Permitted: November 1-April 15
Rhode Island	Permitted: November 15-April 1
South Carolina	Permitted if not projected more than 1/16-inch when compressed.
South Dakota	Permitted: October 1-April 30. School buses and municipal fire vehicles permitted to use studs anytime.
Tennessee	Permitted: October 1-April 15
Texas	Not permitted. Only studs that will not damage the highway are permissible.
Utah	Permitted: October 15-March 31
Vermont	Permitted: No restrictions
Virginia	Permitted: October 15-April 15
Washington	Permitted: November 1-April 1
West Virginia	Permitted: November 1-April 15
Wisconsin	Not permitted except for authorized emergency vehicles; vehicles used to deliver mail; automobiles with out-of-state registrations (only if automobile is in the course of passing through the state for a period of not more than 30 days). Also school buses from November 15-April 1.
Wyoming	Permitted: No restrictions. Chains required in snow emergencies.

SOURCE: AMERICAN AUTOMOBILE ASSOCIATION



<u>Exceptions</u>
Florida—Studs that do not damage the highway are permitted
Georgia—Exception: snow and ice driving conditions.
Maryland—Exception: western counties Nov. 1-March 31
Michigan—Exception: certain conditions.
Minnesota—Exceptions: nonresidents, who are subject to certain restrictions, rural mail carriers under certain conditions.
Texas—Studs that will not damage the highway are permissible.
Wisconsin—Exceptions: authorized emergency vehicles, vehicles used to deliver mail, vehicles with out-of-state registrations, school buses from Nov. 15-April 1.

Figure B-1. States in Which Studded Tire Use Is Not Permitted

INTERNATIONAL REGULATIONS ON USE OF STUDDED TIRES (LU 1994)

Canada	
Ontario	Prohibited
Quebec	Permitted October 15-April 15
Nova Scotia	Permitted October 15-April 15
Newfoundland	Permitted November 1-April 30
New Brunswick	Permitted October 16-April 14
Prince Edward Island	Permitted October 1-May 31
British Columbia	Permitted October 1-April 30
Manitoba	Permitted October 1-April 30
Saskatchewan	No Restriction
Germany	Prohibited
Sweden	October 31-Easter
Finland	November 1-March 31
Japan	Prohibited