Impacts of Studded Tires on Pavement and Associated Socioeconomics
Final Report

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16. Abstract

In conjunction with this study, a comprehensive literature search was performed, surveys sent to other state officials and New England tire dealers, and parking lot surveys completed during winter and summer months at five Vermont locations. Surveys sent to state officials reveal that in almost all cases the main reason for seasonal restrictions of studs has been a concern over pavement damage from excessive stud use. However, in no case (according to respondents) has a complete study or set of observations been made to quantify or qualify that the seasonal bans have had any true impact at all. It was determined during the parking lot surveys it that only 0.8% of vehicles used studded tires in the summer versus 10.3% during the winter. Given the fact that the 0.8% represents only around 6000 vehicles out of 745,000 registered in the state, summer time use does not appear to be a severe problem.

Vermont would not appear to be a candidate for a full-scale, year round studded tire ban, given our sometimes-dangerous winter driving conditions; the negative safety effects would most likely be considerable. Given the information presented in this study, proposing regulations that would ban the use of studs in the summertime is seen as a possible option, as it would not affect many citizens overall. This being the case, however, it must be considered as to whether or not it is worthwhile to put forth the effort to do so, as enacting this type of regulation most likely will not have a large effect on the roadways or provide much benefit to the population as a whole. A major drawback of enacting such a policy is the need to enforce the regulations going forward, which may lead to increased overall costs or logistical work. Overall, it does not appear that Vermont has an issue with studded tires being used during the summer months in the areas of the state surveyed, however it could be a more significant problem in the more mountainous regions, therefore the above small-scale policy changes could be considered.

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Abstract

Specific conditions under which studded tires have a large advantage over other types of winter tires is very limited: on smooth ice near the freezing point. Winter tires, especially studless winter tires, have equal, if not greater, traction when compared to studded tires during other conditions; some studies also suggest that studded tires may increase stopping distance during dry conditions. The advantages of studded tires on smooth ice near the freezing point are considerable, however, with numerous studies supporting their benefits.

In general, throughout most states, provinces, and foreign countries with studded tire issues, regulating bodies have decided to move towards seasonal bans of studded tires in most cases. Full studded tire bans, according to studies from Finland and Japan, create increased costs; infrastructure costs were decreased but the overall safety and road salting/sanding costs outweighed the pavement damage decrease, making this an unrealistic option. With the onset of seasonal bans, there has been limited noticeable (studied) decrease in the rate of pavement deterioration or safety aspects.

In conjunction with this study, a comprehensive literature search was performed, surveys sent to other state officials and New England tire dealers, and parking lot surveys completed during winter and summer months at five Vermont locations. Surveys sent to state officials reveal that in almost all cases the main reason for seasonal restrictions of studs has been a concern over pavement damage from excessive stud use. However, in no case (according to respondents) has a complete study or set of observations been made to quantify or qualify that the seasonal bans have had any true impact at all. Parking lot surveys reveal that only 0.8% of vehicles use studded tires in the summer versus 10.3% during the winter. Given the fact that the 0.8% represents only around 6000 vehicles out of 745,000 registered in the state, summer time use does not appear to be a severe problem.

Vermont would not appear to be a candidate for a full-scale, year round studded tire ban, given our sometimes-dangerous winter driving conditions; the negative safety effects would most likely be considerable. Given the information presented in this study, proposing regulations that would ban the use of studs in the summertime is seen as a viable option, as it would not affect many citizens overall. This being the case, however, it must be considered as to whether or not it is worthwhile to put forth the effort to do so, as enacting this type of regulation most likely will not have a large effect on the roadways or provide much benefit to the population as a whole. A major drawback of enacting such a policy is the need to enforce the regulations going forward, which may lead to increased overall costs or logistical work. Overall, it does not appear that Vermont has an issue with studded tires being used during the summer months in the areas of the state surveyed, however it could be a more significant problem in the more mountainous regions, therefore the above small-scale policy changes could be considered.

1. Introduction

The Vermont Agency of Transportation's (VTrans) mission is to provide for the movement of people and commerce in a safe, reliable, cost-effective, and environmentally responsible manner. One of the most crucial aspects in achieving this mission is to maintain an acceptable condition of one of the State's most valuable assets, our 3,200 miles of highway managed by the Pavement Management Unit of the Highway Safety and Design Section. The ability to efficiently rehabilitate and maintain this essential portion of Vermont infrastructure in a cost-effective manner is a daunting task as pavements are subjected to various traffic stream characteristics, ambient conditions, and other physical parameters including pavement design and underlying support. Anecdotal evidence suggests that studded tire use may contribute to accelerated pavement damage thereby increasing maintenance costs as well as other health concerns such as increased noise levels and dust resulting in reduced air quality. Advocates argue that studded tires reduce accident risk through an increase in traction under wintery conditions and that prohibiting studs produces a net increase in total costs.

Nationwide studded tire regulations vary greatly including prohibition, seasonal restriction, and unrestricted use. Currently, the State of Vermont allows unrestricted use of studded tires throughout the year including summer months when studded tires do not offer any safety advantages in comparison to other types of tires. However, placing restrictions on their use requires public policy and enforcement both of which increase the financial burden on taxpayers. Yet this cost might be offset by the reduction in pavement damage, and any fuel savings effected by eliminating studded tires. Banning the use of studded tires altogether would minimize damage associated from their use with the exception of those unaffected by the ban (out of state traffic) though the costs of accidents plus increased maintenance activities to improve surface traction may outweigh any financial gain.

The objective of this research initiative was to summarize the benefits and drawbacks to the use of studded tires, as well as the potential impacts of imposing a summertime ban. This was conducted in four parts: an in-depth literature search, a survey of similar states, a survey of the local tire industry, and small-scale parking lot surveys throughout the state to quantify studded tire use during summer and winter months.

1.1. Background

Vehicle traction forces are significantly reduced on snowy or icy surfaces, specifically during stopping, starting, cornering, and hill climbing. Reduced traction increases stopping distances and decreases controllability (*1*). Snow and ice have been shown to be the main factors affecting reduced pavement skid resistance resulting in an increase of wintertime accidents (*2*).

Studded tires were first introduced in the United States in the early 1960s. Since that time, the public has come to associate improved traction and driver safety in winter with the use of studded tires (*3*). However, numerous references have also indicated that the use of studded tires increases noise levels, generates dust resulting in reduced air quality, increases the rate of pavement wear for both asphalt and Portland cement concrete surfaces, and may reduce traction under certain wet and dry conditions.

One of the Agency's principal goals is safety and the reduction of vehicular accidents throughout the state. The use of studded tires reportedly produces increased traction during winter months with respect to the formation of snow and ice. Two studies were recently conducted by the Finnish National Road Administration (*4*) and the State of Alaska to compare the traction performance of studded and studless winter tires. Research conducted by the Finnish Road Administration (FinnRA) indicated that the friction produced with studded tires was better than that of studless winter tires in all of the examined conditions on the ice track. The greatest difference was observed in the lock-braking tests on ice, in which the friction of the studless tires was about a third lower than that of the studded tires. The State of Alaska specifically examined stopping distances and starting traction performance of lightweight studded tires, standard studded tires and so called 'studless' winter tires on snow and icy surfaces. All measurements indicated that lightweight and standard studded tires presented better traction performance (stopping and starting). In contradiction, a study performed by the Washington State Transportation Center found that studded tires might not offer any safety advantages in comparison to modern radial winter tires in non-icy road conditions. In fact, studs may decrease tire-road friction in these situations (*5*).

Undoubtedly, studded tires produce accelerated pavement wear in the form of rutting and pavement marking damage. The Washington State Department of Transportation and Washington State Transportation Center (*6*) explains that the dynamics of studded tire action include three phases; as the studded tire moves over the pavement, there are "spikes" in the force at the beginning and at the of the contact. During these spikes, energy is transferred to the pavement in the form of scratching. Between these spikes, the studs have a "punching" action that wears the pavement surface generating ruts. This type of rutting is also considered raveling as the studs cause progressive disintegration of the pavement layer from the surface downward as a result of the dislodgement of aggregate particles.

Typical asphaltic pavement rutting is caused by permanent deformation within any of the pavement's layers or subgrade and is usually caused by consolidation or lateral movement of the materials due to traffic loading, otherwise known as shoving. Studded tire rutting can be differentiated from standard rutting in two ways. First, material from studded tire rutting has raveled and therefore is no longer present. Conversely, material from typical rutting has simply been displaced or consolidated, thus creating a differing road profile. The second prominent difference between the two types of rutting is that studded tire ruts are usually caused by passenger vehicles, while load induced rutting is generally caused by larger vehicles carrying heavy loads. As such, wheel path ruts attributed to studded tires are typically narrowly spaced. In general, for normal ruts the distance between wheel paths is around 70 inches and for studded tire ruts, 60 inches (*7*). In either case, ruts filled with water may cause hydroplaning resulting in a loss of tire traction. Therefore, moderately raveled pavements generate a risk to the traveling public.

1.2 History of Studded Tires

Different forms of studs have been used on tires for well over 100 years. The first documented case of studs was in the form of metallic cleats used on tires in 1890 (*6*). Modern studs were first introduced in Scandinavia in the late 1950s and subsequently in the United States in the early 1960s. These studs were comprised of tungsten carbide cores, an inorganic chemical compound that exhibits similar wear characteristics to that of rubber tire tread. During the same period, their use spread throughout Europe, Japan, and other countries around the world with temperate and cold climates.

Throughout the following decades of the 1970s and 80s, studded tire use began to escalate as knowledge of the reported safety benefits spread. While the percentage of stud usage rose, so did concern over related social issues, which subsequently led to widespread research. As a result of these studies, many countries, states, and provinces began banning their use and implementing regulations during the 1990s, in an effort to limit disadvantages such as pavement wear, noise pollution, asphalt dust inhalation, and numerous other concerns. In conjunction with these policies the use of 'studless tires' grew in popularity, as their use does not cause several of the drawbacks of studded tires highlighted previously.

Studs used in the 1960s protruded approximately 0.087 inches from the tire and weighed about 0.081 ounces. To limit perceived negative side effects of studded tire usage, studs were modified. Studs called "Controlled Protrusion" have a decreased protrusion length between 0.039 and 0.059 inches, and weigh between 0.059 and 0.067 ounces, allowing the stud to descend back into the stud jacket as the rubber tire tread is worn down. All studs used in the US are now controlled protrusion studs (*6*). In the late 1980s, "studless" tires were introduced to the market, most notably Bridgestone Blizzaks widely distributed throughout Japan in 1988. These tires incorporate thousands of microscopic cells that, according to Bridgestone, resemble Swiss cheese. As the tire wears, the pores are exposed, thus creating thousands of biting edges that grip the road.

Also during the late 1980's and early 90's extensive research was performed by Scandinavian countries on new lightweight studs (*3*). These studs were developed using two types of modified jackets, a lighter metal and plastic jackets. Findings indicate that both reduced pavement wear significantly over standard studs, with the metal jackets proving to be superior in this aspect. These studs weigh roughly 0.03 ounces as compared to the 0.08 ounces of the standard studs. Even through the innovations, today, as in the 1950's, studs are still primarily comprised of tungsten carbide cores.

2. Safety

Studded tires are most effective at or near 32^{o}F through increased traction with the underlying roadway as compared to studless or all season tires. However, as the temperature increases or decreases, studded tires proportionally lose traction. As this is a limited roadway surface condition, the advantages of studded tire use are realized for only a small portion of the season. As the temperature decreases, the studs wear, or the ice roughens, the benefits of the studs are negated (*8*) In conjunction, Finnish studies reveal that studded tires have, in general, better traction on ice but they provide no benefit in snow, wet, or other deleterious conditions (*9,10*). This study differs slightly from a previous Finnish study (*4*), which concluded that a slight advantage, with regards to stopping distance and traction, was found in most conditions with the use of studded tires.

Braking distance is the single best indicator of tire performance. In stopping distance tests performed in Alaska, studded, studless (Blizzaks), and all season tires performed as near equals on snow; on smooth ice, however, stopping distances for studded tires were 15% shorter than for Blizzaks, and 28% shorter than those of all season tires. In a second series of tests, Blizzaks displayed the best performance, including braking on snow and ice, with studded tires second and all seasons third. It was also determined that vehicles with studded tires only on the front axle produced braking performance that was halfway between that of vehicles with only studded tires and only all season tires. Conversely, on bare pavement, studded tires generally have worse traction than non-studded tires, especially on concrete (*8*).

There are three prevailing thoughts on the effects of studded tires on driving behavior, which may or may not support establishing associated regulations. They are as follows: (1) drivers that utilize studded tires are more dedicated to safety, therefore they drive safer anyway; (2) drivers that utilize studded tires have a false sense of security from the studs, so they drive faster and more reckless; and (3) drivers that do not utilize studded tires generally drive less when weather conditions are suspect. None of these three thought processes can accurately be determined, and likely the thought process of the population is a combination of the three (as well as numerous others) (*8*). A previous study conducted in Finland found that drivers with studded tires drive faster in slippery conditions and slower in bare road conditions than drivers with studless winter tires (*11*).

Overall, the majority of studies do, in fact, reveal that the use of studded tires produce a net safety benefit during winter driving conditions.

3. Pavement Wear

As with many pavement studies there is an exorbitant number of variables associated with long-term performance including traffic characteristics, roadway geometry, environment, quality of construction, materials, and numerous other site-specific considerations. Studies have found that pavement rutting (associated with raveling) occurs more readily under cold and wet conditions, i.e. a cold, wet pavement is more susceptible to stud damage than a warm, dry pavement.
The pavement damage caused by studded tires, most particularly rutting, can cause hydroplaning from the collection of water in the ruts, a tremendous amount of road spray, and deterioration of pavement markings. Conversely, it has been reported that the roughening of pavement and ice from studded tire wear actually results in a benefit to all traffic, by causing a higher coefficient of friction on the driving surface (*8*).

Many studies to characterize the correlation between studded tire usage and pavement wear were performed in the 1960s and 70s. Findings determined that large amounts of pavement damage was due to the studs, however technology of both tires and pavement design have improved, therefore it is believed the amount of damage is far less today.

Finnish studies conducted during the 1960's found that the cumulative pavement damage for the decade from a car with four studded tires was approximately 11 kg, meaning that each vehicle with studded tires would remove 11 kg of pavement material from roadways during a ten year period. With improvement to the studs, the amount of pavement damage reduced significantly to approximately 2.5 kg in the 1990's. This represented an overall decrease of 77% over the course of 30 years (*12*). Nationally available statistics show that studs used during the 1960s were four to ten times more detrimental to the health of pavement. It was noted that although this is true, current traffic volumes are far greater, which may reduce the benefit from current studs as compared to 30 years ago (*2*).

A study conducted for the Oregon Department of Transportation (*7*) determined wear rates of Portland cement concrete (PCC) and hot mix asphalt. Their results revealed that the PCC wear rate is far less than that of asphalt; a rate of about 0.0093 inches per 100,000 studded tire passes as compared to a rate of 0.0386 for asphalt, or about 315% greater wear. Asphalt pavements experiencing average daily traffic (ADT) volumes of 35,000 and 20 percent studded-tire use should reach a predefined threshold rut of ¾ in. in 7 years. It is important to note that a traffic level of 15,000 ADT yields no reduction in the asphalt pavement life, defined as 14 years within this study, as it is expected to take 16 years to reach a ¾ in. rut at this traffic level. In contrast, Angerinos et al. (*6*) reported a 'rule of thumb' estimate of 0.1 inches of rutting per 1 million studded tire passes on asphalt, giving an expected range of between 0.01 and 0.0386 inches of rutting per 100,000 passes.

In Nordic countries, lightweight studs are generally utilized by most drivers. While it was concluded that use of these studs resulted in no measurable decrease in safety, they have reduced pavement wear by an estimated 50% since their inception. Japanese studies associated with banning studded tire use have shown that any monetary savings with reduced pavement repair is offset by the increased need for sanding and salting to keep the roads safe. As an aside, it is unclear how precisely studies from the Nordic countries and Japan can be directly related to driving conditions and philosophies in the U.S. and North America.

Many studies have been conducted by state agencies, provinces, and countries in an attempt to quantify maintenance costs associated with studded tire wear. The Finnish National Road Administration reportedly estimated annual maintenance costs due to studded tires at $22 million dollars (*4*). The Alaska Department of Transportation estimates highway damage from studded tire use in Alaska to be $5 million annually. The Oregon Department of Transportation estimated studded tire damage during 1994 was $37 million on the state highway system and $33 million on the city and county roads for a total of $70 million in damage statewide (*7*).

4. Socio-Economic Factors

4.1 Noise Levels

Noise from vehicles with studded tires has been shown to be greater than that of vehicles without studded tires. Results from a recent study conducted in Sapporo, Japan indicated that studded tires had a noise level 4.8 to 6.4 dB higher than studless tires (*13*).

4.2 Air Quality

References suggest that studded tires generate particulate matter thereby negatively impacting air quality. However, doctors have indicated that in most clinical cases, dust pollution generated by studded tires is filtered through the nasal cavity, and the relationship between dust pollution and negative health effects, such as respiratory diseases is difficult to establish (*13*). A recent study conducted by the University of Alaska found that there does not appear to be any human health benefit associated with banning studded tires as a reduction in roadway particulate levels would be offset by increased dust levels due to increases in the volume of winter traction sand. In addition to particulate matter in the air, the use of studded tires reduces fuel efficiency of vehicles (lowering their mile per gallon ratings), thus adding to the exhaust released into the air and using slightly more natural resources.

4.3 Overall Economic Impacts

Finland and Japan found that prohibiting studs produces a net increase in total costs. Overall pavement repair costs are greatly reduced, but costs of accidents plus the increased requirement of surface applications to improve surface traction results in an overall increased financial burden at the state level.

According to FinnRA, when searching for the socioeconomic optimum, the accident costs become the most important factor, and the accident costs strongly support retention of the baseline situation: the use of salt and studded tires should be continued at current levels despite their drawback (*4*). The Civil Engineering Research Institute of Hokkaido examined the effects of banning studded tires from an economic standpoint using a benefit incidence matrix (BIM). Positive effects of the studded tire regulation include reduced noise levels, improved environment, and cost savings in road surface maintenance. Adverse effects include increased travel time and costs because of more traffic congestion, increased nitrogen oxides, higher travel costs and the costs to keep the roads free of ice. Annual costs, in Japan, attributed to banning studded tires were found to be an increase of $137 million as compared to allowing their use, which includes all maintenance, safety, and user benefits and drawbacks. (*13*).

5. Studded Tire Regulations and Restrictions

Studded tire use is regulated by each individual state rather than the Federal government. The University of Alaska Anchorage, on behalf of the Alaska Legislature, (*13*) performed a study detailing several aspects of studded tires, including a comprehensive list of state studded tire restrictions. Table 1 displays the results of this effort, summarizing current policies as of 2005. It is important to note that some restrictions listed in the table have further exceptions; please refer to each individual state's departments of transportation for full regulations.

Table 1. State studded tire restrictions as of 2004 (only permitted between dates indicated).

State	Restrictions	State	Restrictions
Alabama	Prohibited	**Montana**	Oct 1 to May 31
Alaska	Sept 15 to May 1; South of 60º Sept 30 to April 15	**Nebraska**	Nov 1 to April 3
Arizona	Oct 1 to May 3	**Nevada**	Oct 1 and April 30
Arkansas	Nov to April	**New Hampshire**	No restrictions
California	Nov 1 to April 30; may be extended by DOT commissioner	**New Jersey**	Nov 15 to April 3
Colorado	No restrictions	**New Mexico**	No restrictions
Connecticut	Nov 15 to April 30	**New York**	Oct 16 to April 30
Delaware	Oct 15 to April 15	**North Carolina**	No restrictions
DC	Oct 15 to April 15	**North Dakota**	Oct 15 to April 15
Florida	Prohibited	**Ohio**	Nov 1 to April 15
Georgia	Only allowed when required for safety	**Oklahoma**	Nov 1 to April 3
Hawaii	Prohibited	**Oregon**	Nov 1 to April 3
Idaho	Oct 1 to April 30	**Pennsylvania**	Nov 1 to April 15
Illinois	Prohibited	**Rhode Island**	Nov 15 to April 3
Indiana	Oct 1 to May 3	**South Carolina**	No restrictions
Iowa	Nov 1 to April 3	**South Dakota**	Oct 1 to April 30
Kansas	Nov 1 to April 15	**Tennessee**	Oct 1 to April 15
Kentucky	No restrictions	**Texas**	Prohibited
Louisiana	Prohibited	**Utah**	Oct 15 to March 31
Maine	Oct 1 to April 30	**Vermont**	No restrictions
Maryland	Prohibited, except for 5 counties Nov 1 to March 31	**Virginia**	Oct 15 to April 15
Massachusetts	Nov 2 to April 30	**Washington**	Nov 2 to March 31
Michigan	Prohibited except for Upper Peninsula	**West Virginia**	Nov 1 to April 15
Minnesota	Prohibited except for nonresidents	**Wisconsin**	Prohibited
Mississippi	Prohibited	**Wyoming**	No restrictions
Missouri	Nov 2 to March 31		

As of the time of this compilation, seven states had banned the use of studded tires including northern states subjected to snow and ice during winter months such as Illinois, Michigan, Minnesota, and Wisconsin. Conversely, eight states allow virtually unrestricted use of studded tires on state roads and highways including Vermont and New Hampshire. As shown in Table 1, the remaining 36 states and the District of Columbia allow the use of studs with seasonal restrictions. The range of dates for allowable stud usage varies from between September 15th through November 15th and March 31st through May 31st.

Canada and other foreign countries have also enacted regulations to either prohibit or allow the use of studded tires. As of 1994, Germany and Japan had prohibited the use of studs, while Sweden and Finland both had implemented seasonal restrictions with use allowed during winter months (*6*). Each Canadian province determines their own laws with respect to studded tires, with many allowing wintertime use, Saskatchewan having no restriction, and Ontario prohibiting their use.

The information provided in the Table 1 above may no longer be accurate as studded tire regulations are a constant topic of legislation throughout all countries dealing with their use. Many of these regulations have changed since 1994 and in some cases possibly several times. The state/provincial survey conducted within this study suggests some of these entities, Ontario for example, have enacted different regulations.

6. Vermont's Studded Tire Usage

As part of this research effort, parking lot surveys were conducted to quantify studded tire use during summer and winter months in Vermont. The study population included five parking locations throughout the state. Selected lots, displayed in Table 2, were typically adjacent to larger shopping centers or other human service providers. Surveys were performed at each location once during the summer and winter to characterize seasonal use of various tire types including studded tires, snow tires, all seasons, and standard tires.

Table 2. Locations and Dates of Parking Lot Surveys

Survey Town	Location	Summer Date	Winter Date
Bennington	Monument Plaza	September 22	December 8
Berlin	Central Vermont Hospital	September 28	January 4
South Burlington	University Mall parking garage	August 26	December 14
Rutland	Diamond Run Mall	August 27	December 8
St. Albans	Highgate Commons Shopping Center	August 26	December 14

In an effort to determine an adequate sample size for these surveys, the following formula was used:

$$n = \frac{z^2 pq}{E^2}$$

Where:

n is the sample size,
z a number based on the confidence level,
p and q the variance of the population and,
E the maximum error of the estimation

A confidence level of 95% was selected for this analysis, along with the most conservative variance estimates of 0.5 for both p and q, and an acceptable error of 3%..

Using these values result in a required sample population of 1067. It was decided that 1000 vehicles surveyed (200 per site) would be a satisfactory number, as this resulted in an error of only 3.1%. This was determined to be more than adequate; therefore, the following data may have an intrinsic 3.1% error at a 95% confidence level. This calculation assumes a completely random distribution, which the population may not be given the fact that specific locations were chosen for the surveys. Even with this in mind, the analysis should be representative of the entire population of the Vermont Department of Motor Vehicles reported 744,454 registered vehicles in 2008.

A field form was used to maintain data collection consistency between field personnel. A single row was utilized for each vehicle inspected, and one selection was checked off under each category per vehicle. The purposes of the specific selections were to best describe the type of vehicle, drive train, and tire type. The five categories and their associated selections are listed below.

1. Vehicle Type: Car/Minivan, SUV, Pickup, Miscellaneous
2. Drive: 2 Wheel Drive, 4 Wheel Drive
3. Tire Type: Studded, Winter, All Season, Normal (other)
4. Location of Studs: Front, Rear, Both
5. Vehicle Registration and Notes: List the state of registration and any notes

Vehicle type determination was straight forward, with the miscellaneous category consisting of vehicles that would not fit into the first three categories, such as motorcycles, large trucks and vans, etc. The wheel drive system was recorded as what was clearly stated on the vehicle. All wheel drive vehicles were placed into the 4 wheel drive category.

Tire types were determined by close inspection of the wheels on the vehicle. All season tires are marked with an M+S, as seen in Figure 1, left. M+S stands for mud and snow and is now the standard industry denotation of all season tires. Winter tires have a ‘snow in mountain’ emblem printed on them, shown in Figure 1, right, with possibly also an M+S symbol. Finally, if a tire had studs, easily visible on the tread of a tire, it was marked as a studded tire and subsequently the vehicle was examined as to whether it had studs on only the front tires, only the rear, or both. For the purposes of this study a tire was considered to be in only one category, i.e. if a tire had studs as well as the other symbols it was considered only a studded tire.

Figure 1. M+S (mud and snow) symbol on all season tires (left) and snow and mountain symbol found on winter tires.

Subsequent results from the parking lot surveys are summarized in Tables 3 through 7 provided below. The sample population was binned by several fields to examine variability between the summer and winter surveys. Table 3 presents a comparison between the vehicle type for all five parking lot surveys and seasonality. There was little to no difference between these variables. Roughly 65% of the sample population was found to be passenger cars and minivans, while 25% was found to be SUV's, and the remaining 10% pickups or other miscellaneous vehicles.

Table 3. Vehicle Type Counts for Summer vs. Winter Months

Location	Summer				Winter			
	Car	SUV	Pickup	Misc	Car	SUV	Pickup	Misc
Bennington	132	47	19	2	116	55	29	0
Berlin	133	44	21	2	129	54	16	1
Rutland	126	58	13	3	122	65	13	0
S. Burlington	151	42	7	0	147	37	16	0
St. Albans	121	53	25	1	132	46	22	0
Total out of 1000	663	244	85	8	646	257	96	1

The distribution of the drive train by season is shown in Table 4. Once again, the distribution of 2-wheel and 4-wheel drive vehicles is fairly consistent at all sample locations and during the summer and winter seasons. Slightly more 4-wheel vehicles (6%) were documented during the winter. This increase, however, is not so large to suggest an imbalanced population.

Table 4. Drive Type Counts for Summer vs. Winter Months

Location	Summer		Winter	
	2 Wheel	4 Wheel	2 Wheel	4 Wheel
Bennington	136	64	111	89
Berlin	132	68	119	81
Rutland	125	75	118	82
S. Burlington	145	55	141	59
St. Albans	124	76	129	71
Total out of 1000	662	338	618	382

Table 5 displays the tire distribution of the sample population. Studded tire use of less than 1% (8 out of 1000) of the entire population was recorded during the summer season. Stud use rose to 10% during the winter months. Of the five locations, studded tire use during the winter was found to be most prevalent in Berlin with a 24% use rate. In addition to the increase in studded tires, there was also an increase in the number of winter tires, from 12% usage in the summer to 31% in the winter. A 12% usage rate during the summer months seems high, however since they are not studded it is speculated that people most likely feel no need to remove them, although it severely reduces their useful life. In all, when winter and studded tires are added together, it results to an overall user rate of 44% winter/studded tires during winter months.

Table 5. Tire Type Counts for Summer vs. Winter Months

Location	Summer				Winter			
	Studs	Winter	AS	Normal	Studs	Winter	AS	Normal
Bennington	1	9	167	23	9	47	132	12
Berlin	5	26	137	32	47	76	75	2
Rutland	0	34	140	26	13	58	119	12
S. Burlington	2	25	168	7	10	68	110	12
St. Albans	0	27	151	22	24	62	109	5
Total out of 1000	8	121	763	110	103	311	545	43

With a stud usage rate of less than 1% during the summer months, it is unlikely that this contributes heavily to pavement damage. It is important to consider that these surveys only took into account certain areas in the state, specifically areas that were heavily populated where it would be easy to locate 200 vehicles in a time efficient manner. It is safe to assume that if more mountainous areas were selected, the stud usage rate in both the winter and the summer may have been greater; however these are generally more rural locations with smaller populations and AADTs.

Some states, such as Maine, require studded tires to be on each axle of the vehicle when used. This is an important factor, as having tires of differing frictional characteristics could increase tire slippage in accelerating or decelerating conditions, thus creating increased yaw effects (*5*). The location of the studded tires, one or both axles, was also examined as displayed in Table 6. All vehicles using studded tires during the summer months used these tires on both axles. During the winter, 5 of the 103 vehicles with studded tires utilized the studs on only one axle (in all cases the rear), a fairly small percentage. From this data, it would seem that having studs on only one axle is of minimal concern overall in Vermont.

Table 6. Stud Location Counts for Summer vs. Winter Months

Location	Summer			Winter		
	Front	Rear	Both	Front	Rear	Both
Bennington	--	--	1	--	3	6
Berlin	--	--	5	--	1	46
Rutland	--	--	--	--	--	13
S. Burlington	--	--	2	--	--	10
St. Albans	--	--	--	--	1	23
Total out of 1000	--	--	8	--	5	98

The state or province of origin was recorded to ensure an adequate Vermont population and examine the tire preferences of out-of-state vehicles. Table 7 compares the number of out-of-state vehicles documented during the summer and winter surveys. The out-of-state population was fairly consistent between the seasons, decreasing from 10% in the summertime to 8% in the wintertime. As would be expected, mid-state locations (Berlin) had very few out-of-state vehicles, while a border city (Bennington) had nearly 25% out-of-state vehicles during each survey. When cross-referenced with studded tire usage, there were no documented cases of studded tire usage on any of the out-of-state vehicles during the summertime survey. However, 4 out of 80 out-of-state vehicles surveyed during the winter months were equipped with studded tires representing 5% of this population and only 0.4% of the entire population.

Table 7. Out-of-State Vehicle Registration Counts for Summer vs. Winter Months

Location	Summer	Winter
	Out-of-State	Out-of-State
Bennington	49	49
Berlin	3	1
Rutland	13	12
S. Burlington	18	7
St. Albans	17	11
Total out of 1000	100	80

7. Modeling of a Vermont Roadway

In an effort to determine the actual effects of studded tire usage in Vermont, a modeling exercise was performed on a section of roadway that has displayed excessive rutting. This section is located along I-89 NB between mile markers 53.0 and 62.6 in Montpelier and Middlesex. There is a perception that studded tires may have contributed to some portion of the excessive rutting.

Traffic stream characteristics and pavement distress data was obtained from the VTrans Traffic Research the Asset Management Units. The 2008 AADT for the northbound barrel of the interstate between these mile markers was 12,500 vehicles per day, with an estimated 71% of these in the travel lane and 29% in the passing. An estimate of the number of vehicles with studded tires traveling on the road was calculated using the data obtained in the parking lot surveys. Assuming 10.3% of vehicles have studs during six wintertime months and 0.8% of vehicles have studs during six summertime months, approximately 180,600 studded vehicles traverse over the travel lane annually and 73,800 on the passing lane. For comparative purposes, minimum and maximum rutting rates due to studded tire wear were calculated utilizing estimates discussed in Section 3 (0.1 inches per 1 million studded vehicle passes for the minimum (*6*) and 0.0386 inches per 100,000 studded vehicle passes for the maximum (*3*)). Graphical representations of the estimated and actual rutting rates for the driving and passing lanes are provided in Figures 2 and 3. Rutting values were measured in 2005, 2007, 2009, and 2010; year one, three, five and six of the pavements life.

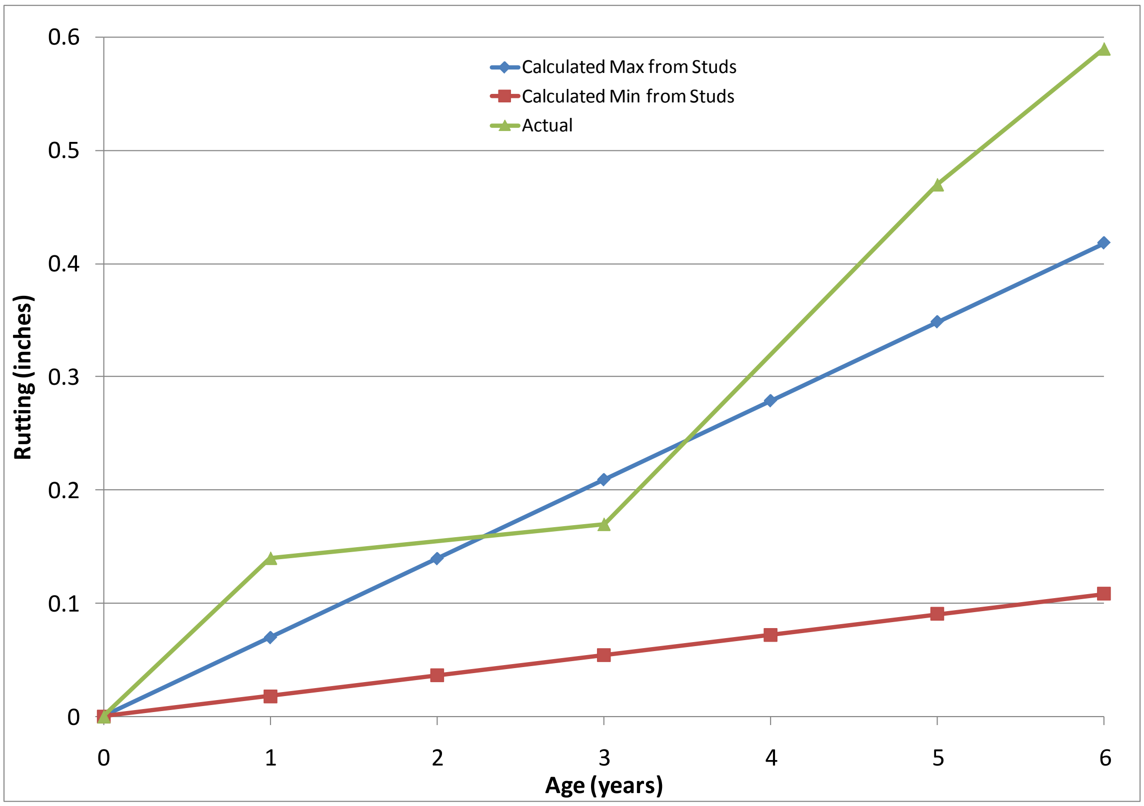

Figure 2. Actual and estimated rutting of I-89 northbound between mile marker 53.0 and 62.6, travel lane.

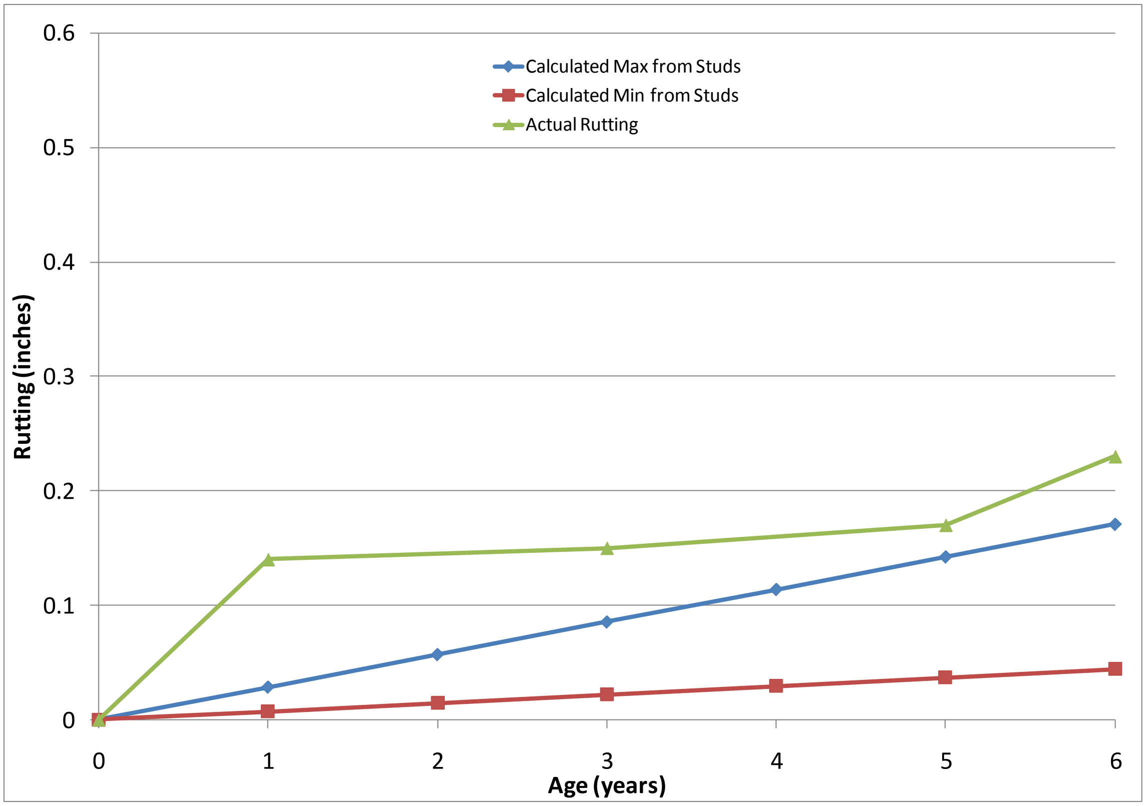

Figure 3. Actual and estimated rutting of I-89 northbound between mile marker 53.0 and 62.6, passing lane.

The figures show that, for almost every year rut readings were measured, actual rutting exceeded that of the broad estimates provided by other publications, for both the travel and passing lanes. Assuming the estimates are adequate for our roadways, this would imply that the excessive rutting at this location is caused by factors beyond that of studded tire damage.

8. Questionnaires and Surveys

8.1. Survey of States and Provinces

A survey was distributed to other surrounding New England and northern states seeking correspondence related to studded tire induced pavement distress and rationale behind restrictions or prohibition. When applicable, respondents were asked to describe the effects of instituting regulations on the use of studded tires. A copy of the survey is provided in the Appendix.

Surveys were sent out to both Departments of Motor Vehicles and Transportation Safety personnel through two group mailings. Glen Button, the Motor Vehicle Enforcement and Safety Directory of the Vermont DMV, forwarded the DMV survey to Fred Porter, Regional Director for Member Support for the American Association of Motor Vehicle Administrators (AAMVA) Regions I and II, who sent it out to other members of the organization. The second mailing was issued to transportation safety representatives via Bruce Nyquist, VTrans' Traffic and Safety Engineer, to a list of North East Traffic Engineers, as well as through the AASHTO Traffic Engineers mailing list.

In total, fifteen surveys were completed, eight from states (seven different states), and seven from Canadian provinces. All responses from these surveys are presented in Table A1 in the Appendix. Answers to questions 7 and 8 have been omitted from the table as they pertained to contact information. As with any survey, an intrinsic fault with this information is that it may not be accurate, but rather is the respondent's best answer based upon their knowledge and experience. Several areas of state/provincial transportation were represented amongst respondents, from engineers, to DMV officials, to state police, administrators, and many others.

Almost all respondents with studded tire restrictions noted that they were enacted to eliminate pavement damage resulting from their use. However, there were no documented cases of decreased pavement damage (qualitative or quantitative) or increases in service life since implementing the restrictions. Additionally, the respondents are unaware of any applicable studies. Overall, there is a very wide range of years in which regulation enactments began, as well as numerous amendments to those regulations in many states and provinces. This shows that the questions, problems, and policies behind the use of studs are ever evolving and the issues behind safety versus infrastructure damage versus all other aspects are extremely complex.

Fines and enforcement associated with the various laws are also variable. Every state or province that has placed restrictions on the use of studded tires also issues traffic violations and fines for their illegal use. Although all issue these fines, the extent of fines is varied, from a low nominal amount of $25 up to $300, with some provinces, and likely states, also issuing points on drivers licenses for the violations. New York's laws also state that imprisonment could be awarded, for not more than 30 days, however the survey respondent thought it to be highly unlikely that this had been given or would be based solely on studded tire usage. Even with this information it is difficult to determine how much, if any, of a deterrent these fines are and how much they are actually enforced. Amongst respondents that differentiated between primary and secondary offenses indicated that illegal studded tire usage was a primary offense, meaning that a police officer could stop a motorist simply for driving a vehicle with studded tires.

8.2. Survey of New England Tire Industry

A second survey pertaining to historical studded tire sales, current use, and number of vehicles that leave studs on throughout the year, was distributed through the New England Tire and Service Association list of directors, which was found at www.driveusa.net/netsa. This list is comprised twenty-nine tire sales people throughout New England, four of which were located within Vermont. Unfortunately, only five directors responded to the survey. Two other associations were also contacted in an effort to receive a wider range of responses from the industry, with no success. Of the responses, two of the individuals were from within Vermont, two from Massachusetts, and one from Maine. A copy of this survey is also provided in the Appendix.

Studded tire usage rate appears to be quite variable among Massachusetts, Vermont, and Maine. It must also be noted that responses are also only for a particular region of each state, the location of the knowledge base of each respondent. Respondents reported a studded tire use rate of approximately 10 to 40% within Vermont and Maine and less than 5% in Massachusetts. All indicated yearlong studded tire use is little to none. These numbers substantiate those found in the parking lot surveys, which found 10.3% of vehicles using studs in the winter and less than 1% during the summer. The peak season for installing and taking off studded tires was around late October and April, respectively.

Answers to remaining questions were surprisingly more inconsistent. Historically trends in studded tire sales over the past 10 years indicate a decline in usage in Maine and Massachusetts. One VT respondent reported no change while the second believes there has been an increase in usage. When asked about what types of studs are being used, standard or lightweight, three replies reported lightweight while the other two indicated standard studs. Finally, results from the survey suggest that roughly 15 to 20% of vehicles are now using alternative tires such as Blizzaks. One response was significantly higher than the others, at 80%, which likely was not the response that was intended.

9. Summary and Recommendations

Studded tires, in their current form, were introduced in Scandinavia in the late 1950s, and subsequently introduced to the US market in the early 1960s. Since that time, they have gone through many advances in technology to provide for both better safety and reduced pavement wear. The current trend is the use of lightweight studs, which are less than half the weight of standard weight studs.

According to publications, the specific conditions under which studded tires have a large advantage over other types of winter tires is on smooth ice near the freezing point. Other than this specific condition, winter tires, especially studless winter tires, have equal, if not greater, traction when compared to studded tires; some studies also suggest that studded tires may increase stopping distance during dry conditions. The advantages of studded tires on smooth ice near the freezing point are considerable, however, with numerous studies supporting their benefits. With each increment in better winter tire technology, the industry is capable of cutting into the studded tire market. In the near future, it is quite possible that the studs themselves will be nearly obsolete, and hopefully their replacements will be much friendlier to pavements.

Currently eight states allow unrestricted use of studs (Vermont included), seven prohibit their use, and thirty-six allow their use but with some seasonal restrictions. Along with this, studies from Finland and Japan concluded that the complete prohibition of studs creates increased costs; infrastructure costs were decreased but the overall safety and road salting/sanding costs outweighed the pavement damage decrease, making this an unrealistic option.

In general, throughout most states, provinces, and foreign countries with studded tire issues, regulating bodies have decided to move towards seasonal bans of studded tires in most cases. The dates of regulated use vary from region to region depending on climates or specific situations, but range from being allowed from the earliest possible snowfall to the last usual snowfall. In most cases there has been no noticeable (studied) decrease in the rate of pavement deterioration or safety aspects since the enactment of seasonal or stud composition restrictions. As compiled through the surveys sent out to other state officials, in almost all cases the main reason for seasonal restrictions of studs has been a concern over pavement damage from excessive stud use. However, in no case (according to respondents) has a complete study or set of observations been made to quantify or qualify that the seasonal bans have had any true impact at all.

The use of lightweight studs has become more prevalent in recent years, with many states requiring only their use over traditional standard weight studs. Some studies have indicated that the use of lightweight studs over standard could reduce pavement wear anywhere between one-third and one-half, with little, if any, safety drawbacks. It is unclear, unfortunately, as to what percentage of vehicles in Vermont already utilizes lightweight studs.

From the data obtained during the Vermont parking lot surveys it was revealed that only 0.8% of vehicles surveyed had studded tires on in the summer versus 10.3% during the winter. Given the fact that the 0.8% represents only around 6000 vehicles out of 745,000 registered in the state, summer time use does not appear to be a severe problem. In addition, pedestrians encountered during the surveys believed that a summertime restriction was already enacted.

Vermont would not appear to be a candidate for a full-scale, year round studded tire ban, given our sometimes-dangerous winter driving conditions; the negative safety effects would most likely be considerable. Given the information presented in this study, proposing regulations that would ban the use of studs in the summertime is seen as a viable option, as it would not affect many citizens overall. This being the case, however, it must be considered as to whether or not it is worthwhile to put forth the effort to do so, as enacting this type of regulation most likely will not have a large effect on the roadways or provide much benefit to the population as a whole. A major drawback of enacting such a policy is the need to enforce the regulations going forward, which may lead to increased overall costs or logistical work. Also of note is the possibility that the majority of motorists that use studded tires all year long may also be unable to afford a second set of tires and/or the fees for twice-a-year service to change the tires. Enacting such a policy may place a financial burden on these citizens.

In addition to a seasonal ban, Vermont could also consider moving towards allowing only the use of lightweight studs. Many states have already taken this step, as research has shown that lightweight studs can reduce pavement damage a considerable amount while wearing as well as, if not better than standard studs; drawbacks for this policy would be identical to those of seasonal bans.

An alternative to a ban is improved driver awareness on the issues. Education can increase the public's knowledge on the subject of pavement damage due to year round studded tire use, as well as the facts that studded tires lower fuel mileage in vehicles, thereby also increasing emissions, and promote noise pollution. None of these outcomes is in the driver's direct interests. Supplying the public with further information on the topic may lead to a reduction in undesirable studded tire usage.

Overall, it does not appear that Vermont has an issue with studded tires being used during the summer months in the areas of the state surveyed, however it could be a more significant problem in the more mountainous regions, therefore the above small-scale policy changes could be considered.

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Appendix

Studded Tire Parking Lot Survey

Date & Time:______________________________ Surveyed by:_______________________________
City/Town:________________________________ Location:___________________________________

Vehicle Type **C** = Car, Minivan **S** = SUV **T** = Pickup **M** = Misc.				**Drive** **2** = 2 wheel **4** = 4 wheel		**Tire Type** **S** = Studded **W** = Winter **A** = All Season **N** = Normal				**Location of Studs** **F** = Front **R** = Rear **B** = Both			**Vehicle Registration & Notes**
C	**S**	**T**	**M**	**2**	**4**	**S**	**W**	**A**	**N**	**F**	**R**	**B**	
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Studded Tire Survey of States

Studded Tire Survey of States

Page 1 - Question 1 - Open Ended - Comments Box

What are the current regulations regarding snow tire usage in your state?

Page 1 - Question 2 - Open Ended - One Line

When were these regulations enacted?

Page 1 - Question 3 - Open Ended - Comments Box

What factors were involved in deciding upon these regulations?

Page 1 - Question 4 - Open Ended - Comments Box

Has there been any noticeable change in any safety aspects since the regulations went into effect?

Page 1 - Question 5 - Open Ended - Comments Box

Has there been any noticeable change in any pavement wear since the regulations went into effect?

Page 1 - Question 6 - Open Ended - Comments Box

What penalties are there for studded tire usage violations?

Page 1 - Question 7 - Open Ended - Comments Box

Are these penalties enforced, and if so, how?

Page 1 - Question 8 - Open Ended - One Line

Name

Page 1 - Question 9 - Open Ended - One Line

Title

Page 1 - Question 10 - Open Ended - One Line

State

Page 1 - Question 11 - Open Ended - One Line

Email Address

Studded Tire Survey of Industry

Studded Tire Survey of Industry

Page 1 - Question 1 - Open Ended - One Line

What percentage of passenger vehicles do you believe use studded tires during the winter?

Page 1 - Question 2 - Open Ended - One Line

What percentage of passenger vehicles do you believe have studded tires on all year long?

Page 1 - Question 3 - Open Ended - One Line

What is the busiest time period for putting studded tires on?

Page 1 - Question 4 - Open Ended - One Line

What is the busiest time period for taking studded tires off?

Page 1 - Question 5 - Open Ended - Comments Box

What are the trends in studded tire usage since, say, 10 years ago; are there more or less sales of studded tires in Vermont and/or the northeast?

Page 1 - Question 6 - Open Ended - One Line

What types of studs are being used most, standard or lightweight?

Page 1 - Question 7 - Open Ended - One Line

What percentage of vehicles have now gone to using alternative tires, such as Blizzaks?

Page 1 - Question 8 - Open Ended - Comments Box

Additional comments or information

Page 1 - Question 9 - Open Ended - One Line

Name

Page 1 - Question 10 - Open Ended - One Line

Company

Page 1 - Question 11 - Open Ended - One Line

City, State

Table A1. Summary of responses to State and Provincial studded tire survey.

	Question Number						
10	**1**	**2**	**3**	**4**	**5**	**6**	**9**
Idaho	Oct 1 to April 30, Lightweight only	2002/03	Damage to pavement	No	No	$52	Assistant Chief Engineer (Operations)
Indiana	None						Director of Registrations
Kentucky	None						Deputy State Highway Engineer for Project Delivery
Maryland	Some counties Nov 1 to March 31, prohibited in others	1957, amended 2003	Damage to pavement	No	No	$130, no points	Administrative Officer, State Police
Maryland	Some counties Nov 1 to March 31, prohibited in others	1977, with amendments	Highway safety and pavement damage	No	Noticeable decrease, but unmeasured	None	Deputy Administrator
Michigan	Prohibited except for Upper Peninsula Oct 1 to May1	1977	Damage to pavement			Set by Michigan courts	Senior Analyst
New Jersey	Nov 15 to April 1	1964	Highway safety and maintenance	Unknown	Unknown	Between $25 and $50	Director, Legal and Regulatory Affairs
New York	Oct 15 to May 1	1970	Damage to pavement	No	No	Fine not exceeding $150 and/or no more than 30 days imprisonment	Assistant Counsel
New Brunswick	Oct 15 to May 1	1955	Unknown	No study	No study	$172.50, with a 2 point loss	Licensing Officer
Northwest Territories	None	1992				$40	Senior Policy and Programs Analyst
Nova Scotia	None (Response not accurate)					$50 1st offense, $100 2nd, $200 after	Registrar of Motor Vehicles
Ontario	Oct 1 to April 30	2005	Government pre-election promise	Too early	No	$110 for passenger, $240 for commercial	Senior Research Engineer
Prince Edward Island	Oct 1 to May 31					$70	Safety Coordinator
Quebec	Oct 15 to May 1; must be on rear or both axles; vehicle must not exceed 3,000 kg	2008	Literature studies and pavement wear	No	No	$300 for heavy vehicles	Engineer
Saskatchewan	None						Manager

Table A2. Summary of responses to Industry studded tire survey.

Question Number							
1	**2**	**3**	**4**	**5**	**6**	**7**	**11**
10%	Very few	Oct-Dec	April-May	About the same	Standard	People who use studs still use studs	Vermont
40%	2%	Oct-Nov	April-May	More use studs now	Lightweight	5%	Vermont
1%	Less than 0.2%	Mid Oct	Mid April	Declining usage is the trend	Lightweight	80%	Massachusetts
<5%	Next to none	Near 1st significant snowfall	Late April	Less	Lightweight	20%	Massachusetts
30%	0	Oct-Jan	April	Less, due to more 4x4 and front wheel drives	Standard	30%	Maine