

SWT-2016-10

JULY 2016

TEN SURPRISING FINDINGS ABOUT WINTER TIRES: IT IS NOT JUST ABOUT SNOW

JOHN WOODROOFFE



**SUSTAINABLE WORLDWIDE
TRANSPORTATION**

UNIVERSITY OF MICHIGAN

TEN SURPRISING FINDINGS ABOUT WINTER TIRES:
IT IS NOT JUST ABOUT SNOW

John Woodrooffe

The University of Michigan
Sustainable Worldwide Transportation
Ann Arbor, Michigan 48109-2150
U.S.A.

Report No. SWT-2016-10
July 2016

Technical Report Documentation Page

1. Report No. SWT-2016-10		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Ten Surprising Findings About Winter Tires: It Is Not Just About Snow				5. Report Date July 2016	
				6. Performing Organization Code 383818	
7. Author(s) John Woodrooffe				8. Performing Organization Report No. SWT-2016-10	
9. Performing Organization Name and Address The University of Michigan Sustainable Worldwide Transportation 2901 Baxter Road Ann Arbor, Michigan 48109-2150 U.S.A.				10. Work Unit no. (TRAIS)	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address The University of Michigan Sustainable Worldwide Transportation				13. Type of Report and Period Covered	
				14. Sponsoring Agency Code	
15. Supplementary Notes Information about Sustainable Worldwide Transportation is available at http://www.umich.edu/~umtriswt .					
16. Abstract <p>This report explores the safety performance of winter tires in the context of vehicle braking, cornering and loss of control. It examines tire certification, the influence of winter tires on crash frequency, and how they perform on four-wheel drive vehicles compared with two-wheel drive vehicles. The report considers winter-tire requirements for connected and automated vehicles and documents legislative and incentive programs implemented within North America (Canada) to encourage the use of winter tires. The report concludes with a list of ten main findings regarding winter-tire performance.</p>					
17. Key Words Tires, winter tires, snow tires, ice tires, traction, passenger vehicle, connected vehicle, automated vehicle.				18. Distribution Statement Unlimited	
19. Security Classification (of this report) None	20. Security Classification (of this page) None	21. No. of Pages 16	22. Price		

Contents

Introduction.....	1
Traction and Braking	2
Winter-Tire Certification	3
Crash Studies	5
Four-Wheel Drive Vehicles	6
Crash-Avoidance Technologies	7
Winter Tires on All Four Wheels.....	9
Connected and Self-Driving Vehicles	9
Legislation and Incentives in North America	10
Conclusions.....	11
References.....	12

Introduction

It may not be obvious, but selecting tires for your car has a distinct similarity to choosing shoes for your feet. When we leave the comfort of home and venture outdoors, it is important to consider appropriate footwear for the season. We have summer shoes that are cool, light and expressive; we have fall shoes that are sturdy and can handle water and slippery surfaces; and we have winter boots that are warm and provide excellent traction in ice and snow. We make our footwear choices based on experience, comfort and, most importantly, feedback from our feet to minimize the chance of falling. There is an old saying in the alpine world: “trust your boots.” For this to be true, however, our boots must be trustworthy and have the grip necessary for a given season. The same logic applies to tire choice.

In the automotive world, “trusting your boots” is an expression reserved for motor sport because race cars operate at the limit of tire adhesion. In warm weather, the general public rarely experiences the limits of tire adhesion, and when they do, it often ends badly. However, during winter, slippery road conditions are common, and this is when tire selection is most crucial. By selecting the correct tire for conditions, we effectively increase tire adhesion limits in slippery conditions, meaning that the vehicle is less likely to lose braking power or directional control, and we are more likely to arrive at our destination safely.

Traction and Braking

There is a general perception that the main benefit of equipping vehicles with winter tires is to achieve better startup and acceleration performance and to prevent getting stuck in snow. While winter tires certainly do this, their actual primary safety benefit is through improved adhesion, braking and cornering performance, which improves overall vehicle control (TRAC, 2015). On warm, dry pavement, most drivers never approach the tire adhesion limit in braking or cornering. But when roads are slippery, particularly due to ice and snow, the limit of tire adhesion is often experienced within the normal vehicle operating range. This sharply increases the likelihood of loss of control and compromises the ability of the driver to execute evasive maneuvers and emergency braking. With winter tires, a vehicle's stopping distance and cornering performance are greatly improved, making the vehicle much safer.

Finding #1: The main benefit of winter tires is improved tire adhesion, braking and cornering performance—not acceleration performance.

Another common misperception is that winter tires are only useful in snow. Winter tires are also specifically designed to provide improved traction on ice, and somewhat surprisingly, cold roads. The rubber compound used in winter tires is specially formulated to remain pliable in cold conditions, which improves grip. These tires have a low glass-transition temperature with specific tread-block size and thin slits called 'siping' to improve traction. Summer and all-season tires have higher glass transition temperatures so they can withstand the high road-surface temperatures experienced during summer. Winter tires should not be used during warmer seasons, as their performance diminishes and they will experience excessive tread wear.

Tires are very complex systems full of compromises that result in a wide range of competing performance characteristics. Several hundred ingredients are used to produce quality tires, and the manufacturing and curing processes are highly complex and controlled to produce desired characteristics. Tires made for warm weather conditions do not perform as well in cold weather, and vice versa. In general, a tire optimized for a specific application will almost certainly be suboptimal in a different application. Winter tires are optimized to operate when road surface temperatures are at or below 7 °C (45 °F), and in general they outperform other tires below this temperature even when ice

and snow are not present (TRAC, 2015). Even on dry pavement at temperatures just below freezing, stopping distances for vehicles with winter tires are as much as 30% shorter than for vehicles with all-season tires. Winter tires deliver better traction on an ice- or snow-covered road surface at -30 °C (-22 °F) than all-season tires at 4 °C (39 °F) (TRAC, 2015).

Finding #2: Winter tires provide improved traction on roads that are below 7 °C (45 °F) even when snow and ice are not present.

Comparing tire traction performance by tire type is difficult because the friction coefficient of ice and snow is highly temperature dependent, particularly when near freezing. Based on limited data from a literature review of winter tires conducted by the Traffic Injury Research Foundation (Brown, 2012), it is estimated that the relative stopping-distance performance of winter tires on packed snow is approximately 35% shorter than for all-season tires and about 50% shorter than for summer tires. Substantial improvements in high-speed vehicle cornering performance with winter tires were also reported (Brown, 2012).

Finding #3: Stopping-distance performance of winter tires on packed snow is typically about 35% shorter than all-season tires and 50% shorter than summer tires.

Finding #4: Winter-tire improvements in stopping distance also extend to improvements in cornering capability.

Winter-Tire Certification

In the US and Canada, winter tires are certified using a specific test protocol—ASTM F1805—referenced to a Standard Test Tire having known tractive properties (ASTM, 2016). A similar standard is used in Europe—ECE R117— (ECE, 2011). Tires that conform to these performance standards display on the tire sidewall the so-called ‘Alpine’ symbol, or the three-peak-mountain with snowflake referred to as ‘3PMSF’ shown in Figure 1.



Figure 1. ‘Alpine’ symbol, or the three-peak-mountain with snowflake (3PMSF), on the tire sidewall indicates conformance with winter traction performance standards

This international symbol came into force in November 2012 under EU Regulation 661/2009 on the Safety of Motor Vehicles (EU, 2009). The 3PMSF can only be used if a tire passes a minimum required performance on snow—the so called ‘snow grip index.’

“Mud and Snow” (either marked as M+S, M.S. or M&S) has been used to indicate winter tires for many years. Although M+S has a legal definition tied to a tire manufacturer's declaration (ETRMA, 2016), it is not related to minimum performance requirements but has been widely used by tire manufacturers to indicate winter products. M+S remains a permitted marking, but while M+S tires have better snow traction than regular tires, they do not necessarily pass the legal snow-grip threshold (Goodyear, 2016).

An example of this performance difference was found in tests conducted by Transport Canada (Mahler, 2008), where all-terrain tires (M+S) with and without the 3PMSF symbol were tested. The (M+S) tires without the symbol in this study had 40% longer stopping distance than the (M+S) tires with the symbol. Both tires had aggressive tread patterns, which would suggest good performance on ice and snow. This particular case underscores the importance of the 3PMSF certification as a means to identify certified winter performance. Furthermore, Transport Canada states that wide, high-performance tires, other than those that are specifically designed as winter tires (3PMSF), are not suitable for use on snow-covered roads (Transport Canada, 2015).

As recommended by Tire and Rubber Association of Canada, winter tires should not be used during the non-winter seasons (TRAC, 2015).

Finding #5: Tires designated as mud and snow tires do not necessarily perform well on packed snow and ice. Such tires without the 3PMSF symbol were found to require 40% longer stopping distance than similar tires with the symbol.

Finding #6: Tires with aggressive treads will not necessarily perform well in slippery winter conditions unless they have the 3PMSF symbol.

Crash Studies

There have been few safety studies examining crash frequency related to winter tire use. A Canadian study conducted by the Province of Québec (Austen, 2011; Transports Québec, 2011) attributed a 5% reduction in serious crashes to the implementation of mandatory winter-tire legislation. While this improvement in safety performance may seem modest, prior to the law being enacted in 2008, it was reported that approximately 90% of Québec motorists already used winter tires compared to approximately 51% in the rest of Canada (TRAC, 2015). In light of the preexisting use of winter tires, the 5 percent reduction in serious crashes attributed to the new legislation is noteworthy.

Seasonal variation of crash frequency is not clearly present in the crash data, likely because many drivers reduce their speeds in winter. Consequently, many winter crashes are of lower severity and are not contained in census crash data that are based exclusively on fatal crashes. This point is illustrated by insurance company statistics such as those provided by Aviva Canada (Aviva Canada, 2011). Based on five years of data, Aviva reported that a 49% increase in customer auto claims occurs between December and February in comparison to the rest of the year. These data indicate that winter months produce a surge in crash-related insurance claims. Therefore, it can be concluded that the winter months between December and February represent a higher crash-risk period. It is reasonable to assume that much of this elevated risk is attributable to slippery road conditions in winter.

Finding #7: In Canada, during the winter period from December to February, there is a reported 49% increase in insurance claims. Much of this elevated risk is

attributable to slippery road conditions in winter. Winter tires reduce crash frequency during winter months.

Four-Wheel Drive Vehicles

There has been a steady increase in the production of four-wheel drive vehicles as a percentage of the vehicle population. Figure 2 shows that the market share of four-wheel drive vehicles in 2015 was about 30 percent and that the trend toward four-wheel drive vehicles is increasing at the expense of two-wheel drive vehicles.

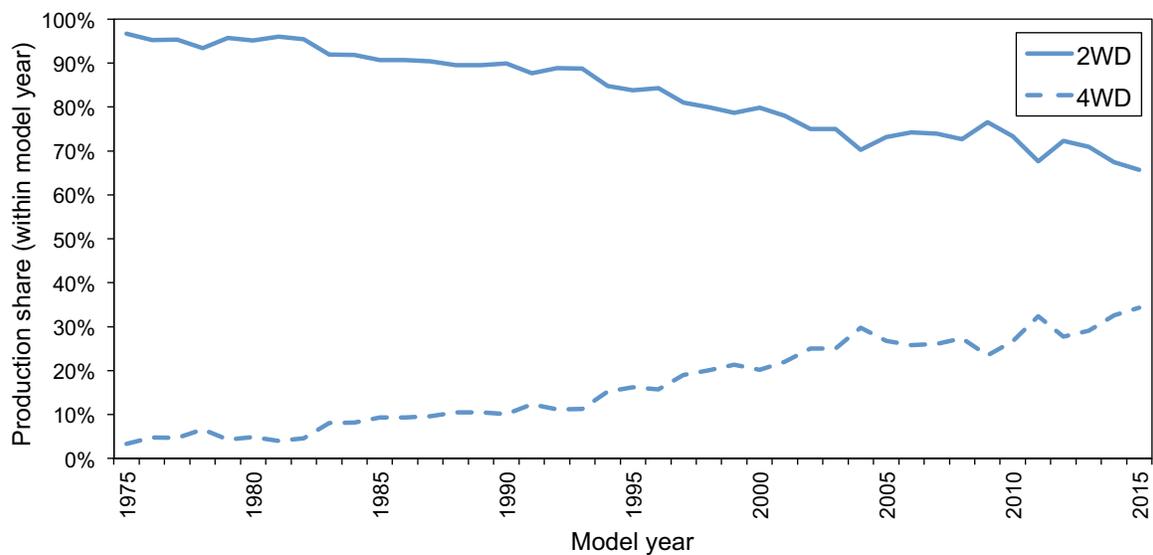


Figure 2. Trend of production share of four- and two-wheel drive vehicles (EPA, 2015).

Many believe that winter tires are not required in four-wheel drive vehicles, as they can power through snow, and are less likely to become immobile than two-wheel drive vehicles. Arguably, this perception may instill a sense of false confidence concerning road friction (slipperiness), because four-wheel drive vehicles are able to accelerate more quickly than two-wheel drive vehicles for a given low road-friction condition. However four-wheel drive vehicles and two-wheel drive vehicles fitted with the same tires perform similarly during braking and cornering on slippery roads because under braking the number of driven wheels becomes irrelevant. More to the point, in terms of crash avoidance, a two-wheel drive vehicle fitted with winter tires will

significantly outperform a four-wheel drive vehicle with all-season tires (experiencing approximately 35% shorter braking distance due to the performance difference between winter and all-season tires, as discussed previously). The performance advantage also holds true on curves by a similar amount under most conditions. This could explain why a disproportionate number of 4X4s and SUVs are in the ditch during early-season storms (Nokian Tyres, 2011).

There is a strong argument that as a vehicle class, four-wheel drive vehicles are at greater risk in slippery conditions because of drivers' inaccurate perception of braking and cornering capabilities based on improved acceleration performance compared with two-wheel drive vehicles. The perception that four-wheel drive vehicles do not require winter tires in cold climates for braking and cornering is false.

Finding #8: A two-wheel drive vehicle with winter tires will outperform a four-wheel drive vehicle with all-season tires in braking and cornering. The perception that four-wheel drive vehicles do not require winter tires in cold climates is false.

Crash-Avoidance Technologies

Every new automobile sold in the US and Canada today is fitted with some crash-avoidance technologies that intervene when loss of control is imminent. Federal Motor Vehicle Safety Standard (FMVSS) No. 126 requires electronic stability control (ESC) systems on passenger cars, multipurpose passenger vehicles, light-duty trucks, and buses. ESC systems use automatic computer-controlled braking of individual wheels to assist the driver in maintaining control in critical driving situations (NHTSA, 2011a). NHTSA estimated ESC will reduce single-vehicle crashes of passenger cars by 34% and single-vehicle crashes of sport utility vehicles (SUVs) by 59%, with even a much greater reduction of rollover crashes. NHTSA estimated ESC will save 5,300 to 9,600 lives and prevent 156,000 to 238,000 injuries in all types of crashes annually once all light vehicles on the road are equipped with ESC (NHTSA, 2011b). Figure 3 illustrates how ESC alters vehicle directional stability in understeer and oversteer situations.

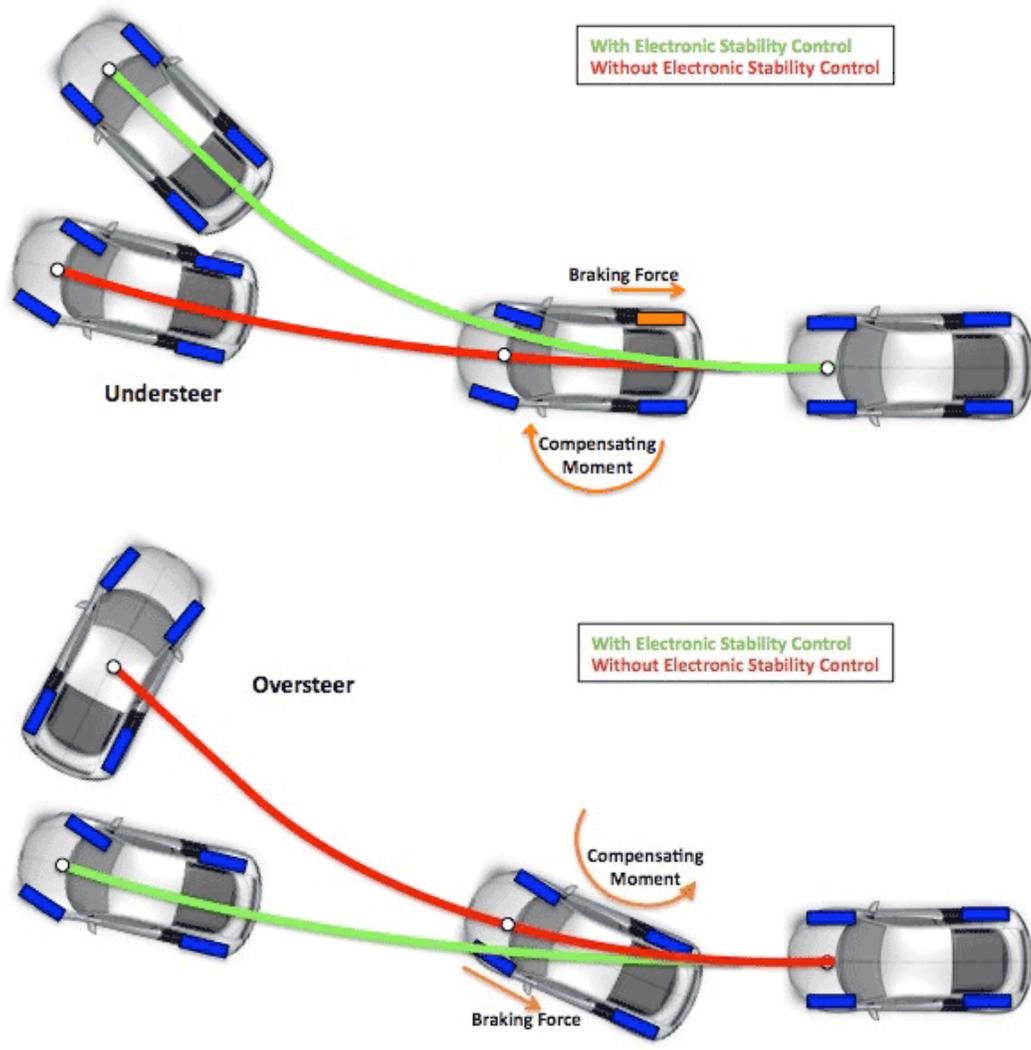


Figure 3. Illustration of electronic stability control for understeer and oversteer. (Images from CVEL [2015].)

ESC uses steering-wheel position, yaw rate, lateral acceleration, and wheel speed sensors to provide real-time data to an onboard computer processor that determines when the limits of stability are being challenged. Once triggered, the system activates countermeasures that are unique for each imminent loss-of-control event. The system countermeasure uses selective braking on certain wheels to help prevent unrecoverable loss of control.

Another example of crash-avoidance technology is forward-collision warning with automated braking. Both ESC and automated braking use countermeasures that depend on effective vehicle brake performance, and brake performance depends on tire

adhesion. Clearly, tire choice will influence the effectiveness of these collision-avoidance technologies. On cold, slippery surfaces, if winter tires are present, the technology can function more effectively than if winter tires are not present. By not using winter tires on slippery roads, the entire vehicle system, including crash-avoidance technologies, will be partially compromised and cannot deliver the maximum safety benefits. Because of advancements in crash-avoidance technologies, winter tires are becoming increasingly important, rather than less important, as vehicle technology matures.

Finding #9: Crash-avoidance technologies such as electronic stability control depend on tire adhesion to function optimally. Therefore, winter tires are becoming increasingly important, rather than less important, as crash-avoidance technologies mature.

Winter Tires on All Four Wheels

It is imperative that winter tires be fitted to all four wheels and not just the driven wheels of a two-wheel drive vehicle. The danger is that by mixing winter tires with other tires, vehicle handling characteristics will be altered. They will tend to oversteer (front-wheel drive) or understeer (rear-wheel drive), leading to loss of control even in dry conditions. Therefore, mixing winter tires with other tires on a vehicle under certain conditions likely presents a greater loss-of-control safety risk than not using winter tires (Cooper Tire, 2016).

Finding #10: It is important that winter tires be fitted to all four wheels and not just the driven wheels of a two-wheel drive vehicle.

Connected and Self-Driving Vehicles

Looking to the future of self-driving vehicles, tire choice will likely be a significant consideration. In the connected-vehicle world, vehicles communicate their position and vehicle dynamic state to neighboring vehicles, and this information is used to improve safety by helping to define relative vehicle position in the traffic stream. Since braking performance depends so significantly on tire choice, particularly during winter operation, it is conceivable that winter tires will be required on all connected

vehicles to ensure that they have consistent and predictable brake- and cornering-performance characteristics.

Self-driving vehicles will likely have the same requirement for winter tires, because the success of such vehicle systems will depend very much on predictable and uniform system behavior. Outliers within the automated traffic stream will create unique challenges that have the potential to compromise the overall safety performance of the system.

Legislation and Incentives in North America

In North America, legislation and incentives related to the 3PMSF winter tire designation is concentrated in Canada.

In 2008, the Province of Quebec introduced a law to mandate winter tires on all passenger vehicles. Winter tires are required from December 15 to March 15 (SAAQ, 2016).

The government of Ontario recently implemented new legislation (effective January 1, 2016), requiring all insurance providers in the province to offer a reduction in auto insurance premiums to drivers that have four winter tires installed on their personal passenger vehicles (OMF, 2015).

An innovative program from the government of Manitoba, and administered by Manitoba Public Insurance, offers low-interest loans for the purchase and installation of qualifying winter tires. The program was first launched in September 2014, and since then, more than 30,000 applications have been processed. This program provides loans to a maximum of \$2,000 per vehicle, for up to 48 months at the rate of prime, plus two per cent (MPI, 2016).

British Columbia recently updated the language on signage for certain mountainous highways, indicating the need to use tires marked with the Three-Peak Mountain Snowflake Symbol (British Columbia, 2015).

Conclusions

The ten surprising facts about winter tires:

1. The main benefit of winter tires is improved tire adhesion, braking and cornering performance – not acceleration performance.
2. Winter tires provide improved traction on roads that are below 7 °C (45 °F) even when snow and ice are not present.
3. Stopping-distance performance of winter tires on packed snow is approximately 35% shorter than for all-season tires and 50% shorter than for summer tires.
4. Winter tire improvements in stopping distance also extend to improvements in cornering capability.
5. Tires designated as mud and snow tires do not necessarily perform well on packed snow and ice. Such tires without the 3PMSF symbol were found to require 40% longer stopping distance than similar tires with the symbol.
6. Tires with aggressive treads will not necessarily perform well in slippery winter conditions unless they have the 3PMSF symbol.
7. In Canada, during the winter period from December to February, there is a reported 49% increase in insurance claims. Much of this elevated risk is attributable to slippery road conditions in winter. Winter tires reduce crash frequency during winter months.
8. A two-wheel drive vehicle with winter tires will outperform a four-wheel drive vehicle with all-season tires in braking and cornering. The perception that four-wheel drive vehicles do not require winter tires in cold climates is false.
9. Crash-avoidance technologies such as electronic stability control depend on tire adhesion to function. Winter tires are becoming increasingly important rather than less important as vehicle technology matures.
10. It is imperative that winter tires be fitted to all four wheels and not just the driven wheels of a two-wheel drive vehicle.

References

- ASTM (2016). *Standard Test Method for Single Wheel Driving Traction in a Straight Line on Snow and Ice-Covered Surfaces* (ASTM F1805-12).
- Austen, I. (2011, December 7). *In Quebec, Winter Tire Law Reaps a Modest Measure of Success*. Available at: http://wheels.blogs.nytimes.com/2011/12/07/in-quebec-winter-tire-law-reaps-a-modest-measure-of-success/?_r=0
- Aviva Canada. (2011, November 23). *Auto insurance claims spike dramatically during winter months*. Toronto: Aviva Canada.
- British Columbia [Province of British Columbia]. (2015). *Winter driving*. Available at: <http://www2.gov.bc.ca/gov/content/transportation/driving-and-cycling/traveller-information/seasonal/winter-driving>
- Brown S.W., Vanlaar W.G.M., and Robertson R.D. (2012). *Winter tires: A review of research on effectiveness and use*. Available at: http://www.tirf.ca/publications/publications_show.php?pub_id=284
- Cooper Tire. (2016). *Service Bulletin No.114*. Available at: http://ca.coopertire.com/CooperTiresCanada2015/media/Documents/Service_Bulletin_114.pdf
- CVEL [Clemson University Vehicular Electronics Laboratory]. (2015). *Electronic Stability Control*. Available at: http://www.cvel.clemson.edu/auto/systems/stability_control.html
- ECE R117 (2011). Testing method for measuring the wet grip index of C1 tyres. UNECE Regulation No. R117, Ref ECE/TRANS/WP29GRRF/2011/12.
- EPA [Environmental Protection Agency]. (2015). *Light-duty automotive technology, carbon dioxide emissions, and fuel economy trends: 1975 through 2015* (Report No. EPA-420-R-15-016). Available at: <https://www3.epa.gov/fueleconomy/fetrends/1975-2015/420r15016.pdf>
- ETRMA [European Tyre and Rubber Manufacturers Association]. (2016). *Winter tyre*. Available at: <http://www.etrma.org/activities/transport/winter-tyre>

- EU (2009). *Type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor* (Regulation 661/2009).
- Goodyear. (2016). *How to recognize a true winter tire*. Available at: http://www.goodyear.eu/corporate_emea/our-responsibilities/road-safety/winter-tire-recognition.jsp
- Mahler, J. (2008, March 1). *New winter tire logo losing market value: Transport Canada tests of alpine-rated winter and all-season rubber show wide results*. Toronto: Toronto Star.
- MPI [Manitoba Public Insurance]. (2016). *Winter tire program*. Available at: <https://www.mpi.mb.ca/en/Rd-Safety/Winter-Tires/Pages/winter-tire-program-overview.aspx>
- Nokian Tyres. (2011). *Nokian Tyres FAQ*. Available at: <https://www.nokiantires.com/innovation/facts-about-tires/faq/>
- NHTSA [National Highway Traffic Safety Administration]. (2011a). *Crash prevention effectiveness of light-vehicle electronic stability control: An update of the 2007 NHTSA evaluation* (Report No. DOT-HS-811-486). Available at: <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811486>
- NHTSA [National Highway Traffic Safety Administration]. (2011b). *Electronic stability control. Rules*. Available at: [http://www.nhtsa.gov/Laws+&+Regulations/Electronic+Stability+Control+\(ESC\)](http://www.nhtsa.gov/Laws+&+Regulations/Electronic+Stability+Control+(ESC))
- OMF [Ontario Ministry of Finance]. (2015). *Drivers with winter tires eligible for insurance discount*. Available at: <https://news.ontario.ca/mof/en/2015/10/drivers-with-winter-tires-eligible-for-insurance-discount.html>
- SAAQ [Société de l'assurance automobile du Québec]. (2016). *Behaviours - Adapting your driving: Winter driving*. Available at: <https://saaq.gouv.qc.ca/en/road-safety/behaviours/adapting-your-driving/winter-driving/>
- TRAC [Tire and Rubber Association of Canada]. (2015). *2015 TRAC winter tire report*. Available at: <http://news.tracanada.ca/winter-tires>

Transport Canada. (2015). *Winter tire safety tips*. Available at:

http://www.tc.gc.ca/eng/motorvehiclesafety/safevehicles-safetyfeatures-wintertires-index-468.htm?campaign=Facebook-eng&WT.mc_id=jv2kq

Transports Québec. (2011). *Mise en oeuvre de la mesure rendant obligatoire l'utilisation de pneus d'hiver pour certains véhicules*. Available at:

https://www.transports.gouv.qc.ca/fr/securite-signalisation/securite-conditions-hivernales/Documents/Rapport_pneus_hiver.pdf