CONFIDENCE REPORT: LOW ROLLING RESISTANCE TIRES

ABSTRACT

This report documents the confidence that North American Class 8 trucking should have in low rolling resistance tires for improved fuel efficiency. The study team engaged the entire industry in the data that is presented here. Thanks to all of those who contributed to this important work.

Trucking Efficiency

Trucking Efficiency is a joint effort between NACFE and the Carbon War Room to double the freight efficiency of North American goods movement through the elimination of market barriers to information, demand and supply.

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TRUCKING EFFICIENCY CONFIDENCE REPORT:
Low Rolling Resistance Tires
Executive Summary

The fuel costs faced by the tractor-trailer industry have been swiftly and steadily rising over the past decade. By 2013 diesel fuel costs reached $0.65 per mile, costing the industry more per annum than the combined costs of drivers' wages and benefits. Despite recent fuel cost decreases, all indications are that fuel price volatility will continue, forcing the industry to find solutions that increase its fuel efficiency in order to stay profitable.

Fortunately, myriad technologies that can cost-effectively improve the fuel efficiency of Class 8 trucks are readily available on the market today. Unfortunately, multiple barriers have stymied industry adoption of such technologies, including a lack of data about the true performance gains these technologies offer and a lack of confidence in the data that does publicly exist today. To overcome those barriers and facilitate the industry's trust in and adoption of the most promising fuel efficiency technologies, the North American Council for Freight Efficiency (NACFE) partnered with Carbon War Room (CWR) to form Trucking Efficiency. The work of Trucking Efficiency has begun with a series of Confidence Reports, of which this report on low rolling resistance tires, both duals and wide-base, is the sixth.

The goals of this Confidence Report are: (a) to give fleets an unbiased understanding of the impact their tire choices have on fuel economy, as well as the benefits and challenges of the various options currently available on the market; and (b) to increase the use of lower rolling resistance tires across the industry.

Fuel Efficiency Technologies Covered in This Report

Two features—rolling resistance and tire configuration—distinguish between the tires considered in this Confidence Report. The rolling resistance of a tire is defined as the force needed to keep the tire rolling at a constant speed on a level surface, and is usually expressed in the form of a rolling resistance coefficient (RRc). Tires are made of flexible materials, and as they move underneath the weight of the truck they deform against the ground. Overcoming that deformation and keeping a tire rolling forward requires energy, and therefore fuel. Low rolling resistance (LRR) tires refer to any tire on the SmartWay verified tire list, though some tires on that list will have an even lower resistance than others.

"Low rolling resistance tires, whether in dual or wide-base configurations, are proven to save fleets fuel and therefore have a good case for adoption." - Mike Roeth, Operation Lead, Trucking Efficiency

METHODOLOGY

This report's conclusions were generated through desk research, conversations at a variety of trucking industry events around the country, and a series of structured interviews with tire manufacturers, tractor and trailer OEMs, fleets, and others.

Trucking Efficiency conducted confidential, over-the-phone interviews with eleven large fleets, all of whom had significant experience with low rolling resistance tires.

Insights from medium and smaller fleets were garnered via an online Fleet Forum—53 fleets participated, 36 of which had direct experience with low rolling resistance tires.

Trucking Efficiency Confidence Reports to date:

1. Tire Pressure Technologies (August 2013)
2. 6x2 Axle Systems (January 2014)
3. Idle Reduction Technologies (June 2014)
4. Electronically Controlled Transmissions (December 2014)
5. Electronically Controlled Transmissions (February 2015)
6. Low Rolling Resistance Tires (August 2015)

Visit www.truckingefficiency.org to download these and other reports

Tire configuration refers to if the tires of a truck are spec'd in either a dual or a wide-base configuration. All of the wide-base tires available today qualify for the SmartWay verified tire list as having low rolling resistance. So while the report distinguishes between LRR and non-LRR dual tires, there is no such thing as a non-LRR wide-base tire. The report instead considers an emerging class within the Smartway list of super low rolling resistance tires, both wide-base and duals.

Key Findings of This Report

1. Rolling Resistance: Low rolling resistance tires, whether in a dual or a wide-base configuration, will save significant amounts of fuel when compared to tires that are not designed for low rolling resistance.

2. Tire Configuration: Tire configuration should be assessed based on total cost of ownership, including fuel consumption.

3. Industry Trends: More and more fleets are recognizing that the benefits of low rolling resistance tires outweigh the challenges, and that LRR tires represent a good investment for managing fuel economy.

Rolling Resistance

This report finds that low rolling resistance tires, whether in a dual or a wide-base configuration, will save significant amounts of fuel when compared to tires that are not designed for low rolling resistance. Some of the costs to operate LRR tires may be higher than those of non-LRR tires, but these costs are recovered over the tire's operational lifetime.

Calculating the lifecycle cost of tire ownership is critical. Traditionally, the per-mile cost of tires is defined solely in terms of their initial purchase price, and as tire replacement may be more frequent with LRR than with non-LRR tires, the value of the LRR options has been under-recognized by the industry.

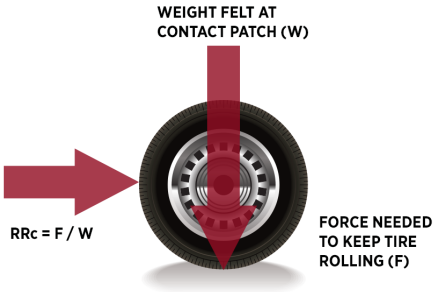
In fact, the cost of the fuel that a tire consumes due to its rolling resistance is five times greater than the initial purchase price of the tire. Rolling resistance accounts for ~30–33% of the total fuel cost of a modern, aerodynamic, Class 8 truck, or about $0.21 per mile with dual tires; the typical upfront purchase cost of the tires is only ~$0.04 per mile. But given the range in rolling resistance among dual tires on the market today, tires could be claiming anywhere from $0.14/mi to $0.28/mi in fuel costs. Put simply, fleets that are purchasing tires without considering the fuel expenditure impacts of those tires are going to be miscalculating the relationship of their tires to their bottom line.

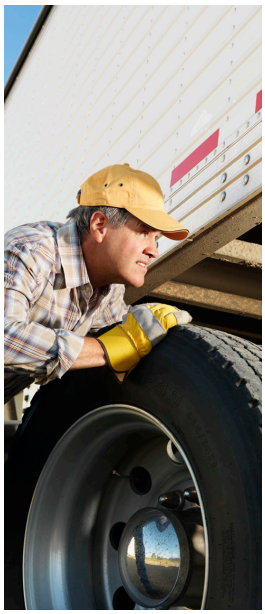
Not only do LRR dual tires reduce fuel consumption; their upfront purchase price is equivalent to non-LRR duals of similar makes and models, and by adopting them fleets will enjoy the benefits of increased regulatory compliance.

However, LRR duals do come with some challenges. As mentioned, tire replacement may be more frequent, since one of the primary characteristics of LRR tires is a thinner tread. Fleets and drivers also express concerns that LRR tires sacrifice traction. This study finds that, while concerns around tread life and traction are not baseless, continual advances in tire design and rubber compounds make them less and less important with each new tire model.

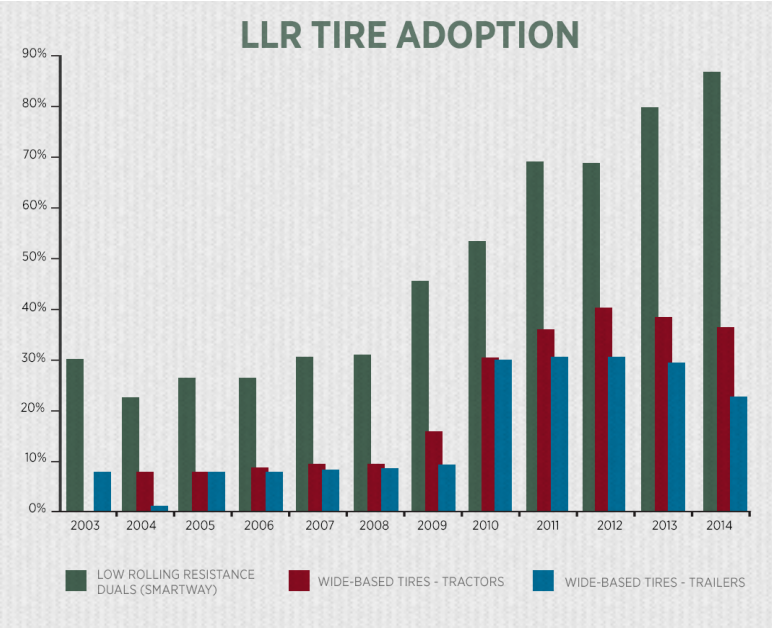
Already today, a new non-LRR dual tire would need double the tread life of a comparable LRR model for the cost savings of that longer tread life to surpass the fuel savings of the decreased rolling resistance. And tire manufacturers predict that differences in tread life between LRR and non-LRR tires will soon disappear altogether.

ROLLING RESISTANCE COEFFICIENT





"Fleets that are purchasing tires without considering the fuel expenditure impacts of those tires are going to be miscalculating the relationship of their tires to their bottom line." - Yunsu Park, NACFE Study Manager



Tire Configuration

Fleets seeking to maximally reduce the fuel consumption caused by their tires will not only consider the rolling resistance of their tires, but will also compare between two available tire configurations—duals or wide-base singles. The Confidence Report finds that the benefits of wide-base tires compared to duals include lower rolling resistance, an up-to-1% reduction in overall vehicle weight, an equivalent upfront purchase price (one wide-base tire will cost about the same as a similar pair of dual tires), and the potential for reduced maintenance.

On the other hand, the industry perceives the challenges associated with wide-base tires to include limited product availability, an increased cost for on-road breakdowns, a decrease in resale value, a reduction in the ability to retread the tires, and poor driver acceptance. Additionally, as wide-base tires have low rolling resistance, they face the same concerns around a decrease in traction and tread life as LRR duals. The Confidence Report discusses each of these concerns, and finds that some of them are more real than others today.

Considering purely the fuel economy associated with the rolling resistance of a tire, the Confidence Report finds that wide-base tires generally display lower rolling resistance when compared with a similar dual tire with the same tread pattern and rubber compound. However, not all wide-base tires will outperform all LRR dual tires, as a range of rolling resistance coefficients exist in both tire configurations.

Industry Trends

There is a definite trend among on-highway truck fleets to increase their use of low rolling resistance tires. The figure below shows the results of NACFE's most recent Annual Fleet Fuel Study (www.nacfe.org/project), in which all 14 of the fleets involved are moving toward low rolling resistance tires, both dual and wide-base.

This trend is also apparent in the growth of the EPA SmartWay verified tire list, launched in 2004 to accelerate adoption of fuel-saving technologies. By 2010 the list contained only eight tire brands. But in the last 5 years the list has grown dramatically, and as of mid-2015, the list contains over 170 tire brands, and continues to grow. SmartWay does not track verified purchases, but agrees that anecdotal evidence indicates that more truck fleets are spec'ing verified LRR tires.

However, a limitation of the SmartWay list is that it creates only one threshold for distinguishing between LRR and non-LRR tires—that of a decrease in rolling resistance that reduces fuel consumption by 3% or more relative to the comparable best-selling new tires for line-haul tractor-trailers. In fact, there is a significant range of rolling resistance coefficients among the tires on that list—some are now much lower than others. But since manufacturers do not publically share the coefficients of their tires, it can be difficult for fleets to fully assess their options.

In sum, industry trends prove that more and more fleets are recognizing that the benefits of low rolling resistance tires outweigh the challenges, and that LRR tires represent a good investment for managing fuel economy.

"The newest tires, ones with much lower resistance, are emerging as great economic investments." - Mike Roeth, Operation Lead, Trucking Efficiency

RECOMMENDATIONS AND TOOLS FOR FLEETS

THE FOLLOWING DECISION GUIDE SUMMARIZES THE RECOMMENDATIONS OF THE CONFIDENCE REPORT, AND SERVES TO ASSIST FLEETS IN MAKING CHOICES ON ROLLING RESISTANCE AND TIRE CONFIGURATION:

DESCRIPTION OF THE FLEET AT PRESENT	SUGGESTED FLEET ACTION	
	OVER THE SHORT TERM:	OVER THE LONG TERM:
Does not purchase SmartWay verified LRR tires and does not consider a tire's impact on fuel consumption.	Spec SmartWay verified LRR dual tires from a trusted brand.	Test several SmartWay verified LRR dual tires to find the one with minimal trade-offs for your fleet.
Only purchases and wants to stay with SmartWay verified LRR dual tires, but does not know if there is a difference between any of the listed tires.	Ask your tire representative or distributor for more information on super LRR SmartWay verified tires with even lower rolling resistance.	Test one or several super LRR SmartWay verified tires to see if they lower your fleet's fuel costs further.
Purchases wide-base tires for their weight savings.	Ask your tire representative or distributor for information about his or her lowest rolling resistance wide-base tire.	Test one or several super LRR SmartWay verified wide-base tires to see if they lower your fleet's fuel.
Purchases super LRR SmartWay verified dual tires, and has the resources to test wide-base tires.	Investigate the impact of wide-base tires on your fleet, taking into consideration the challenges listed in this report.	Spec some of your next vehicles with wide-base tires to test their impact on your fleet's costs.
Purchases super LRR SmartWay verified wide-base tires but is not satisfied with their performance or impact on residual value.	Make sure the tires are maintained as well as possible and issues are well supported with data.	Test some of the newest super LRR SmartWay verified dual tires to see if they can exceed the performance of the wide-base tires.
Purchases super LRR SmartWay verified wide-base tires and is satisfied with their performance.	Continue to stay up to date with the latest tire technology.	Continue to test the newest tires of all types with the lowest rolling resistance, to achieve the greatest fuel efficiency.

Recommendations

Fleets should begin to investigate their rolling resistance options in greater detail than simply asking whether their tires are SmartWay verified. Though that list is a great starting point for addressing rolling resistance, tire manufacturers are now offering tires with substantially lower resistance than the SmartWay threshold. Those super LRR tires will allow fleets to save even more on fuel costs.

In addition to using the most fuel efficient tires possible, following some best practices for adoption and use of those tires—including with respect to alignment, wheel balance, mounting and wheel-end issues, and tire inflation—will help to optimize their performance.

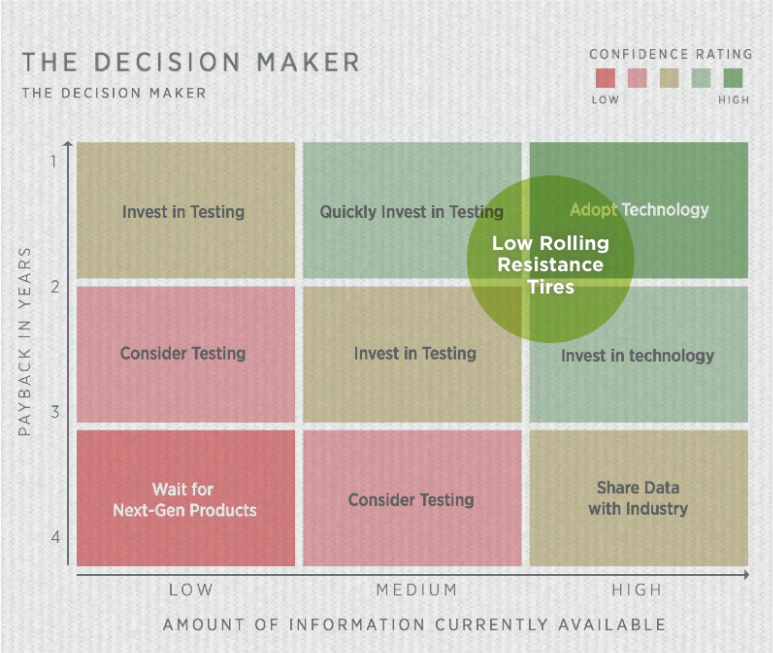
Fleets are not the only actors in this space, however. Tire manufacturers need to contribute greater transparency to the rolling resistance discussion. Currently, rolling resistance is not a publically available data point for tires. Some major manufacturers, like Michelin and Goodyear, offer tools for comparing the rolling resistance of different tires, but their tools are not comprehensive, and it can be hard to make comparisons between options. Making it easier for fleets to understand and compare the rolling resistance of different tire options will move the industry forward towards greater fuel economy.

Confidence Rating

The confidence matrix (below this text) illustrates the Trucking Efficiency study team's confidence in the investment case for low rolling resistance tires. This Confidence Rating indicates a high confidence that low rolling resistance tires, in both dual and wide-base configurations, are proven to save on fuel costs, and have a good case for adoption.

Trucking Efficiency hopes this report will catalyze significant additional interest in low rolling resistance tires. Reducing the rolling resistance of a truck's tires is a proven method for the industry to profitably increase its fuel efficiency and thereby reduce its greenhouse gas emissions.

Trucking Efficiency is always seeking to expand the data or case studies that we can provide to the industry. We invite you to share with us your own experiences with low rolling resistance tires ■



Trucking Efficiency

Trucking Efficiency is a joint effort between NACFE and Carbon War Room to double the freight efficiency of North American goods movement by eliminating barriers associated with information, demand, and supply.

Worldwide, heavy-duty freight trucks emit 1.6 gigatons of CO_2 emissions annually—5.5% of society's total greenhouse gas emissions—due to the trucking sector's dependence on petroleum-based fuels. With fuel prices still commanding nearly 40% of the cost of trucking, the adoption of efficiency technologies by all classes of trucks and fleets offers significant cost savings to the sector while reducing emissions. These technologies are relatively cheap to implement and widely available on the market today.

Trucking Efficiency provides detailed information on cost-effective efficiency technologies, including data from across a variety of fleets and best practices for adoption. This Confidence Report series from Trucking Efficiency aims to serve as a credible and independent source of information on fuel efficiency technologies and their applications.

In order to generate confidence on the performance claims of efficiency technologies, Trucking Efficiency, via these reports, gathers and centralizes the multitude of existing sources of data about the performance results of different technology options when employed in a variety of vehicle models and duty cycles, and makes all of that data openly accessible and more easily comparable. Furthermore, we assess the credibility of the available data, and provide an industry-standardized ranking of confidence in performance results, including ROI and efficiency gains.

About Confidence Reports

Our Confidence Reports assess current technologies, discuss challenges and best practices for their adoption, and provide figures on performance gains and payback periods, along with a multitude of datasets from industry testing.

They are intended to help end users and manufacturers determine whether to adopt a specific technology or set of solutions. The reports are born out of conversations with the industry, which made clear the need for a credible and independent source of information on fuel efficiency technologies and their applications.

In order to generate confidence on the performance claims of efficiency technologies, Trucking Efficiency gathers and centralizes the multitude of existing data sources about the performance results of different technology options when employed in a variety of vehicle models and duty cycles, and makes all of that data openly accessible and more easily comparable through Confidence Reports. Furthermore, we assess the credibility of the available data, and provide an industry-standardized ranking of confidence in performance results, including ROI and efficiency gains.

The full list of Confidence Reports can be found at:

www.truckingefficiency.org

Trucking Efficiency welcomes outside views and new partners in our efforts to help accelerate the uptake of profitable, emission-reducing trucking technologies.

CARBON WAR ROOM

Carbon War Room (CWR) was founded in 2009 as a global nonprofit by Sir Richard Branson and a group of likeminded entrepreneurs. It intervenes in markets to accelerate the adoption of business solutions that reduce carbon emissions at gigaton scale and advance the low-carbon economy. CWR merged with Rocky Mountain Institute (RMI) in 2014 and now operates as an RMI business unit. The combined organization engages businesses, communities, institutions, and entrepreneurs to transform global energy use to create a clean, prosperous, and secure future. The combined organization has offices in Snowmass and Boulder, Colorado; New York City; Washington, D.C.; and Beijing.

www.carbonwarroom.com

NACFE

The North American Council for Freight Efficiency works to drive the development and adoption of efficiency-enhancing, environmentally-beneficial, and cost-effective technologies, services, and methodologies in the North American freight industry by establishing and communicating credible and performance-based benefits. The Council is an effort of fleets, manufacturers, vehicle builders and other government and non-governmental organizations coming together to improve North American goods movement.

www.nacfe.org

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1 Introduction

This Confidence Report forms part of the continued work of Trucking Efficiency, a joint initiative from the North American Council for Freight Efficiency (NACFE) and the Carbon War Room (CWR) highlighting the potential of fuel efficiency technologies and practices in over-the-road (OTR) goods movement. Prior Confidence Reports and initial findings on nearly 70 available technologies can be found at www.truckingefficiency.org.

The fuel costs faced by the tractor-trailer industry have been swiftly and steadily rising over the past decade (Figure 1). By 2013, as Figure 2 shows, fuel costs had reached $0.65 per mile, surpassing even the costs for the driver (wages plus benefits). And although very recently a reduction in fuel costs has occurred, all indications are that fuel prices will continue to be volatile, thus the industry is in need of solutions which reduce its fuel dependency if it is to stay profitable.

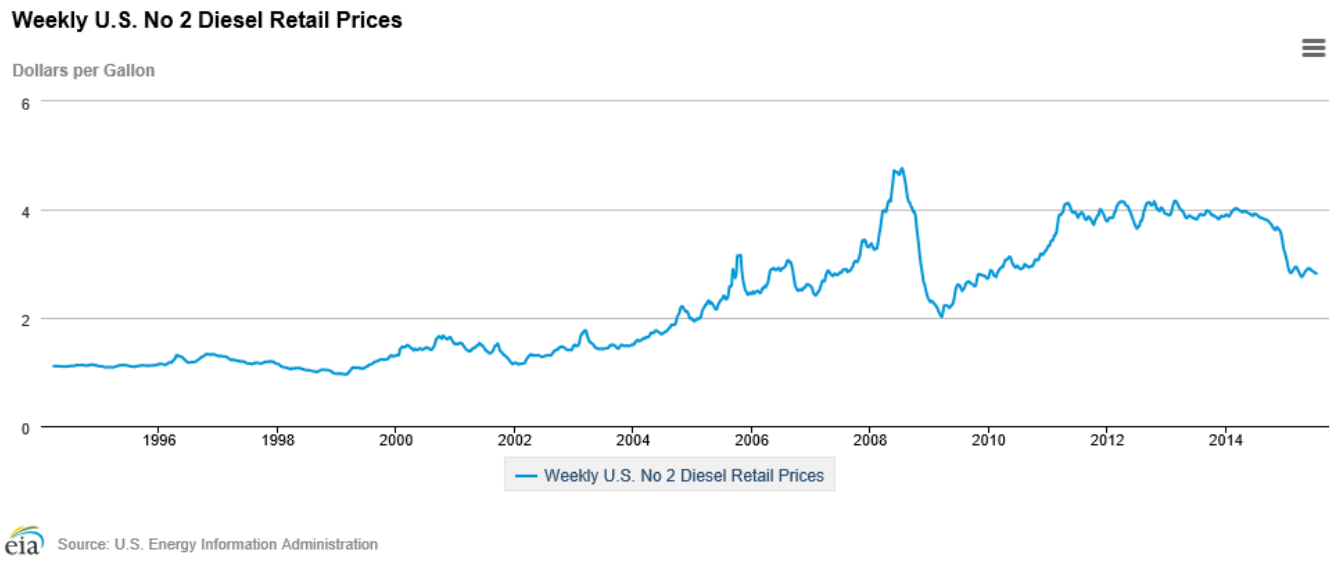

Figure 1: US Diesel Fuel Prices

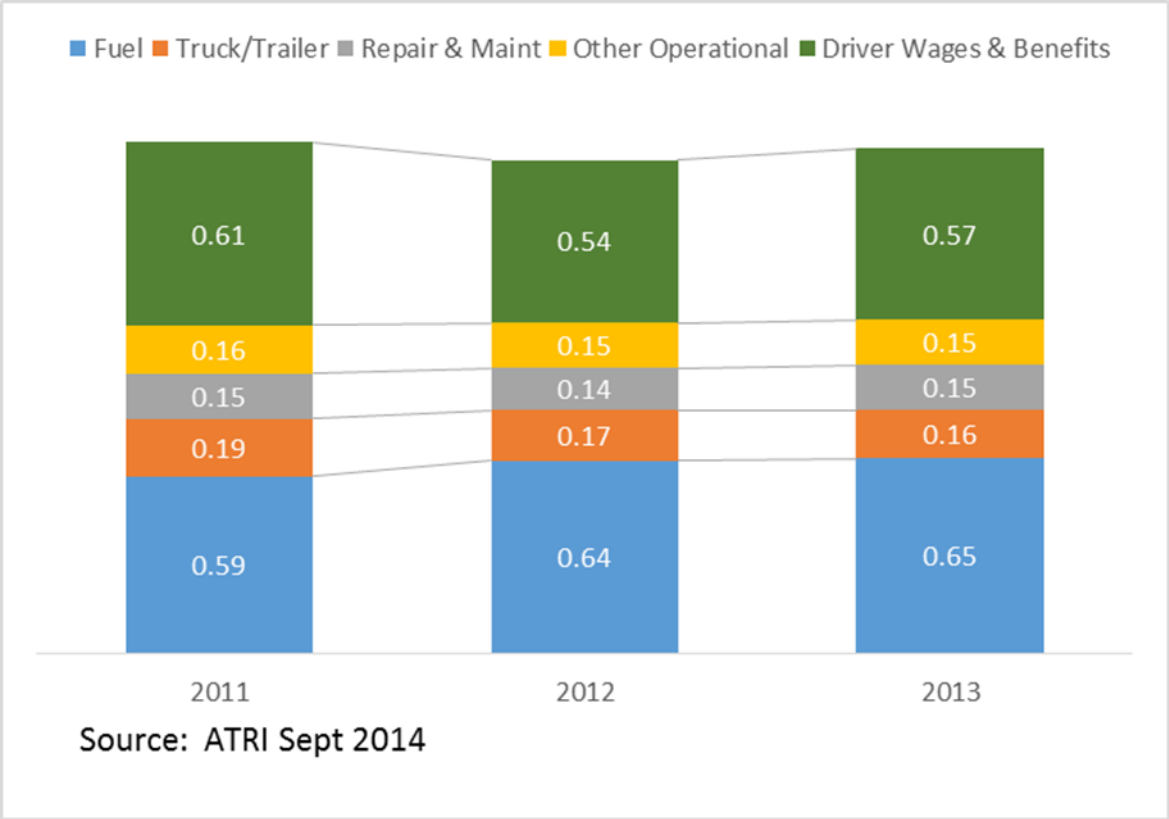

Figure 2: Trucking Operational Cost

Investment into proven technologies and practices that allow a truck or fleet to increase their fuel efficiency – meaning that they can do the same amount of business while spending less on fuel – is a hugely promising option for the industry in light of this trend.

To understand, and thereby better facilitate, the uptake of such technologies, NACFE conducts an annual review, the "Fleet Fuel Study," of the industry-wide adoption rates of nearly 70 fuel efficiency technologies currently available for Class 8 tractors and trailers. This work, available on the www.nacfe.org website, has been called "the most comprehensive study of Class 8 fuel efficiency adoption ever conducted." (Truck News, 2012)

Figure 3: Fleet Fuel Study Participants

The overriding take-away from the most recent Fleet Fuel Study, completed in 2015, is that fleets are enjoying dramatic improvements in their fuel efficiency by adopting combinations of the various technologies surveyed — savings of about $9,000 per tractor per year compared to a fleet that has not invested in any efficiency technologies. It found that these fleets have fleet-wide fuel economy of just under 7.0 mpg, while the USA average, for the approximately 1.5 million tractors involved in over-the-road goods movement, is 5.9 mpg. This finding was drawn from research into the use of fuel efficiency products and practices by 14 of the largest, most data-driven fleets (Figure 3). Those fleets represent both regional and long-haul tractors and trailers, in both dry goods and refrigerated cargo movement, and boast a combined inventory of 53,000 tractors and 160,000 trailers. The 2015 study reviewed twelve years of adoption decisions by these ten fleets, and describes their specific experience with the nearly 70 technologies. Each fleet shared the percentage of their new purchases of tractors and trailers that included any of the technologies. They also shared twelve years' worth of annual fuel economy data for the trucks in their fleet. With these two pieces of information, which will be updated every year, NACFE is able to generate insights into the following aspects of the industry:

- Adoption curves for each of the technologies, indicating which technologies have the steepest adoption rates, which are being adopted steadily but slowly, and which are not being purchased at all. These curves also show how uniformly (or not) fleets are acting in their adoption patterns.
- Identification among the various fleets of the innovators, early-majority, late-majority, and even laggards, in new technology adoption.
- Comparison of technology adoption rates to overall fuel efficiency.
- Identification of three key insights: that the adoption of automated manual transmission has reached high levels, that aerodynamics are now available for natural gas tractors, and that the optimization of engine parameters is being pursued more widely as a fuel-saving strategy by large, medium, and small fleets.

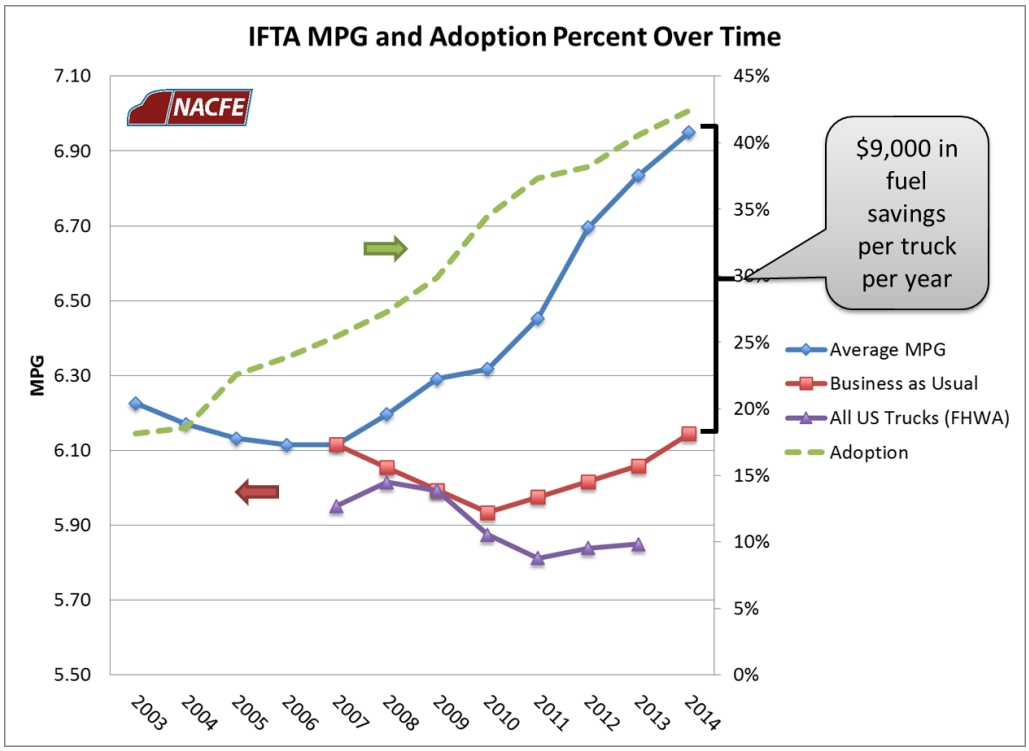

Figure 4: Savings in Fuel per Truck

1.1 Trucking Efficiency's Confidence Reports

NACFE's Fleet Fuel Studies provide useful insights into adoption trends in the industry, as well as into the specific practices of different major fleets. NACFE hopes that this information could alone spur additional investment, particularly by fleets that may be lagging behind the overall industry when it comes to certain widely-adopted technologies. However, in the course of conducting the studies, it became clear that some technologies are still only being adopted by the most progressive or innovative of fleets in spite of their showing strong potential for achieving cost-effective gains in fuel efficiency. In order to facilitate the wider industry's trust in and adoption of such technologies, NACFE and CWR formed Trucking Efficiency and began this series of reports, called "Confidence Reports," which will take an in-depth look at those most-promising but least-adopted technologies one-by-one.

Confidence Reports provide a concise introduction to a promising category of fuel efficiency technologies, covering key details of their applications, benefits, and variables. The reports are produced via a data mining process that both combs public information and collects otherwise-private information (which is shared with Trucking Efficiency for the purpose of the reports), in order to centralize an unparalleled range of testing data and case studies on a given technology set.

Low rolling resistance (LRR) tires, both in a traditional dual setup or in a wide-base format, are one such technology set. The core objective of this Confidence Report, therefore, is to provide the leadership of fleets with a comprehensive overview of the total cost of ownership for low rolling resistance tires for improved fuel efficiency. As this report will demonstrate, there are many (sometimes competing) factors which a fleet must weigh in its decision-making process for tire purchasing. This report therefore does not conclude with a guide of which tires will be right for which

fleets, but rather with a decision tree that fleets can use as they asses their own duty cycles, business models, supplier relationships, and other considerations.

Tires are where fuel economy truly "hits the road," but the fuel economy benefits of operating tractors and trailers with LRR tires in some or all locations must be compared against factors including wear/tire life, re-treadbility, traction, and a fleet's tire pressure practices, when determining the total cost of ownership of the tires.

Visit www.truckingefficiency.org to view this and other completed reports on tire pressure systems, 6x2 axles, idle reduction, electronically controlled transmissions and engine parameters.

1.2 Technologies Considered in this Confidence Report

There are two features – the rolling resistance coefficient and the tire configuration or width – which distinguish between the tires considered in this confidence report, creating three essential categories of tires. For the purposes of this report, "low rolling resistance" (LRR) refers to any tire on the SmartWay verified technologies list, though it is recognized that some tires on that list will have lower resistance than others. In terms of tire width, the terms "dual" and "wide-base" are used. All of the wide-base tires (also sometimes referred to as wide singles or super singles) available today for over-the-road line haul applications do fall on the SmartWay verified technology list, so this report only briefly distinguishes a class of extremely low rolling resistance wide-base tires from among wide-base tires generally.

Therefore, this report discusses and compares between:

1. Non-LRR dual tires
2. LRR dual tires
3. LRR wide-base tires

Note that when the term dual is used without a qualifier as to rolling resistance this report is distinguishing only the tire width, and is referring to both LRR and non-LRR dual tires. Also note that, in this report, common terms like standard, traditional, or conventional are not used, as those may refer to either the rolling resistance or the width of the tires.

1.2.1 What is Rolling Resistance?

The rolling resistance of a tire is defined as the force needed to keep a tire rolling at a constant speed on a level surface, and is usually expressed in the form of a rolling resistance coefficient (RR_c). An easy way to think about RR_c is as the ratio given by the force needed to keep a tire rolling to the weight on the contact patch. (The tire's rolling friction increases as more weight is put on the contact patch since in the real world, the rolling frictional coefficient of a tire is always greater than zero.) (Figure 5).

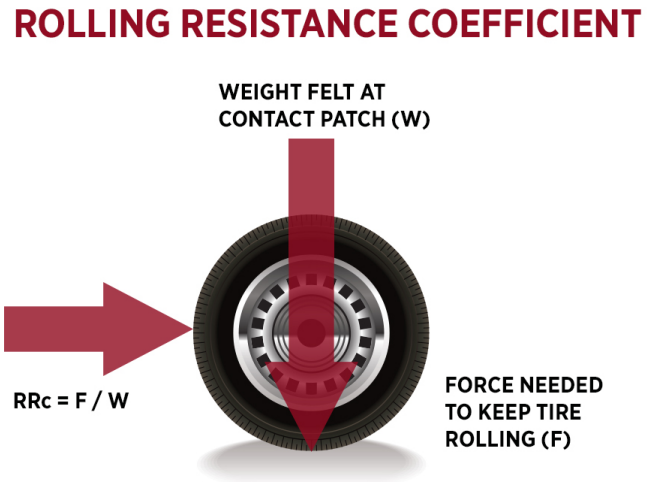

Figure 5: Rolling Resistance Coefficient

There are several standard methods for calculating a tire's RR_c. One common method is prescribed by ISO 28580, which specifies the test rig and conditions under which a tire is tested. An RR_c resulting from an ISO 28580 test is expressed in the unit "kg force per metric ton." Since there are 1,000 kg in a metric ton, this can be used with any unit of measure divided by 1,000. For example, a tire with a rolling resistance of 10 and a load of 10,000 lbs requires 100 lbs of force to keep it rolling at a constant speed (10,000 lbs x 10 / 1000 = 100 lbs). In order for a tire to be accepted as SmartWay verified, at least three tires must be tested using the ISO 28580 or equivalent method and the average of the tests must be below the SmartWay target values for the tire position.

	Steer	Drive	Trailer
SmartWay Target RR_c (ISO 28580)	6.5	6.6	5.1

Table 1: SmartWay RR_c Targets

1.3 Methodology

Trucking Efficiency's Confidence Reports are researched by an unbiased team of trucking industry experts. For this report the core study team included: Yunsu Park, Consultant, NevinAvenue LLC; Jim Rogers, Consultant, retired from McKee Foods; Jim Park, Consultant, Double Park Enterprises; and Mike Roeth, NACFE Executive Director and CWR Trucking Efficiency Lead.

In December 2014 this study team began assessing the current state of low rolling resistance tires for improving the fuel efficiency of Class 8 tractor trailers. The team used a "360°" technique to gather existing data on tires, in order to uncover any points of industry-wide agreement or areas of confusion. The first step in this research was for the team to meet with or use phone interviews to speak with heavy duty tire suppliers, tractor and trailer builders, and many large and small fleets with experience in low rolling resistance tires. The team also used the spring 2015 truck shows; specifically the

Technology and Maintenance Council meetings in Nashville, the MidAmerican Trucking Show in Louisville, the National Private Truck Council event in Cincinnati and the Alternative Clean Transportation Conference in Dallas, to meet with and learn from many of the key industry stakeholders.

Eleven large fleets and five major tire manufacturers were confidentially interviewed by the study team. All 11 fleets had significant experience with LRR tires, usually for multiple duty cycles. Finally, the study team used a Fleet Forum to survey medium and smaller fleets about their perceptions of and experiences with LRR tires, both duals and wide-base; 53 fleets participated in that survey, of which 36 had first-hand knowledge of LRR tires.

The study team presented its initial findings, drawn from these interviews and surveys, to groups of fleets, manufacturers and others – participants in Trucking Efficiency Workshops held in mid-November, 2014, in Allentown, PA, one in Dallas, TX in early May 2015 and another in Salt Lake City, UT in June. These workshops are quarterly, regional meetings where small groups discuss and even debate the findings of Trucking Efficiency's reports. A schedule of upcoming workshops can be found at http://www.truckingefficiency.org/events

1.3.1 Preliminary study questions used in study team interviews

Sample Questions:

- What is meant by low rolling resistance tires?
- Is lower rolling resistance just created by less tread? To what degree does the reduced tread cause a tire to wear more quickly, requiring more frequent tire replacements?
- What is a SmartWay tire, and are they all the same?
- Do they deliver fuel savings?
- How much of an effect do tires have on fuel expense?
- What are the advantages and disadvantages of wide-base tires?
- What tradeoffs do tire manufacturers make to get lower rolling resistance?
- Do new tires being offered wear better?
- What is the total cost of ownership?
- How will Greenhouse Gas Phase 1 or Phase 2 regulations change tire designs, availability, etc.?

2 Why Rolling Resistance Matters

There was a time when knowing the upfront cost and predicted life of the tire was enough for most fleets to make a purchasing decision. Tire costs were a maintenance item and fuel was an operating cost, and the two had little to do with one another. If there was any awareness of a tire's impact on fuel consumption, it was assumed to be negligible, unknowable, or perhaps both.

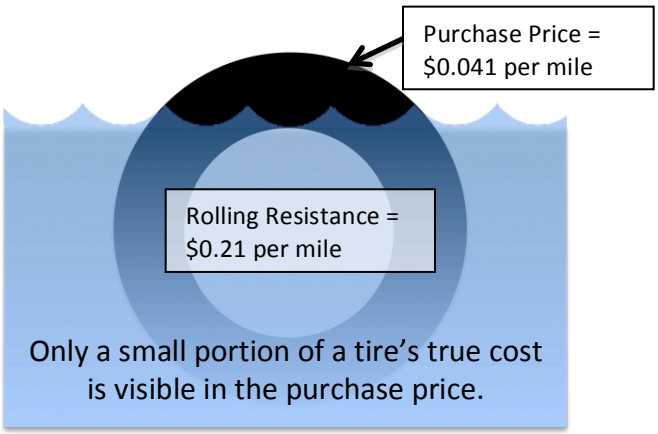

Figure 6: Cost of Tires

Today, many parties including tire manufacturers, truck builders, the EPA SmartWay, and others, are working to raise awareness of the hidden cost of fuel in each tire purchase. A typical fleet's average cost for fuel is approximately $0.645 per mile (ATRI, September 2014). The tire's average contribution to that cost varies depending on road speed, vehicle aerodynamics and other factors. For a fairly aerodynamic long haul truck operating at highway speed, tire manufacturers interviewed by the study team typically attribute about 30-33% of total fuel cost to rolling resistance, or about $0.21 per mile. On the other hand, a typical fleet's costs for the upfront purchase of the tires are approximately $0.04 per mile (ATRI, September 2014). Therefore, as Figure 6 shows, for a typical OTR fleet, the cost of the fuel a tire consumes due to its rolling resistance outweighs the initial purchase cost of the tire by a factor of five.

According to one major US tire manufacturer that has tested many of the tires available on the US market from the various manufactures at an independent lab, the rolling resistance (RR_c) for on-highway truck tires varies from a low of 4.4 to over 9, with the lower figure of 4.4 indicating lower rolling resistance. This means that not only is the hidden cost of fuel far greater than the tire's price, but that the difference in the impact on fuel economy that one tire versus another can have is also greater than those tires' initial cost. Given the range in RR_c among tires on the market today, the fuel cost of one drive tire could range from about $0.005/mi to over $0.01/mi from best to worst rolling resistance. Put simply, fleets purchasing tires without considering the fuel expenditure that will be driven by their tire choice are missing the biggest impact on the fleet's bottom line that the tires will have.

Today, tire manufacturers do not disclose a tire's rolling resistance to the general public, though it may be revealed selectively to some large fleets. The best indication of a tire's RR_c comes from the EPA SmartWay, which has a list of tires it has verified as low rolling resistance. For a tire to qualify for the SmartWay list, it must meet a rolling resistance threshold set by SmartWay for each type of tire. According to SmartWay, the threshold is set at a level that reduces fuel consumption by 3% or more relative to the best-selling new tires for line haul tractor-trailers.

A consequence of this SmartWay list is that it only incentivizes tire manufacturers to make sure their tires fall below the threshold, but not to decrease their rolling resistance any further than that.

Finally, while lower rolling resistance will improve fuel economy, it is not without its trade-offs. Nearly every tire manufacturer has achieved a degree of its rolling resistance reductions by sacrificing tread depth, which has negative effects on tire life and perhaps traction. For fleets weighing those trade-offs, it is important to keep the relative costs in mind. A 3% reduction in fuel (the SmartWay target) equates to nearly $0.02 per mile (3% x $0.645 per mile). For an average fleet incurring $0.04 per mile in tire cost (upfront purchase price), a tire with higher rolling resistance would have to have a tread life that is twice as long as that of a SmartWay-verified LRR tire to offset the gains in fuel efficiency imparted by the lower rolling resistance.

3 What Makes a Tire more Fuel Efficient

An analogy to rolling resistance came to the study team from Tim Miller, recently retired from the Goodyear Tire & Rubber Co. He likened the benefits of low rolling resistance to walking on the beach in wet and dry sand, saying: "notice how much easier it is to walk on the stiffer wet sand than the loose dry sand... using tires with high rolling resistance is equivalent to constantly walking on loose dry sand."

With a non-low rolling resistance tire or a tire designed for high traction, the treads are deep and the tread blocks are separated by wide gaps. As the tire rolls, the tread blocks deform and compress, and the energy required to make those treads deform comes directly from the fuel tank. In the case of a low rolling resistance tire, characterized by a thinner and firmer tread and stiffer compounds, there is less material in the tread face to wiggle and squirm at the contact patch as the tire rolls along the pavement.

The tire that rolls along the road with the minimum of wasted energy is the more efficient tire. The very best example of rolling efficiency would be a steel train wheel on a steel rail -- two smooth polished surfaces, no deformation to speak of, and very little friction between the two surfaces to inhibit rolling. But because steel on steel provides a very low coefficient of friction, traction is quite poor. And while steel wheels on a truck might last forever, the ride quality would be appalling.

3.1 History of low rolling resistance tires

Historically, cost and tread life were the top considerations when specifying tires; fuel efficiency was not a big concern when diesel was one dollar per gallon. Nevertheless, fuel-efficient tires with lower rolling resistance appeared on the market back in the early 1980s, known then as low-profile tires. We know similar tires today by their metric nomenclature, i.e., 295/75R 22.5.

Characterized by a lower aspect ratio -- the difference between the height and width of the tire – and shallower tread, they boasted 3% to 4% better fuel efficiency. They were also about 15% more expensive and the tread life was about 30% less than a non-LRR dual tire. At that time, fuel cost about $1.50 per gallon, so the extra cost of the tire combined with the reduced tread life was difficult to make up in fuel savings. Consequently, sales of such tires were sparse.

High fuel prices in recent times have renewed interest in such tires, but there remains lingering doubt about their cost effectiveness, as rolling resistance is only one of three major considerations in tire design, along with traction and service life. Underlying those are secondary considerations such as re-treadability, durability, ride quality, and cost. The historic view of tire engineering is that dramatic improvement in one of the three primary considerations will usually result in compromises to the other two. That remains the case, but advancing technologies today make possible substantial improvements in efficiency with less compromise to traction and tread life. In fact, as mentioned in a future section of this report, a non-LRR dual tire would have to have double the tread life as the LRR model for the cost savings of that longer tread life to surpass the cost of the fuel savings conferred by a 10% decrease in rolling resistance.

Today's LRR tires are much improved over those early examples; tread mileage in particular is much better due mostly to new materials and production methods that reduce or eliminate the trade-offs that tire manufacturers had to make in the early years. Design philosophy and technical approaches vary with the manufacturers, but all claim that advances in rubber compounding have led extended the tread life of LRR tires.

3.2 Components of a Tire

Every component of a tire has a role to play in determining rolling resistance, traction, and tire life, and every component of a tire can be manipulated in some way to affect those variables. In terms of rolling resistance, the tread normally contributes about 40% to a tire's rolling resistance, the sidewalls and belts another 40% and the bead area about 20% (Michelin).

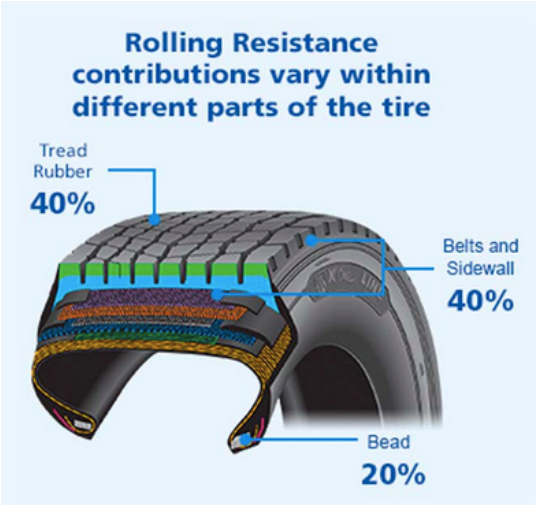

Figure 7: Rolling Resistance Contributions (Photo via Michelin)

3.2.1 Tread Design

Rib-type tread designs roll more easily than lug treads, offering less resistance because they have less movement (squirming and wiggling) of the individual tread blocks as the tire contacts the pavement.

(The distortion of the tread as it makes contact with the pavement consumes energy; the more the tread blocks are supported by each other, the less distortion occurs.)

Figure 8: Rib-steer design (Yokohama)

Figure 9: Tight packed lug with closed shoulder (Goodyear)

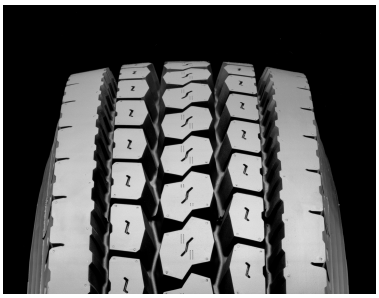

Figure 10: Lug tire with closed shoulder l(Yokohama)

The current trend in LRR tires is moving toward closed shoulder with a tighter tread pattern. Manufacturers are building tires with tightly packed lugs that not only bear a strong visual resemblance to a rib design, they function similarly as well. When tread lugs are packed tightly together, they support one another and squirming is minimized. This is a good example of how engineers can lower rolling resistance with minimal traction reduction.

3.2.2 Tread Depth

Treads are typically shallower on LRR tires for the same reason – to minimize tread movement at the contact patch. There is a general belief that shallower tread provides less traction and will run fewer miles to removal, simply because there is less rubber there to begin with. In the early days of LRR tires, when many tire manufacturers relied heavily on reduced tread depth to meet the SmartWay requirements, this was mostly true. However, tread compounds and manufacturing processes developed by the leading tire manufacturers have improved over the years, enabling engineers to specify stiffer, more resilient rubber for the tread faces that is capable of running more miles per 32nd of an inch of rubber with minimal impact to traction. One leading tire manufacturer indicated that early data received on their newest LRR tires actually have improved tread life, up to 400,000 miles in the drive position.

3.2.3 Sidewalls

While their contribution to fuel efficiency may be small, the sidewall is a critical part of tire design. In a drive tire, sidewalls must be able to withstand the tremendous torque output of today's engines, while remaining supple enough to absorb incidents like curb strikes.

Manufacturers can lower the rolling resistance of a tire by making the sidewall stiffer, as it will consume less energy if it flexes less. This is only possible up to a point however, as making a sidewall stiffer also means sacrificing some of its ability to withstand impact.

3.2.4 Rubber Compounds

Today, different materials are mixed and blended to produce the rubber used not just in the tread, but also the under-tread, the sidewalls, the bead, and the interior of the tire. Engineers are designing

rubber compounds to suit each application, and for LRR tires they are striving for less elasticity overall, or hysteresis, so that less energy is consumed in the process of deforming and then returning to their original shape.

3.2.5 Tire Weight

The weight of the tire, and by extension, the weight of other wheel-end components such as wheels, hubs, axle spindles, etc. has only a minute impact on overall vehicle fuel efficiency. Therefore weight is not an issue in choosing between non-LRR and LRR dual tires. However, a second option is available in the LRR category – wide-bases tires, which offer weight savings of about 800 pounds per truck/trailer over dual tires.

3.3 Wide-base Tires

Wide-base tires are tires designed to replace two dual tires with one tire on drive or trailer axle wheel ends for over-the-road applications. The design has advantages over dual tires in reducing rolling resistance since two sidewalls are eliminated and the size of the overall contact patch is reduced.

Figure 8: Wide-base tires and wheels

When Michelin introduced the first wide-base tire, the X One, to the North American market in the year 2000, it was seen as a radical departure from traditional tire designs. Though popular in Europe from some years prior, they were slow to gain acceptance here, and after fifteen years of exposure wide-base tires have not exactly taken this market by storm. Still, they do offer proven fuel economy benefits of about 3% to 5%, depending on the application.

Much of that efficiency advantage comes from doing away with two sidewalls per wheel end. Depending on the make and model, many of the tread patterns and tread depths found on dual tires are also available on wide-base tires, with some thread patterns unique to the wide-bases.

Low rolling resistance dual tires make up about 30-40% of the truck market today, while wide-base tires currently make up about 5% of the market.

The specific challenges and benefits entailed in adopting wide-base tires instead of duals are discussed in much greater depth later in this report.

4 Measuring Rolling Resistance

While the precise contribution of reductions in rolling resistance to overall fuel economy improvements can be calculated fairly accurately using measured rolling resistance data and assumptions about the rolling resistance component of fuel consumption, highly accurate real-world data are harder to come by. Weather, driver habits, varying weights and other vehicle condition parameters can sway the results, meaning that certain inaccuracies will likely arise when measuring actual fuel burned without temperature compensation and precise mileage inputs. Fleets must be very diligent not to overlook any changes or miss recording a single fill-up when collecting this sort of data.

The principle challenge in any testing is calculating the uncertainty value of the test, which is expressed as a confidence interval. In the case of rolling resistance, the improvement is likely to be small, so an uncertainty value of +/- 2% could negate or overstate the amount of improvement.

On top of that, in long-term on-road tests such as TMC's Type IV test (RO 1103), the actual rolling resistance of the tires under evaluation improves as tread rubber is scrubbed away. Meanwhile, in short-term testing, such as an SAE J-1321 track test, weather and a number of other variables can impact the outcome

For these reasons, fleets testing tires on their own do not always achieve statistically accurate results, thus their tire-buying decisions may be skewed by inaccurate, incomplete or corrupt data.

Tire manufacturers test their tires to determine rolling resistance using one of two recognized test procedures: ISO 28580 or SAE J1269. The actual results of these tests, usually expressed numerically, are not publicly available, but are used by OEMs and various regulatory agencies when calculating, for example, GHG reduction credits. The finding in isolation may not be that useful to a tire buyer as it speaks only to its rolling resistance, which is not the only factor to be considered in a tire specifying decision.

However, several tire manufacturers' websites offer useful rolling resistance comparison tables. Some, like Michelin's table, allows users to compare the LRR values of almost any make and model to a baseline. Users can choose their own baseline tire and the model to compare it with. Goodyear's table allows the user to compare most makes and models, but only against another Goodyear model tire.

The way tire manufactures present their findings can lead to confusion. For example, Michelin presents relative rolling resistance on a scale where the baseline tire has a value of 100 (customer can select the brand and model). The compared tire has a value +/- (again, customer can select the brand and model), e.g., baseline = 100, compared tire = 91, or perhaps 110. The lower number indicates less rolling resistance than the baseline (in this example, the compared tire has a 9% lower RR_c).

Michelin also offers a fuel economy tool, which allows a user to provide information on their vehicle, and then can suggest the fuel economy gains or losses that would result from a given tire selection.

Goodyear presents its comparisons as a percentage of improvement where the customer's current tire (baseline) is compared to a selected Goodyear model. The results displayed indicate which of the two tires has lower rolling resistance expressed as a percentage. For example, the better of the two tires will be displayed as 16.1% better than the other. Other manufacturers offer similar tools to help fleets make decisions.

Finally, the aforementioned EPA SmartWay Verified Tire list offers some guidance in the availability and selection of LRR tires. SmartWay does not reveal the actual RR_c values for any tires but lists the tires that meet its target threshold for a given axle position.

5 Trends in Tire Purchasing

There is a clear trend among on-highway truck fleets to low rolling resistance tires. The figure below shows results of NACFE's most recent Annual Fleet Fuel Study where all 14 of the fleets involved are moving toward low rolling resistance tires, both duals and wide-base.

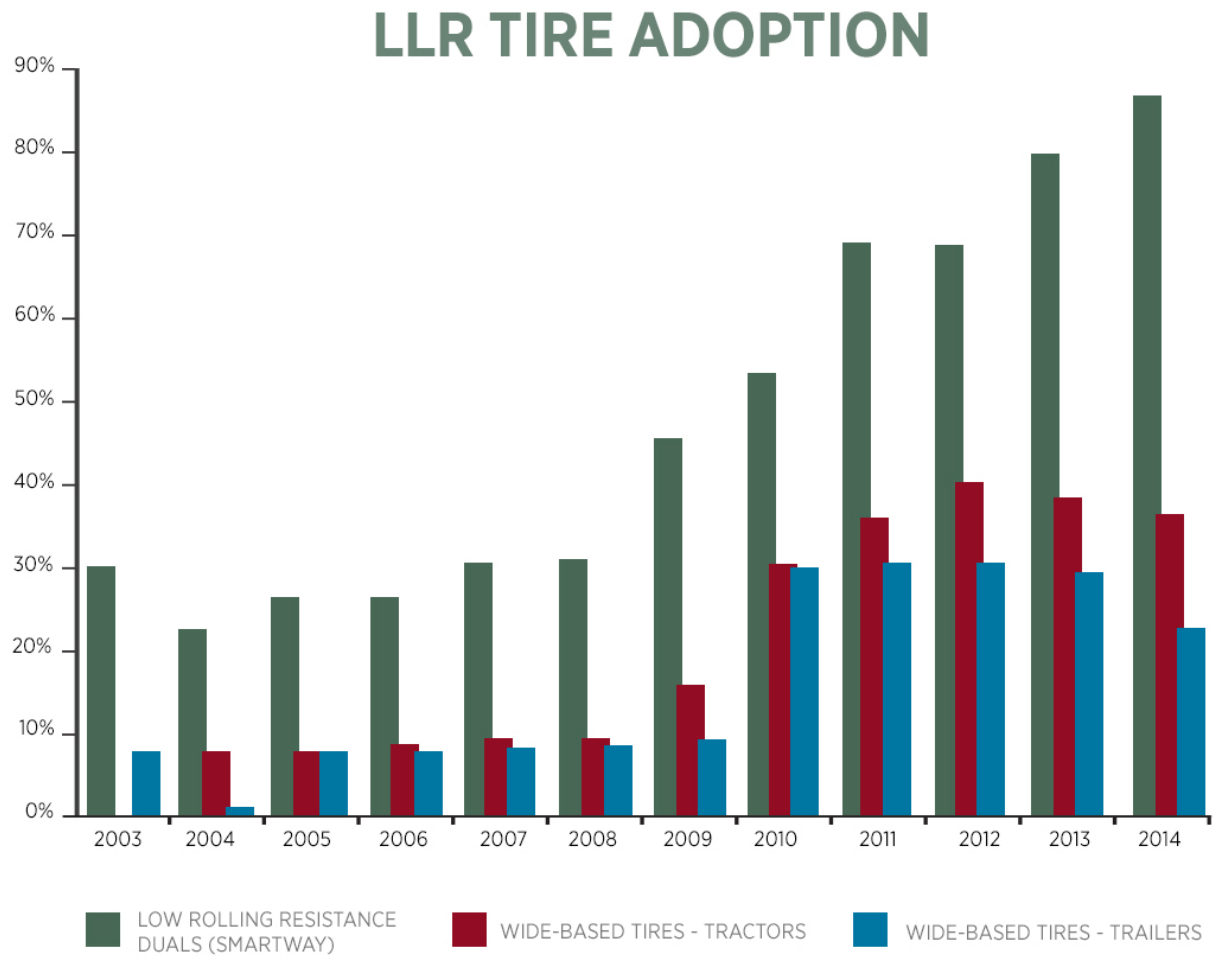

Figure 9: LRR Tire adoption NACFE 2015 AFFS

Another place where this trend is apparent is in the growth of the EPA SmartWay verified tire list. The verified tire list was launched as part of the technology program in 2004 with the aim to accelerate adoption of fuel-saving technologies; six years later, only eight tire brands were listed. But in the last 5 years the list has grown dramatically, and as of mid-2015, the list contains over 170 tire brands with many models from each of those brands, and will likely continue to grow. The presence of a tire on the SmartWay list is no guarantee of its quality in terms of traction, treadlife, or re-treadabilty, but it is an indication of the increasing awareness of the importance of the fuel-efficiency impact of tires. SmartWay does not track verified purchases but agrees that anecdotal evidence indicates that more truck fleets are spec'ing verified LRR tires.

Tire manufacturers do not discuss sales by tire model, but some have gone so far as to say that there is no reason to produce a non-SmartWay verified tire for the on-highway long-haul market. This may have been a generalization, as all tire manufacturers are quick to point out that correct application is critical, and that rolling resistance is only one of several criteria for selecting the right tire. But their

having made this observation nonetheless points to the recognition that the SmartWay list has received in the industry.

Truck OEMs also indirectly confirm this trend. To meet Phase One requirements of the current US EPA greenhouse gas (GHG) regulations, truck manufacturers are required to document the rolling resistance coefficient of the tires fitted to the vehicles they produce. The truck OEMs interviewed by the study team indicated that so far the specs the customers desire have allowed the OEMs to meet the standards - in other words the OEMs have not needed to push for more fuel-efficient tires than were already requested by the customer. As one manufacturer said, "customers seem to know which tire is best for their application," providing as evidence the fact that the average RR_c for the tires the customers specified was lowest in the sub-category associated with on-highway sleeper trucks.

The trend is likely to continue, for it's one that should benefit most on-highway truck fleets. Proposed RR_c targets in phase 2 of the GHG regulations (released on Jun 19, 2015) decrease by 8-27% (depending on vehicle type and axle position) from the Phase 1 target by 2027 and will meet or exceed the SmartWay threshold by 2021 (for non-vocational vehicles). Truck and tire manufacturers continue to educate their customers on the benefits of LRR tires, new tire technology will continue to diminish the traction and tire-life trade-offs associated with LRR tires, and SmartWay and other organizations will continue to look for ways to educate tire buyers about the fuel impact of tires.

Tire Location	EPA SmartWay	GHG1'14	GHG1'17	GHG2'18	GHG2'21	GHG2'24	GHG2'27
Steer	6.5	7.7	7.7		6.2	5.9	5.6
Drive	6.6	7.7	7.7		6.6	6.2	5.9
Trailer	5.1			5.1	5.1	4.7	4.7

Table 2: RR_c Targets (provided by Brian Buckham of Goodyear, 7-13-15)

6 Benefits and Challenges – Low Rolling Resistance Dual Tires

6.1 Benefits of Low Rolling Resistance Dual Tires

Dual tires -- those run on a steer axle or fitted into a dual assembly for drive and trailer axles -- are generally available from all tire manufacturers in both conventional, non-low rolling and low rolling resistance varieties.

Figure 13: LRR dual tires and wheels

6.1.1 Reduced Fuel Consumption

Although non-LRR tires may be the best choice for certain applications which particularly value long service life, resistance to irregular wear, or enhanced traction above fuel economy, LRR tires offer a presumed fuel saving advantage over a similar non-LRR tire.

We say presumed because direct comparisons between two specific tires can be difficult to make, and can be application dependent. An LRR lug-type tire is typically not as efficient as a rib design but may not incur a very large rolling resistance penalty if used at low speeds.

In all cases, current understanding puts the tires' contribution to total truck fuel consumption at roughly 30-33%. The remaining portions can be attributed to internal powertrain component friction, mechanically induced parasitic drag, energy draw from on-board systems such as electrical and HVAC, and aerodynamic drag.

It's important to note that the tires' contribution relative to other types of drag changes with the application and type of equipment as well as with the weight and speed of the truck. At lower speeds aerodynamic losses will not be as great, while tire-related rolling resistance will remain nearly the same, meaning it will assume a larger percentage of the total drag on the vehicle (Table 3).

Vehicle Speed (MPH)	Rolling & Accessory Losses	Aerodynamic Losses
20	72%	28%
40	64%	36%
50	50%	50%
60	38%	62%
65	33%	67%
70	30%	70%

Table 3: Tire Impact on Fuel Economy

Source: National Research Council of Canada, Centre for Surface Transportation Technology

In the years before aerodynamic trucks became popular, tire rolling resistance accounted for about 15%-20% of total fuel consumption. As truck designs became more aerodynamic, tire rolling resistance, proportionately, grew to over 30% of fuel used (Bridgestonetrucktires.com). As aerodynamic refinements continue, and powertrains likewise become more and more efficient, the relative contribution of the rolling resistance of the tires will expand even further.

According to Bridgestone calculations, if tire rolling resistance accounts for about one-quarter to one-third of truck fuel consumption, then an improvement of 5% in rolling resistance would produce about a 1.3%-1.7% improvement (1/4 x 5% = 1.3% and 1/3 x 5% = 1.7%) in fuel economy.

6.1.2 Regulatory Compliance

Low rolling resistance is creeping inexorably into the regulatory lexicon. At present, only the state of California requires the use of LRR tires on certain vehicle configurations, but it's believed these requirements will spread across the country. Nationwide greenhouse gas reduction requirements that went into effect in 2014 brought that prediction closer to reality, but thus far, the use of such tires remains optional.

Those regulations apply only to original equipment manufacturers, but OEMs can earn credits toward their overall compliance goals by including LRR tires in vehicle specifications. Truck buyers still have the option of specifying non-low rolling tires with no pricing penalties, but that may change with the next round of GHG reduction mandates, which are stricter than the 2014 rules.

Trucks sold under the 2014 GHG rule are required to have a compliance label indicating which, if any, fuel-saving technologies were installed on the truck when it was delivered. Those devices or technologies must remain on the truck for its 'useful life,' deemed to be 435,000 miles for Class 8 vehicles, 185,000 miles for Class 6 and 7, and 105,000 miles for Class 3-5. These requirements would prevent a user from switching to non-low rolling resistance tires sometime after the truck was put into service if it was originally equipped with LRR tires.

In California, under requirements imposed by the California Air Resources Board (CARB) for trucks, tractors, and trailers that came into effect in 2013, certain vehicle configurations must use LRR tires (see table below). The rule applies to various model-year trucks and is being phased in on a sliding scale. As of mid-2015, the vast majority of long haul highway trucks operating in that state are required to have LRR tires on both the tractor and the trailer.

Tractors	LRR Tires Required	Compliance Deadline	Exempt from LRR Tire Requirement
2011 MY and newer tractors (sleeper & day cab)	Yes	1/1/2010[1]	Registered short-haul tractor
2010 or older MY tractors	Yes	1/1/2013[2]	Registered short-haul tractor
Trailers			
2011 model year and newer trailers	Yes	1/1/2010[1]	Registered storage trailer, or any trailer pulled by exempt short-haul tractor
2010 or older MY trailers	Yes	1/1/2017	Registered storage trailer, or any trailer pulled by exempt short-haul tractor

Table 4: CARB Requirements

6.1.3 Initial Purchase Price

Actual tire pricing is difficult to determine as manufactures offer preferential pricing to fleets based on fleet sizes, commitment to the brand, and various other concessions. Retail pricing is likely to provide a better model-to-model comparison, but will differ greatly from negotiated pricing.

While any fuel-saving technology is often assumed to come with price premium, a very limited review of tire retail pricing shows that this not necessarily the case for LRR tires. We found several instances where an LRR tire was in fact less expensive than a non-LRR dual tire (same brand and application) in a tire maker's lineup (See table below).

*Denotes SmartWay verified model

Make	Model	Size	Tread	Price
Bridgestone	*M710 Ecopia Drive	11R22.5	26/32	$537
	M726EL Drive	11R22.5	32/32	$510
Michelin	*XDA ENERGY	275/80R22.5	26/32	$566
	XDN2	275/80R22.5	27/32	$575
Yokohama	*TY517MC2	295/75R22.5	28/32	$415
	TY577	11R22.5	30/32	$430

Table 5: Tire Pricing Examples

6.2 Challenges of Low Rolling Resistance Dual Tires

6.2.1 Irregular/premature tread wear

One of the primary characteristics of LRR tires is a thinner tread. Because there are simply fewer 32nd -inches of rubber on the tread face, it is logical to assume the tire will run fewer miles overall before the tread reaches the removal point.

Early versions of LRR tires certainly suffered from shorter than desired tread life; more recently, advances in tire design and manufacturing, as well as tread compounding have succeeded in extending tire life. At least one leading tire manufacturer shared information with the study team indicating that tread life now meets or even exceeds that of its non-LRR tires. It can safely be said that tire design will continue to evolve presumably extending tire life even further.

Still, proving the cost case for lost tire life is easier said than done and requires diligent record keeping -- a capacity many fleets still lack. Measuring is made even more difficult by the fact that tire life is inextricably linked to many other complicating factors, such as maintenance, application, driver habits, vehicle speed, etc.

Despite these difficulties, the findings of fleets surveyed by the study team suggest that fleets are willing to give up some mileage if the cost of the lost miles can be made up in fuel savings. Acceptance of LRR tires appears to be high, with 56.8% of respondents indicating they currently use the tires, with an additional 4.5% currently testing them. Conversely, 31.8% said they do not use LRR duals, while only 6.8% of respondents said they had tested or were using LRR tires but planned to discontinue their use going forward.

Interestingly, of the fleets the study team surveyed that are using LRR tires, the level of satisfaction with the non-fuel performance metrics was high. Slightly more than 68% of respondents said they were very or somewhat satisfied with tread life, while 13.6% had a neutral position on the matter. Almost 64% indicated they were somewhat or very satisfied with traction; 13.6% were neutral, while the same number said they were somewhat dissatisfied.

From these results it can be inferred that LRR tires are meeting expectations more often than not, and by a good margin.

Among the fleets the study team surveyed who responded that they were not using LRR tires, the reasons cited varied:

- 28.6% said they were skeptical of the fuel savings
- 21.4% said purchase price was a factor
- 28.6% cited lack of awareness of product availability
- Only 14.3% named traction concerns as a reason for not adopting LRR tires.

6.2.2 Life-cycle Cost vs. Initial Purchase Price

We have included cost as a challenge as well as a benefit because there are concerns surrounding cost, particularly as it relates to life cycle cost. The value proposition of a LRR dual tire lies in the fuel savings. But confidence around those fuel savings is oftentimes hard to determine. Several respondents to the study team indicated they lacked the resources to conduct fuel economy tests on new tires. Other expressed a need for some impartial test data that would help quantify potential fuel savings (specific fleet factors notwithstanding).

Fleets responding to the study team's questions around the upfront purchase price suggested they expect a premium of about 10% for a LRR dual tire. As noted above, the study team's limited review of retail pricing did not come to the same conclusion, so there may be issues yet to be explored surrounding tire pricing, and possibly a need to make it more transparent. Paying an additional 10% for a tire that is expected to run fewer miles-to-removal does not make a good adoption case unless fuel savings can be factored into the equation. And as noted earlier, that exercise can be notoriously difficult to do accurately.

7 Benefits and Challenges – Wide-Base Tires

7.1 Benefits of Wide-Base

7.1.1 Reduced Fuel Consumption

Wide-base tires are widely assumed to be more fuel efficient than low rolling resistance dual tires, meaning they should have a lower rolling resistance coefficient than a pair of tires in a dual assembly. In reality, not all wide-base tires compare favorably to a given dual tire in all product lineups when it comes to fuel economy.

In a comparison of two similar tires, i.e., the same tread pattern and rubber compound, the wide-base tires generally display lower rolling resistance when compared to a dual tire. The difficulty arises when trying to make such a comparison if similar tread patterns and compounds do not exist between two tire models at a given manufacturer. To compare rolling resistance between two dissimilar tires would be to invite an apples-to-oranges comparison.

However where an appropriate comparison can be made, wide-base tires do often exhibit lower rolling resistance than their dual counterpart, as shown in Table 6.

	Tire Model	Rolling Resistance Index
Example 1	Michelin X Line Energy D dual	100
	Michelin X One Energy D wide-base	82
Example 2	Michelin XDN2 dual	100
	Michelin X One XDN2 wide-base	89
Example 3 (dissimilar tires)	Goodyear G305A T dual	100
	Goodyear G392A SSD wide-base	100
Example 4 (dissimilar tires)	Goodyear G 505 D dual	88.5
	Goodyear G392A SSD wide-base	100

Table 6: Wide base versus Dual rolling resistance

On other manufacturer's websites where fuel efficiency or rolling resistance calculators exist, dual tires can be found that outperform wide-base tires when fuel efficiency or rolling resistance is expressed as a percentage of improvement in fuel saved over a number of miles.

In several comparisons across brands and models, relying on nothing more than model designations, the study team found many examples where a dual tire outperformed a wide-base tire. Important to note, however, no attempt was made to compare similar tires, just leading examples of a given manufacturer's tires against a competitive model.

Fleets reported that as wide-base tires emerged, they had a significantly better fuel performance than the best of the dual tires. But, in the recent years, new improved low rolling resistance dual tires have become available that have decreased this gap. Therefore, the fuel economy of LRR duals are now closer in fuel economy to wide-base than their own predecessors.

7.1.2 Weight Reduction

There is no disputing the fact that spec'ing wide-base tires and wheels will reduce vehicle tare weight. Depending on the baseline weight of your tires/wheels, savings could be in the range of 800 to 1,400 pounds. Lighter equipment typically gets better fuel mileage, not to mention increased payload capacity. It is estimated by the Aluminum Association's Aluminum Transportation Group that a 1% weight reduction can reduce fuel consumption by about 1%. The EPA estimates that a 3,000-pound weight reduction could save about 240 gallons of fuel per year -- or about 1.3%. A previous confidence report published by NACFE covering 6x2 drive axle configurations places the fuel savings resulting from a 1,000 lb weight reduction at about 0.8%.

While 1% is a relatively minor saving in and of itself, the lower vehicle tare weight makes higher payloads possible in some weight sensitive applications. This can produce a greater cumulative reduction in fuel consumption, thanks to the fewer trips required to deliver a given amount of product. For example, if a fuel hauler could haul an additional 1,000 pounds of product, it would be the equivalent of an additional full load of product over 50 trips.

The chart below illustrates the weight-savings potential from a sample of tire makes and models, as well as a comparison of steel versus aluminum disc wheels.

Tire Weight Examples

Make	Model	Size	Tread	Weight
Bridgestone	M710	11R22.5	26/32	121
	M726EL	11R22.5	32/32	131
	M835 (WB)	*445/50R22.5*	*23/32*	*173*
Goodyear	G305 LHD	11R22.5	26/32	125
	G362 LHD	11R22.5	28/32	129
	G392A SSD(WB)	*445/50R22.5*	*25/32*	*188*
Michelin	XDN	11R22.5	27/32	132
	Energy D	11R22.5	23/32	132
	XDN2 (WB)	*445/50R22.5*	*27/32*	*182*

Table 7: Tire Weight Examples

ALCOA wheel weight

Wide base aluminum	22.5 x 14	54 lbs
Dual aluminum	22.5 x 8.25	45 lbs

Possible Transition Examples:

Style	Wheel Material	Tire Weight (lbs)	Wheel Weight (lbs)	Total Weight (lbs)
Dual	Steel	2,096	1,216	3,312
Wide Base	Steel	1,456	1,106	2,472
Dual	Aluminum	2,096	800	2,896
Wide Base	Aluminum	1,456	440	1,896

Table 8: Weight Change Examples

Therefore:

- Switching from dual tires on aluminum wheels to wide-base tires on aluminum wheels will save 1,000 pounds.
- Switching from dual tires on steel wheels to wide-base tires on aluminum wheels will save 1,416 pounds.
- Switching from dual tires on steel wheels to wide-base tires on steel wheels will save 840 pounds.

Information sources:
~ Aluminum Association's Aluminum Transportation Group
www.aluminumintransportation.org
http://www.drivealuminum.org/research-resources/PDF/Webinars/2010/Aluminums-Impact-on-Meeting-Future-Fuel-Economy-Standards-2010-Nov-Commercial-Vehicle-Webinar.pdf

~ Michelin Weight Savings Calculator:
http://www.michelintruck.com/en_CA/tools/weight-savings-calculator/#/

~ US EPA Smartway
http://www.epa.gov/smartway/forpartners/documents/trucks/techsheets-truck/420f09043.pdf

7.1.3 Initial Purchase Cost

When purchasing new equipment, the price differential between a truck spec'd for fitting with wide-base tires and one spec'd for dual tires is negligible. Pricing will vary with OEM tire availability and preferred pricing arrangements. And as with retail pricing, premium tires command higher prices than tier 2 or tier 3 tires. This applies to dual as well as wide-base tires.

There are additional costs associated with a mid-life transition from dual tires to wide-base. These costs are related to axle and hub modifications, but they are a one-time cost.

Regarding the tires themselves, just as for dual tires, actual tire pricing is difficult to determine, as manufactures offer preferential pricing to fleets of different sizes, commitment to the brand, and

various other concessions. Retail pricing is likely to provide a better model-to-model comparison but will differ greatly from negotiated pricing.

OEM tire pricing can vary considerably as well, especially where a captive tire brand is offered at preferred pricing. Switching away from the house brand can add cost that might not be reflected in a similar retail brand-to-brand comparison.

Still, the study team's sampling of retail pricing revealed that individual wide-base tires were generally close to double the price of similar individual dual tires within the same brand – meaning that fitting a given wheel hub with one wide-base tire would cost the same as fitting it with a pair of duals. There were notable exceptions in a few cases, where what is perceived as a manufacturer's top-of-the-line dual tire was priced at more than half of the price of a single wide-base tire, meaning a pair of the duals would be more expensive.

A review of retail pricing at one nationwide retailer (Table 9) similarly, found that in most cases wide-base tires are very close to double the price of a comparable pair of dual tires. There were exceptions to the rule; in a few cases a pair of dual tires were found to cost about 10% more than one wide-base.

Make	**Model**	**Size**	**Price**	**H/(L)**
Michelin	X LINE ENERGY T	11R22.5	$518.99	($62.01)
	X LINE ENERGY T	275/80R22.5	$518.99	($62.01)
	5 XONE LINE ENERGY	*445/50R22.5*	*$1,099.99*	-
Bridgestone	M710 ECOPIA LRG DRIVE	11R22.5	$536.99	$63.99
	M726EL DRIVE	11R22.5	$510.99	$11.99
	GREATEC M835 ECOP	*445/50R22.5*	*$1,009.99*	-
Goodyear	G316 LTH	11R22.5	$501.99	($116.01)
	G572A LHD DRIVE	295/75R22.5	$605.99	$91.99
	G392A SSD Duraseal Fuelmax	*445/50R22.5*	*$1,119.99*	-

Table 9: Retail tire pricing examples (April 2015)

http://www.loves.com/HomeLinks/TruckTireCare/TirePricing.aspx

Finally, this study team's survey found that more than half of responding fleets (58.3%) cited concerns over the initial tire and wheel purchase cost as a reason for deciding not to test wide-base tires.

When it comes to wheel pricing at the retail level, the study team for this Confidence Report found that the purchase price of two dual aluminum wheels is very close to the cost of one wide-base wheel. Prices can vary slightly from brand to brand, but the difference is not significant.

Retail pricing examples, aluminum wheels
http://www.buytruckwheels.com/aluminum-wheels/unimount.html
22.5 x 8.25 Alcoa Aluminum 10 Hole Hub Pilot: $279.00
22.5 x 8.25 Accuride Aluminum 10 Hole Hub Pilot: $249.00

22.5 x 14 Accuride Aluminum 10 Hole Hub Pilot Zero Offset: $415.00
22.5 x 14 Alcoa Aluminum 10 Hole Hub Pilot Zero Offset: $499.00

7.1.4 Reduced Maintenance

None of the fleets surveyed for this Confidence Report detailed any maintenance problems related to the use of wide-bases compared with dual tires; it is believed that wide-base tires do not impose an additional maintenance burden on fleets. In fact, it was noted by several respondents that wide-base tires can reduce the overall maintenance workload simply because there are few of them to service. Specifically, fleets said the time it takes to conduct routine yard surveys and pressure and condition checks reporting is reduced significantly. Additionally, several fleets cited reduced inventory carrying and record keeping requirements as net benefits to the wide-bases.

There are no reported maintenance practices unique to wide-base tires that would add cost, except perhaps for handling equipment designed exclusively for wide-bases, such as warehouse racking, storage bins or dollies designed to facilitate easier handling of the heavier tire and wheel assemblies.

Wide base tires eliminate the need to match tire heights and diameters, as is the case with dual tires. How many fleets pay great attention to this aspect of tire and wheel installation is unknown, but tire manufactures say that a difference in excess of 1/4 inch in height can put more load on the taller tire and have negative effects on tire life.

On the operational front, several fleet respondents noted an intriguing fact; they experienced fewer roadside service calls related to maintenance (i.e., pressure related failures, as opposed to road hazard related failures.) The exact number of wide-base tires failures compared to dual tire failures was not shared with the study team. But for a large fleet to notice a decline in the number of service calls after installing wide-base tires is compelling supporting evidence of the claim.

The reason for the decline is unclear, but several respondents put it down to increased vigilance on the drivers' part. It has been suggested that drivers, knowing they no longer have the opportunity to "limp in" on a single tire, are paying greater attention to the condition and pressure of their tires.

Moreover, fleets using wide-base tires have a higher rate of adoption of tire inflation assistance technologies, such as automatic tire inflation systems and tire pressure monitoring systems. Most purveyors of such equipment suggest that payback on their systems can be realized if they prevent just two blowouts and their related service costs. Preventing blowouts is particularly important for wide-base tires, because of the loss of limping capability and the threat that the replacement tire of choice might not be available at all service locations (tire companies generally dispute this, but lack of availability is cited by many respondents as a major concern when considering switching from dual to wide-base tires).

The study team also received several survey responses suggesting that wide-base tires reduce brake service costs and offer longer reline intervals. This is likely related to the position of the brake drum relative to the wheel – the drum is almost entirely covered by the wheel in a dual arrangements, while the outboard mounting position of the wide-base wheel means that more of the brake drum is

exposed to the air stream, thus allowing brakes to run cooler and ultimately longer. Note that no documentation was offered to support this claim.

Figure 14: Wide-base brake drum (photo by Jim Park)

Anecdotally, wide-base tires do appear to be more susceptible to inner shoulder wear. Bearings play an important role in tire life. Fleets that pay careful attention to bearing adjustment when reinstalling wheels claim they reduce inner-shoulder wear on wide-base tires. Duals are also susceptible to inner shoulder wear related to lose bearings, which can cause a negative camber condition. Proper bearing adjustment is highly recommended as a means of extending tire life.

Many instances of bearing failures were noted about five years ago, and at the time were thought to be related to increased load on the outboard bearing on axles with wide-base tires. Extensive investigation by axle and bearing manufacturers concluded that offset wheels (commonly 2 inches of offset), may have been partially responsible for the increased load on the outboard bearings in axles with tapered axle spindles (). On a tapered axle, the outboard bearing is physically smaller than the inboard bearing. Offset wheels were used mainly in order to enable the retrofitting of dual wheels at some point, usually at resale. To reduce these instances of bearing failure, the axle and bearing makers now recommend using parallel spindles rather than tapered spindles on axles fitted with wide-base tires, as well as using one-inch or zero-offset wheels to reduce the cantilever load on the outer bearing.

7.2 Challenges of Wide Base Tires

7.2.1 Irregular/premature tread wear

The tire wear on wide-base tires is a perennial concern among fleets. Data from the study team's survey for this Confidence Report reveals that very few of the fleet respondents had experienced worse-than-anticipated tire wear. In fact, of fleets using wide-base tires that responded to the question "how satisfied or unsatisfied have you been with tread life," more than 68% said they were either very satisfied (31.8%) or somewhat satisfied (36.4%) with tread life (22 fleets responding).

In a fleet survey conducted by the American Trucking Association's Technology and Maintenance Council (TMC) released in February 2015, responses indicated wide-base tires actually outlasted dual

tires in most wheel positions, and sometimes by quite a margin. The survey showed that in single-drive-axle applications, wide-base tires ran to 192,857 (weighted average) miles, while LRR dual tires were pulled at 155,882 miles. On tandem drive axles, the wide-base tires went 218,750 miles before being removed, while the dual tires ran 212,500 miles. At trailer positions, the split was even closer, 169,828 for dual tires versus 166,667 for wide-base. Trailers are harder to compare tire-to-tire because maintenance practices vary so widely.

51 fleets responded to the TMC survey, the vast majority being line haul and regional operators running Class 7-8 vehicles. Of the responding fleets, 43% had 100-499 power units while 41% had 500 or more power units.

Tires removed from service with little or no irregular wear can be said to have lived a normal productive life. Fleets that the study team interviewed indicate that even-wearing wide-base tires can last from 200,000 miles to over 300,000 miles in a drive position.

The difficulty in quantifying tread life or the tire's susceptibility to irregular wear lies in determining the root cause of the wear. Irregular wear almost always results from some external factor, such as an alignment or balance problem, or some other mechanical issue. Therefore it's difficult to isolate the cause of the premature remove without knowing something about the mechanical condition of the truck, its maintenance history, and the application in which the tire is operated.

Additionally, since tires begin life with varying tread depths, it is reasonable to assume that tires with thinner treads will come off sooner, making, miles-per-32nd-inch of rubber the most accurate metric for determining good or bad tire life. However, various tire manufacturers use different rubber compounds -- often weighted toward either traction or long life -- which can react differently in distinct applications or even exposure to certain types of pavement (concrete versus asphalt).

The data that the study team collected on tread wear did not reveal any of the above factors or conditions, making it difficult to come to firm conclusions about which type of tire is likely to last the longest, in wide-base or dual configuration.

There is, however, anecdotal evidence that suggests some wide-base tires are less tolerant of certain maintenance shortcomings, such as bearing adjustment and inflation pressure. This would be difficult to prove in a field study because it would be natural to assume that as problems are detected they would be rectified – saving the tire, but spoiling the data.

7.2.2 Availability

Product availability was a genuine concern in the early days of wide-base tires, but it now seems to be resolved. It remains a commonly expressed concern among non-users, but fleets that currently use or have used wide-base tires for several years do not share this concern. There have been reports of difficulty in obtaining specific tires, particularly newer models, but this can be said of dual tires as well.

According to discussions that the study team had with tire manufacturers and dealers, more than 90% of tire dealers now stock at least the more popular models of wide-base tires.

When asked specifically about their experience with replacement tire availability, respondents to the study team's survey were very positive. More than 66% or respondents said they were either very or somewhat satisfied with the availability of wide-base tires nationwide. Only 19% said there were somewhat unsatisfied. None reported being very unsatisfied.

7.2.3 Increased cost of on-road breakdown

Since the labor and service charges connected to a tire failure road call are roughly the same for wide-base or dual tires, this challenge is not necessarily connected to tire cost but more connected to the increased likelihood of wheel damage. Fleets have advised typical wheel cost for an on-road purchase can range between $400 and $600 (compared to $250 to $275 retail). If a wide-base is operated underinflated or flat, wheel damage may be more likely, as there is no companion tire to hold the wheel off the pavement.

When fleets running wide-base were questioned about on-road wheel damage, responses indicated very few instances connected to tire failure where new wheels had to be purchased. This study team's survey indicated 38% of respondents were either very or somewhat satisfied with wheel damage issues. An additional 38% reported being neither satisfied nor unsatisfied. Fewer than 24% percent said they were somewhat or very unsatisfied with the likelihood of wheel damage – likely this group of respondents had previously experienced some wheel damage.

Given that a wheel replacement would be an incremental cost not associated with tires in dual assemblies, fleets should watch this metric carefully, as at some point the cost of the wheels would wipe out any fuel savings associated with wide-base tires for that specific truck (but would likely not be greater than the fuel savings fleet-wide). If a fleet was experiencing an inordinate number of on-road failures, the cause of those failures would need to be determined. If they were deemed to be inflation related, a change to the fleet's maintenance practices should resolve the problem.

7.2.4 Residual/resale decrease

Another challenge to wide-base adoption is that secondary markets in some regions see wide-base tires as a negative when considering trade-in value. When fleets using wide-base tires were queried by the study team, their responses were mixed regarding resale value. Several fleets who concurred that this is a challenge, say that it is necessary to change the tires and wheels back to duals upon retirement of equipment. Only 14.3% of respondents were very satisfied with the residual values of wide-base equipped trucks and trailers, while 23.8% were very or somewhat unsatisfied. However, the majority (61.9%) claimed they were neither satisfied nor unsatisfied, suggesting that wide-base tires do not in fact generally have an impact on anticipated residual values.

Several truck dealerships that the study team spoke with advised that they preferred trade-ins to have dual tires as they seemed to sell better.

The North American Dealers Association reported that, as of May 2015, it had not yet established an official valuation on equipment with wide-base versus dual tires. It was suggested anecdotally by an

Associate member that wide-base equipped trucks see a deduction of between $1,500 and $3,000. Truck Black Book, on the other hand, reported that it does not consider wide-base tires a liability.

7.2.5 Ability to re-tread

Re-treading can dramatically lower a tire's lifecycle cost. Typically a well-maintained long-haul dual tire will be re-treaded twice, or perhaps three times if a fleet has a regional or local operation in which to run the tire out. We hear from fleets that use them that wide-base tires are generally re-treaded only once and then scrapped.

Of the respondents to this study team's survey, only 14.3% expressed dissatisfaction with the ability to re-tread wide-base tires. Fully 52.3% said they were satisfied with re-treadability, and 33.3% were neutral on the question.

The brand of tire to be re-treaded seems to be significant. Several fleets told us they had better experiences re-treading one manufacturer's wide-base tires, claiming the reason lay in the design of the casing, something which (for patent reasons) other manufacturers have not yet managed to replicate.

The study team for this Confidence Report spoke with a major regional re-treader who said that, in the early years of wide-base tires, there were issues with the re-treading process and the machines. He went on to say that these issues have largely been resolved, but stressed that he has better success re-treading certain brands of wide-base tires than others. Furthermore, he said that a second re-tread is possible with good casings, provided the customer is prepared to limit the exposure of the tire to lighter service, such as regional or local operation.

Like dual tires, wide-base tires are subject to several inspections in advance of re-treading, including checking for previous repairs, ensuring they were done properly and that the number of repairs doesn't exceed allowable limits and there is no evidence the tire had been run underinflated.

The three major tire manufacturers interviewed by the study team for this confidence report all agreed that limited re-treadability was perceived as a barrier to the adoption of wide-base tires.

7.2.6 Driver acceptance

Driver acceptance is an important consideration for the adoption of any technology. While only 14.2% of the fleets surveyed by the study team said that driver acceptance was a real challenge to introducing wide-base tires, 61.8% indicated that their drivers were happy with them. So while many tire manufacturers are still quick to acknowledge that driver acceptance is a barrier to adoption, our survey results indicate that acceptance has not been a problem in practice.

The most commonly expressed driver concerns surround traction and stability. Curiously, both are subjective values in the real world. Many drivers express concerns about traction with dual LRR tires as well. Clearly there's something about the thin tread, ribbed, closed shoulder designs seen on both LRR duals and wide-base tires that worry drivers. Specifically for wide-base tires, drivers express concerns about roadside service and the time involved in getting the tires serviced. As previously noted, those

concerns are mostly hearsay, but the impression among drivers remains. In reality, availability isn't a concern for wide-base tires any longer, and limping in on a dual tire is illegal anyway. Driver concerns can be address with training and education, as well as actual experience driving trucks equipped with wide-base tires.

8 Best Practices

Today's new-generation of low rolling resistance tires require no new or additional maintenance, however proper and diligent maintenance has proven to be critical to the life and performance of these tires. Wide base tires are included in that statement, with the proviso that poor maintenance is even more likely to reduce tire life and performance than might be the case with dual tires.

The premature pulling of a tire is usually accompanied by much cursing and carrying on, with epithets hurled in the general direction of the tire maker. The truth, however, is that premature tire wear is often merely the symptom of some other problem, such as bad alignment, poor balance, loose wheel bearings, failed shock absorbers, etc. Simply replacing a prematurely worn tire with a new tire without rectifying the problem consigns that second tire to the same early grave as the first.

Moreover, any condition that causes irregular tire wear is also hurting fuel economy. Fuel must be burned to produce the energy needed to carve those cups or wavy lines into your tires.

The list of mechanical tire killers is a long one. Fortunately, dying tires usually exhibit telltale signs of what's killing them. One of the best resources for tracking down mechanical faults via the tire's wear signature is the ATA's Technology & Maintenance Council's “Radial Tire Conditions Analysis Guide." Every shop should have a copy.

The most common faults with tractor and trailer maintenance are as follows:

Alignment: Improper alignment not only chews rubber off of a tire, it hurts fuel economy in the process. Some studies have concluded that serious misalignment can decrease fuel mileage on a tractor-trailer by 2% or more. Many leading fleets conduct regular alignment checks on tractors, but trailers are often over looked or done only after a tire wear issue has been identified. In many cases it's too late for that trailer tire by then, as it is difficult to change irregular wear once it starts. Keeping both the tractor and the trailer in alignment will help support the reduction of two of the highest costs of any fleet – tires and fuel.

Balance: For some time, wheel balance has only been used in an attempt to correct wheel vibration and to address driver ride complaints. Recent studies, however, have shown a direct connection between wheel balance and tire wear -- there was even study done at an accredited testing facility that linked balanced tires to a slight increase in fuel economy. Any evenly one worn tire will have less rolling resistance than a tire with irregular tread wear, and any reduction in rolling resistance typically improves fuel mileage.

Mounting and Wheel-end Issues: Non-concentric tire mounting is not uncommon, especially when insufficient or improper bead lubricant is used. Tire technicians should be trained or reminded of proper tire mounting practices, and mounts should be checked using at least the mounting ring embossed in the tire sidewall, though a runout gauge would be preferable. Loose wheel bearings are another source of out-of-round running conditions, though usually lateral (side-to-side) rather than radial (up-and-down), in the case of non-concentric mounting. Bearings should be properly installed and checked with a runout gauge.

You may have noticed that these recommendations are the same as dozens of other recommendations you have read over the years. That's because basic tire maintenance does not have to change to accommodate LRR or wide-base tires. It should be noted here that some LRR tires and even some wide-base tires are more susceptible to certain wear-causing conditions. If anything, you need to be more vigilant with the more expensive fuel-efficient tires if you want to get the best return on your investment.

Tire Inflation: All of the tire manufacturers the study team interviewed for this report said correct tire inflation pressure is the most important element in a tire maintenance program.

Under inflation increases irregular tread wear and can damage the casing, as it is not the tire that supports the load but the air inside the tire. Without enough air to support the load, the tire is in an overloaded condition, which causes excessive flexing of the sidewall and the tread area. That flexing generates heat which can damage the rubber compounds in the tread, the under-tread area and the inner liner. Additionally, the flexing of the sidewall weakens the steel cord within the sidewall, which can lead to zipper ruptures or the outright destruction of the tire (blowouts remain the leading cause of on-road tire replacements and service calls).

A lesser consequence to under inflation is uneven tread wear, which can lead to premature removal of the tire, and degradation in fuel mileage.

According to the U.S. Department of Energy, there’s a direct link between under inflation and reduced fuel mileage. While exact numbers would vary with the application, tests have shown that a reduction of just 10 psi from a tire’s recommended air pressure can decrease fuel mileage by about 1%. Simply put, softer tires require more energy to roll them along the pavement due to the flexing of the casing and the tread. The energy needed to overcome that reluctance to roll comes from your fuel tank.

Moreover, for dual assemblies, maintaining correct and equal inflation pressure helps insure the tires' diameters are matched. Mismatched dual tires can impact both tire longevity and fuel mileage. Tests have shown that a mismatch in the height of a tire of as little as 5/16 of an inch causes the shorter of the two tries to drag the equivalent of about 13 feet for every mile traveled -- or about 246 miles per 100,000 miles traveled. That obviously shortens the usable life of the tire, not to mention increases rolling resistance, thereby reducing fuel economy.

9 Decision Making Tools

9.1 Confidence Rating

The below matrix (Figure 11) summarizes the findings of the desk research, interviews, and surveys conducted for this Confidence Report by indicating how confident the Trucking Efficiency study team is in the investment case for low rolling resistance tires.

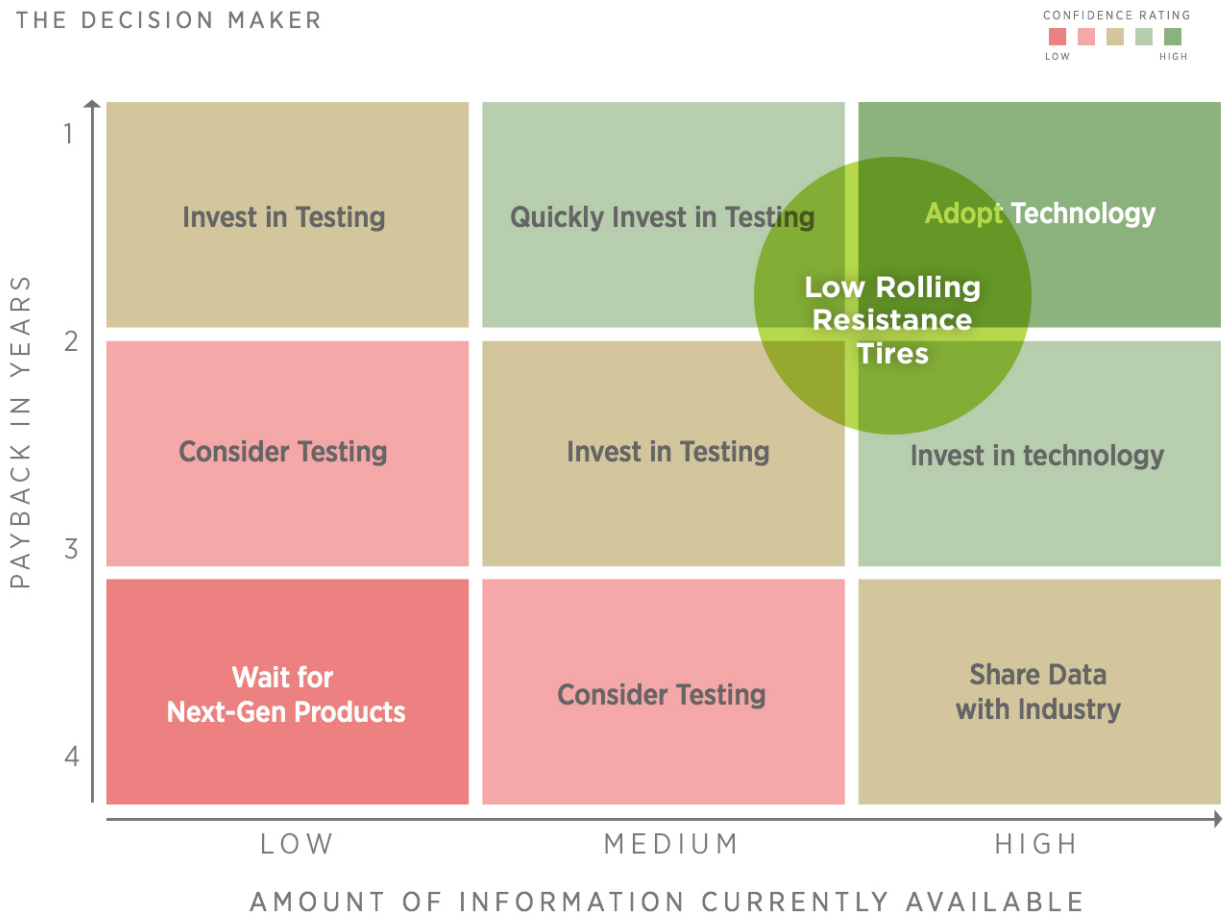

Figure 15: Confidence Matrix for LRR duals and wide-base tires

This Confidence Rating indicates that Trucking Efficiency is highly confident that low rolling resistance tires, in both dual and wide-base configuration, are proven to save on fuel costs, and have a good case for adoption.

9.2 Decision Guide

The study team has developed the following Decision Guide to assist fleets in making choices on low rolling resistance and wide-base tires, by defining a starting point for fleets.

RECOMMENDATIONS AND TOOLS FOR FLEETS

THE FOLLOWING DECISION GUIDE SUMMARIZES THE RECOMMENDATIONS OF THE CONFIDENCE REPORT, AND SERVES TO ASSIST FLEETS IN MAKING CHOICES ON ROLLING RESISTANCE AND TIRE CONFIGURATION:

DESCRIPTION OF THE FLEET AT PRESENT	SUGGESTED FLEET ACTION	
	OVER THE SHORT TERM:	OVER THE LONG TERM:
Does not purchase SmartWay verified LRR tires and does not consider a tire's impact on fuel consumption.	Spec SmartWay verified LRR dual tires from a trusted brand.	Test several SmartWay verified LRR dual tires to find the one with minimal trade-offs for your fleet.
Only purchases and wants to stay with SmartWay verified LRR dual tires, but does not know if there is a difference between any of the listed tires.	Ask your tire representative or distributor for more information on super LRR SmartWay verified tires with even lower rolling resistance.	Test one or several super LRR SmartWay verified tires to see if they lower your fleet's fuel costs further.
Purchases wide-base tires for their weight savings.	Ask your tire representative or distributor for information about his or her lowest rolling resistance wide-base tire.	Test one or several super LRR SmartWay verified wide-base tires to see if they lower your fleet's fuel.
Purchases super LRR SmartWay verified dual tires, and has the resources to test wide-base tires.	Investigate the impact of wide-base tires on your fleet, taking into consideration the challenges listed in this report.	Spec some of your next vehicles with wide-base tires to test their impact on your fleet's costs.
Purchases super LRR SmartWay verified wide-base tires but is not satisfied with their performance or impact on residual value.	Make sure the tires are maintained as well as possible and issues are well supported with data.	Test some of the newest super LRR SmartWay verified dual tires to see if they can exceed the performance of the wide-base tires.
Purchases super LRR SmartWay verified wide-base tires and is satisfied with their performance.	Continue to stay up to date with the latest tire technology.	Continue to test the newest tires of all types with the lowest rolling resistance, to achieve the greatest fuel efficiency.

9.3 Total Cost of Ownership Calculator

An MS Excel-based "total cost of ownership" tool has been developed and is included with this report. Users may input various operational features such as the axle configuration of their tractor and trailer and associated miles driven as well as tire-specific data for the steer, drive, and trailer tires that are

under consideration. The tool then calculates the total cost of ownership impact of various user supplied alternatives. Figures 16 and 17 provide two example results from this model; one moving from high rolling resistance tires to very low and another from low rolling resistance tires to even lower ones.

Truck Information	Truck	6x4
	Trailer	4x0
	Annual Miles	120,000
	Cost of Fuel	$2.80
	Labor cost to Replace Tire	$40
	Gross Vehicle Weight (lbs)	80,000

	Current Tires		Best Tire Combination		Fuel $/mi Better/(Worse)	Repl. $/mi Better/(Worse)	Total $/mi Better/(Worse)
Steer	*Goodyear*	*G395*	**Goodyear**	**Fuel Max LHS**	**0.005**	**(0.001)**	**0.004**
Drive	*Goodyear*	*G362*	**Goodyear**	**Fuel Max LHD G505D**	**0.042**	**(0.009)**	**0.033**
Trailer	*Goodyear*	*G314*	**Goodyear**	**G316 LHT Fuel Max**	**0.026**	**(0.002)**	**0.024**
Total					**0.073**	**(0.012)**	**0.062**
						Annual Savings per Truck	**$ 7,396**

Figure 106 TCO Model Example 1

Truck Information	Truck	6x4
	Trailer	4x0
	Annual Miles	120,000
	Cost of Fuel	$2.80
	Labor cost to Replace Tire	$40
	Gross Vehicle Weight (lbs)	80,000

	Current Tires		Best Tire Combination		Fuel $/mi Better/(Worse)	Repl. $/mi Better/(Worse)	Total $/mi Better/(Worse)
Steer	*Michelin*	*XZA2 Energy*	**Michelin**	**XZA2 Energy**	**0.000**	**0.000**	**0.000**
Drive	*Michelin*	*XDN2*	**Michelin**	**X One Line Energy D**	**0.027**	**(0.005)**	**0.022**
Trailer	*None*	*None*	**0**	**0**	**0.000**	**0.000**	**0.000**
Total					**0.027**	**(0.005)**	**0.022**
						Annual Savings per Truck	**$ 2,680**

Figure 117 TCO Model Example 2

10 Conclusions and Recommendations

10.1 Conclusions

As the study team completed this Confidence Report, some high-level findings emerged that are shared here in order to help educate and accelerate the adoption of low rolling resistance duals and wide-base tires among Class 8 over-the-road tractor trailers.

- Low rolling resistance tires, whether in a dual or a wide-base configuration, save significant fuel.
    - When compared to tires that are not designed for low rolling resistance, LRR tires help the vehicle use less fuel. The amount of fuel saved is directly related to the low rolling resistance coefficient – the lower the coefficient the higher the fuel efficiency of the tractor and trailer.
    - Ever greater reductions in rolling resistance are being developed, helping deliver even higher fuel savings with fewer trade-offs in traction and tread life
- The purchase price of LRR tires may be higher than non-LRR tires, but these costs can be overcome through fuel savings when considering lifecycle cost.
    - Traditionally, the cost-per-mile of tires is defined solely in terms of the initial purchase cost, and tire replacement which may be more frequent than for non-LRR tires. But to account for the fuel savings, this report strongly suggests that fleets use a total-lifecycle-cost-of-ownership to make tire decisions.
    - As tire manufacturers create better LRR tires with advanced material compounds and innovative tire designs, LRR tires will actually be able to wear longer than non-LRR tires, further reducing one element of the total cost of ownership for LRR tires.
- Adoption rates of LRR tires in the over-the-road trucking are high, and will continue to increase.
    - Purchases of LRR tires will continue to grow, and as even-lower, “super” low rolling resistance tires are developed, their demand and adoption will grow as well.
- The perception of traction issues or driver acceptance problems is worse than the reality.
    - For general over the road goods movement, these LRR tires are performing well for traction and driver acceptance.
    - Traction for LRR tires may not be acceptable in certain applications, and as tread wears, traction will be reduced, but this is true for any tire.
- The MPG gap between the lowest LRR dual tires and the best wide-base tires has been reduced over the last five years.
    - Tire companies continue to develop tires in pursuit of lower life cycle cost and improved traction. Recent innovations have improved the fuel efficiency of duals to the point where dual tires may have a lower total cost of ownership than wide-base, considering wear, replacement cost, and fuel.

10.2 Recommendations

- Fleets should understand the total lifecycle cost for tires in their specific operation, including: the up-front purchase price, fuel, weight, wear, re-treadability, etc.
- Fleets should use the lowest rolling resistance tires for their specific needs from a trusted manufacturer. Tires on the EPA SmartWay list meet only a specific rolling resistance threshold and can encompass a wide range of quality and fuel efficiency.
- Tire manufacturers should continue to develop even lower LRR tires while still lessening the trade-offs in traction and tread life.
- Tire manufacturers should work to agree on a testing protocol, with the goal of making RR_c data widely available to tire purchasers.
- Tire manufacturers should publicly share the rolling resistance coefficient for all their tires, once industry-wide collaboration and agreement to a standard testing protocol is achieved.
- Tractor and trailer makers and their dealers, industry associations, EPA SmartWay, TMC, NACFE and others can better assist fleets in these decisions by making data more accessible to tire purchasers.
- EPA SmartWay should develop tiers of rolling resistance tire categories to encourage early adopters to utilize the best tires for their needs.

11 References

Aluminum Association's Aluminum Transportation Group, "Aluminum's Role in Meeting Heavy Truck Fuel Economy Standards," http://www.drivealuminum.org/research-resources/PDF/Webinars/2010/Aluminums-Impact-on-Meeting-Future-Fuel-Economy-Standards-2010-Nov-Commercial-Vehicle-Webinar.pdf, 2010.

American Transportation Research Institute (ATRI), "An Analysis of the Operation Costs of Trucking: A 2014 Update," http://www.atri-online.org/wp-content/uploads/2014/09/ATRI-Operational-Costs-of-Trucking-2014-FINAL.pdf, September, 2014.

BF Goodrich, "Truck Tires," Product Information, http://www.bfgoodrichtrucktires.com, 2015.

Buytruckwheels.com, Product Information, http://www.buytruckwheels.com/aluminum-wheels/unimount.html, 2015.

California Environmental Protection Agency Air Resource Board, "Facts About Low Rolling Resistance Tire Information," http://www.arb.ca.gov/cc/hdghg/fact_sheets/lrr_tire_info.pdf, 2015.

Counteract, "Balancing the wheels of transportation," Product Information, http://www.counteractbalancing.com/#/tests/, 2015.

Fisher, Peggy, "Study Group Sessions: S.2 Tire and Wheel," Presentation at American Trucking Association Technology and Maintenance Council (TMC) Annual Meeting & Transportation Technology Exhibition, February, 2015.

Goodyear Truck, "Truck and Commercial Tire Solutions," Product Information, http:www.goodyeartrucktires.com, 2015.

Love's, "Tire Pricing," Product Information, http://www.loves.com/HomeLinks/TruckTireCare/TirePricing.aspx, 2015.

Michelin America, "Truck Tires - A Better Way Forward," Product Information, http://www.michelintruck.com, 2015.

National Research Council Canada: Centre for Surface Transportation Technology, "Heavy Vehicle Testing Facilities," http://www.nrccnrc.gc.caengsolutionsfacilitiessurface_transportation_index.html, 2015.

North American Council for Freight Efficiency (NACFE) "Annual Fleet Fuel Efficiency Study," http://nacfe.org/wp-content/uploads/2015/05/NACFE-2015-Annual-Fleet-Fuel-Study-Report-050115.pdf , 2015.

Park, Jim, "Mismatching Dual Tires: A Sure-Fire Way to Kill Two Tires at Once," Heavy Duty Trucking, Truckinginfo.com, http://www.truckinginfo.com/article/print/story/2014/01/two-for-the-price-of-one.aspx, January, 2014.

Pinotti, Carlos E., Ostrander, Robert, Kuan, Scott, et. al., "Understanding the Impact of Wide Base Single Tires on Axle and Wheel End Systems," Meritor, http://www.meritor.com/ourcompany/news/whitepapers/pdfs/TP1201_10-28-11.pdf, 2011.

U.S. Environmental Protection Agency Smartway Transport Partnership, "Technology: Verified Low Rolling Resistance Tires," http://epa.gov/smartway/forpartners/technology.htm, 2015.

U.S. Environmental Protection Agency Smartway Transport Partnership, "Verified Low Rolling Resistance Tires Performance Requirements," http://www.epa.gov/smartway/forpartners/documents/verified/420f12024.pdf, 2015.

U.S. Environmental Protection Agency Smartway Transport Partnership, "Weight Reduction a Glance at Clean Freight Strategies," http://www.epa.gov/smartway/forpartners/documents/trucks/techsheets-truck/420f09043.pdf, 2015.

Wikipedia contributors, "Rolling Resistance," Wikipedia, The Free Encyclopedia, https://en.wikipedia.org/wiki/Rolling_resistance, 2015.

Yokohama, "Commercial Tires," Product Information, http://www.yokohamatire.com/tires/commercial/, 2015.

12 Appendix - Case Study: Wide Base Tire Adoption

As with all in this series of Confidence Reports, adoption stories are shared that provide interesting insight and is one source of information for the reports. The following is one such adoption "Case Study" that includes many of the challenges, benefits and best practices discussed above.

12.1 Fleet Description

- Private fleet attached to a manufacturing and distribution operation
- Four distribution/maintenance centers, several smaller satellite terminals
- Lower 48-state operation, some exposure in western Canada
- Fully loaded outbound with diminishing loads, typically 5-6 drops per load
- Raw materials inbound, some general freight, mostly lighter loads
- Average length of haul 500-600 miles, mostly expressway and four-lane
- Annual fleet mileage: 40 million plus
- 350 power units, 700 trailers
- Owned equipment, five-year trade cycle for power, 10 years for trailers
- Retired trucks are well maintained and sought after by repeat buyers
- Company standards for resold trucks include at least 50% tire life left

12.2 Background

Fleets toying with the idea of a major change in truck specification have much to consider beyond getting used to new sales reps calling at the door. Dissimilar inventory, new installation and maintenance procedures, technician training, new condition checks and go/no-go criteria; there are a lot of adjustments to be made. This case study explores the experiences of an early adopter of wide-base tires.

This particular fleet began considering adoption in 2004, when wide-base tires were still new to the market – largely untried and widely untrusted. Being an early adopter meant that certain challenges which are minimal today, like wide availability of replacement tires and diminished residuals, were very real barriers at the time. Still, the fleet went ahead and is now fully transitioned to wide-base at all drive and trailer positions. The fleet is now testing "super" low rolling resistance wide-base tires. Those tires have not been without issues but the evaluation continues.

As this fleet is a private fleet, transportation is pure cost with no opportunity to recover expenses through fuel surcharges, pass-throughs, etc. Consequently, this fleet strives for maximum fuel efficiency; tires are part of that fuel-cost management strategy.

In 2004, the fleet began testing wide-base tires on a small group of tractors. Up to then, it was using dual tires considered to be fuel efficient. Some concerns the fleet articulated going into the test, such as the availability of replacement tires and possible wheel bearing failures, proved to be unfounded. However another concern, that of driver acceptance did continue to be a challenge after testing.

While increased fuel mileage was the main motivation behind testing wide-base tires, the test results revealed fuel economy on the tractors equipped with wide-base tires had increased by at least 0.1 mpg with some showing an increase of almost 0.2 mpg. Moreover, the additional payload opportunities soon became apparent.

12.3 Proceeding with Adoption

Once the decision had been made to switch from dual tires to wide-base, it took about four years for the fleet to fully transition its tractors, ordering each subsequent generation with wide-base tires, but not retrofitting any of the in-service units. The trailer fleet took longer to fully transition because of the trade cycles. The fleet was 100% wide-base by 2011; seven years after the first tests began.

As wide-base equipped trailers were cycled into the fleet, fuel savings increased, proving that the wide-base tires were having the desired effect. Some of that gain was believed to have resulted from eliminating some of the fuel economy concerns associated with dual wheels, such as matching tire size and inflation pressures.

Reported maintenance issues were minimal and manageable, mostly associated with the early days of the transition when technicians, maintenance staff, and drivers were unfamiliar with the new tires. No extraordinary tire failures were noted, just the usual run of curb strikes, punctures and blowouts. Nor were any undue hardship reported from a lack of tire availability arising from roadside service calls.

The biggest challenge faced by this fleet in the early days (and it still exists today but to a lesser extent), was driver acceptance. The company and the tire supplier reduced this challenge by providing some driver training to familiarize drivers with the tires.

Along with driver training, the fleet had to adjust their tire management practices and inventories. Half of the number of tires and wheels now had to be stocked at any one time compared to dual tires, but carrying costs were slightly higher. Tire pressure checks and inspections became less time-consuming because there were fewer tires to inspect per wheel position, and the other traditional concerns associated with inside-dual tires were eliminated. But since wide-base tires do not carry a 20 psi inflation pressure safety margin as duals tires often do, more of an emphasis had to be placed on inflation pressure verification.

This fleet now has over 200 million miles on wide-base tires and has no plans to resume using dual tires. They did not report any decline in residual value at sell-off due to the wide-base tires.

12.4 Fuel Savings Realized

Actual fuel savings were not what the tire manufacturer had claimed they would be.

As mentioned, the initial testing of the wide-base tires showed a fuel economy improvement of between 0.1 and 0.2 miles per gallon. Fuel prices in 2004 averaged $1.81 per gallon, so the fuel savings

across the portion of the fleet then equipped with wide-base tires was about 420 gallons per year per truck, or, $750 per unit annually (calculated with the average price at the time.)

So, small though it was, the fleet did see a fuel cost savings, which when coupled with the weight savings, made wide-base tires a compelling alternative to dual tires.

12.5 Looking ahead: Super low rolling resistance wide-base tires

In 2011 the fleet chose to test "super" low rolling resistance wide-base tires against the wide-base tires its vehicles were by then uniformly equipped with. The super LRR tires showed an additional savings of 0.2 mpg over the wide-base tires. Fuel prices were slightly more than double those of 2004, so the savings were better, $1,650 dollars per truck on 433 gallons of fuel -- but still less than forecast by the tire manufacturer.

A few issues arose in testing the super LRR wide-base tires against their current wide-bases tires. The acquisition cost of that first batch of super LRR tires was (and remains), higher than the wide-base tires they replaced. On top of that, tire life was shortened due to the generally thinner tread on the new tires. Miles per 32nd decreased slightly as well. As the tires wore, lack-of-traction complaints from some of the drivers resurfaced, though that is believed to be more a matter of perception rather than a genuine safety issue.

The overall shorter mileage-to-takeoff did pose a problem for this fleet, but a suitable workaround was implemented. This particular fleet disposes of its own equipment. Their tractors typically have about 600,000 – 625,000 miles at retirement. Drive tires in this fleet typically last about 250,000 miles. In this scenario, a tractor would get tires at 250,000 miles, again at 500,000 miles and be retired with approximately 50% rubber left on the tire. The loss of some tire life seen with the super LRR wide-base tires, would have forced the purchase and installation of a third set of tires during the tractors' life cycle in order to meet the resale requirements in some cases. To solve this problem, units with about 50% tread left on them were identified and those tires were put on the soon-to-be-retired trucks, while the donor truck got the new tires. There were additional labor costs and downtime associated with the tire transplants, but they were less than the cost of putting a third set of tires on each truck

Ultimately, it was determined that, while the super LRR wide-base tires did reduce fuel consumption, those savings were offset by the additional initial cost, the loss of usable tire life, and the possibility of having to purchase an additional set of tires -- including labor to install -- during a tractor's life cycle.

Therefore, the use of super LRR wide-base tires is still under consideration at time of writing. Fleet management says they are open to more testing, and they acknowledge that the test they ran was a fairly small sample on early-generation super LRR wide-base tires. To that end, they currently have a small group of trailers on order which will be equipped with the latest generation LRR wide-base tires. These tires will be closely audited for fuel efficiency and miles-per-32nd as the fleet continues in its quest of gaining MPGs and lowering operating costs.